IMPLEMENTING DIGITAL INTEGRATED QUALITY MANAGEMENT SYSTEMS FOR ACHIEVING QUALITY AND ACCREDITATION OF ENGINEERING PROGRAMS (2014-2021)

by

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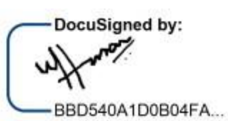
DECLARATIONS

The work contained in this thesis represents the original work by Wajid Hussain. None of the material has been submitted for any other higher degree. I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.



CONFLICT OF INTEREST

No Potential conflict of interest is reported

TERMS OF USE

ABSTRACT

Accreditation being the prime driver of outcomes assessment in most engineering campuses across the US and internationally, means that several engineering programs have adopted a macro approach to applying outcomes to student learning. Manual systems have been employed to complete a very cumbersome task of collating the assessment of student outcomes information and utilize the data for Continuous Quality Improvement (CQI), a crucial requirement for accreditation. Any typical undergraduate engineering program involves learning several hundred skills by the time of graduation. Authentic outcome-based CQI systems should assess all required skills for all students. Manual CQI systems have forced many programs worldwide to adopt short cut approaches and opt for simplistic learning models, selective sampling of students, courses, skills, and primitive methods of their evaluation to avoid massive expenditure of resources and the daunting task of manual management of data collection and reporting activities. Unfortunately, the focus of assessment and evaluation has shifted from achieving authentic outcome-based standards and student centered CQI to models that target minimal accreditation standards. Several practical issues related with manual CQI systems have been mentioned in literature and presented systematically in this research to emphasize their effect on improvement of student learning and propose practical solutions. Engineering programs are now faced with the challenge on how to implement the OBE paradigm, philosophy and principles using manual quality processes. The question is whether digital technology can be used to embed and collate assessment outcomes to help programs implement 'authentic' OBE that has continuous feedback on progress and therefore achieves realistic CQI.

In this thesis, I present a comprehensive methodology based on authentic OBE frameworks for implementing digital Integrated Quality Management Systems (IQMS) for the Islamic University civil, electrical and mechanical engineering programs. Six comprehensive PDCA quality cycles were implemented to ensure Total Quality Management of the education process. The Faculty Course Assessment Report and Performance Vector Table methodology were employed to implement embedded assessment technology. Specific performance indicators and topic specific hybrid rubrics were used to tightly align assessment with actual student learning activity. A customized web-based software EvalTools® that integrates Learning Management (LMS), Outcomes Assessment (OAS) and Continuous Improvement Management (CIMS) Systems streamlined the data collection and reporting activity for accreditation requirements. An *Advising Module* enabled effective developmental advising based on outcomes data collected for every individual student. A *Remote Evaluator Module* enabled virtual accreditation audits facilitating social-distancing during the COVID19 pandemic. A comprehensive eight phase meta-framework was employed to conduct Mixed Methods Theory Based Impact Evaluations of the IQMS providing detailed guidelines to both accreditors and engineering programs for conducting credible remote evaluations. Program evaluation using this novel meta-framework would help consider a range of aspects such as context, construct, causal links, processes, technology, data collection and outcomes results of CQI activity required for credible remote audits of automated

digital quality systems. The IQMS was seamlessly operated for a full six-year period with more than a million documents systematically reported as objective evidence on a cloud based environment and followed with a successful ABET accreditation.

GLOSSARY

AAS	Administrative Assistant System
ABET	Accreditation Board of Engineering and Technology
APPM	Accreditation Procedure and Policy Manual
ASEE	American Society of Engineering Education
ASSP	Application Specific Standard Products
CEAB	Canadian Engineering Accreditation Board
CIMS	Continuous Improvement Management System
COs	Course Outcomes
CQI	Continuous Quality Improvement
EAC	Engineering Accreditation Commission
EAMU	Excellent Adequate Minimal Unsatisfactory
FCAR	Faculty Course Assessment Report
FIE	Frontiers In Education
ICA	International Conference on Outcomes Assessment
IEA	International Engineering Alliance
IQMS	Integrated Quality Management Systems
LMS	Learning Management System
NBA	National Board of Accreditation
NCAAA	National Commission of Academic Accreditation and Assessment
OAS	Outcomes Assessment System
OBE	Outcome Based Education
PDCA	Plan Do Check Act
PEC	Pakistan Engineering Council
PEOs	Program Educational Objectives
PIs	Performance Indicators
PVT	Performance Vector Table
SOs	Student Outcomes
TALE	Teaching Assessment and Learning for Engineering

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A. BACKGROUND AND CONTEXTUAL STATEMENT

i. Background

Outcome Based Education (OBE) is an educational theory that bases every component of an educational system on essential outcomes. At the conclusion of educational experiences, every student should have achieved the essential or culminating outcomes. Classes, learning activities, assessments, evaluations, feedback, and advising should all help students attain the targeted outcomes [1,2,3,4,5]. OBE models have been adopted in educational systems at many levels in several countries around the world [6,7]. A list of current signatories of the Washington Accord presents strong evidence of a global migration towards OBE [8]. The Accreditation Board of Engineering and Technology (ABET) is a founding member of the Washington Accord since 1989 [9]. Recently, the Canadian Engineering Accreditation Board (CEAB) updated its accreditation criteria to adopt the OBE model [10]. National Board of Accreditation (NBA), India became a signatory of the Washington Accord in 2014 [11]. The Pakistan Engineering Council (PEC) secured signatory status in 2017 [12]. In 2014, the National Commission of Academic Accreditation and Assessment (NCAAA) in Saudi Arabia was established, using the OBE model [13]. This shift makes institutions focus more on assessing the expected learning outcomes rather than the quality of the offered curriculum. However, competition to improve rankings of programs has forced many institutions to pursue minimal requirements during accreditation processes [14,15]. Accreditation was the prime driver for outcomes assessment [14,15] and the topic of more than 1,300 journal articles between 2002 and 2004 [17]. Consequently, several aspects of established accreditation processes in many institutions may not truly reflect the paradigm and principles of authentic OBE [16,17,18,19,20,21,22]. Another exhaustive systematic study of 99 research articles by Cruz, Saunders-Smits and Groen (2019) [23] concluded that due to global accreditation requirements the number of published studies from 2000 to 2017 related to assessment and evaluation of transversal skills had significantly increased. They observed that international quality standards for assessment and evaluation of transversal skills such as communication, innovation/creativity, lifelong learning or teamwork were undefined and deficient. Specifically, inadequate standards of language of learning outcomes, validity and reliability of assessments, and vague rubrics, all exacerbated the evaluation of transversal skills [23].

Deming championed the work of Walter Shewhart, including statistical process control, operational definitions, and what Deming called the "*Shewhart Cycle*," which had evolved into Plan Do Check Act (PDCA) cycle for Continuous Quality Improvement CQI [44]. The four phases of a typical CQI cycle are 1) PLAN: developing the educational plan 2) DO: implementing the plan 3) CHECK: monitoring processes/results, conducting failure analysis, implementation of a plan to identify any variations to required processes or deficiencies in intermediate or final results and 4) ACT: Generate and implement appropriate corrective actions to remediate the observed deficiencies or mitigate projected failures. The PDCA cycle focusing on the collection of accurate student outcomes as quality standards and evaluation of their attainment has since been adopted widely in most quality and accreditation CQI models [8,9,10,11,12,13]. ABET's CQI criterion CR4 requires programs to track quality improvement resulting from corrective actions for failures in student performance extracted from evaluating outcomes at the course and program levels [9]. Gloria Rogers' training slides suggest that quality processes can take about 6 years to fully complete a cycle of assessment and evaluation activity. Therefore, ABET evaluators generally require 6 years of CQI data to be available in record with programs and at least 2 years of well documented course materials, SOs based objective evidence and other CQI information as display material during audit visits [9]. The current format of measuring ABET, Engineering and Accreditation Commission (EAC) revised 7 Student Outcomes (SOs) and associated Performance Indicators (PIs), and evaluation of the alignment of the Program Educational Objectives (PEOs) is definitely a cumbersome affair for programs and institutions that utilize manual processes. The general advice provided by ABET was to be selective in using assessments for measuring these SOs to minimize overburdening faculty and program efforts for accreditation [9]. This may be acceptable for the fulfillment of accreditation criteria, but from the OBE model, student-centered point of view, it does not facilitate CQI. Consequently, assessments become deficient, tend to become summative and do not include formative processes, since good assessment practice refers to all activities which can provide necessary feedback to revise and improve instruction and learning strategies [24,25]. Additionally, the learning outcomes data measured by most engineering institutions is rarely classified into all three learning domains of the revised Bloom's taxonomy [26] and their corresponding categories for levels of learning. Generally, institutions classify courses of a program curriculum into three levels: *Introductory, Reinforced*, and *Mastery*, with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for effective program evaluations. This approach presents a major deficiency for CQI in a student-centered OBE model because performance information collected at just the Mastery level is at the final phase of a typical quality cycle and is too late for implementing remedial efforts. Instead, student outcomes and performance information should progress from the elementary to advanced levels and must be measured at all course levels for the entire curriculum [27,28]. A holistic approach for a CQI model would include a systematic measurement of PIs in all three Bloom's domains of learning and provide information on attainment of learning within each domain's learning levels.

A detailed study of an accreditation effort in Canada, in 2011, estimated that the University of Alberta, Edmonton engineering programs spent more than a million dollars, collected more than a ton of data and exhausted more than 16,000 hours of preparation time for the Canadian Engineering Accreditation Board (CEAB) accreditation visit [19]. Similarly, engineering programs worldwide allocate staggering amounts of time and resources for preparing CQI data and display materials for accreditation, but unfortunately, since they employ manual CQI processes, assessment and evaluation data is often deficient and lacks the rigor and quality required by a student-centered authentic OBE model to attain the required standards of holistic learning. Jeffrey Fergus, chair of the ABET Engineering Accreditation Commission (EAC) also echoed a similar opinion regarding ABET's criterion 4, CR4 or Continuous Improvement as being the most challenging for engineering programs worldwide [29]. Several aspects of manual CQI models have been highlighted as being problematic such as standards of learning outcomes statements, vague performance criteria, lack of topic-specific analytic rubrics, reliability and validity issues with assessment and evaluation criteria, random sampling of outcomes data, lack of proper alignment, lack of comprehensive coverage of Bloom’s three domains of learning, lengthy quality and evaluation cycles, inability to achieve real-time learning improvements in cohorts etc. [19,20,22,24,25,27,28,30,31,32,33,35,43].

Compliance for outcomes assessment has been quoted by many [35,36,37,38,39,40,41,42] as a major issue in achieving realistic CQI. Many faculty members are not keen to get involved in the assessment process, mostly because the manual assessment and evaluation tools employed lack integration of essential components, require manual data entry, and multiple analytical computations to often yield results which do not accurately represent the actual state of student learning. Instructors are, therefore, unable to realize the tangible benefits of using valid outcomes assessment processes that enhance teaching and learning in an authentic OBE model. Myriad complexities attributed to improper tools that do not integrate multiple components of direct/indirect outcomes assessment for identification of failures, remedial actions and CQI may be identified as the root cause for the lack of faculty involvement. Therefore, there is a dire need to explore ways to improve faculty engagement in the assessment process at the course and program levels. A paper-free web-based digital system with a user-friendly interface would help encourage faculty participation while integrating multiple outcomes assessment processes for CQI. The indispensable necessity of the state of the art digital solutions to automate and streamline outcomes assessment for achieving excellent CQI results and accreditation has been adequately explained in research literature [20,32,33,34,38,39,40,41]. Typical education technology such as BlackBoard® or Moodle® comprise of Learning Management Systems (LMS) that do not include sophisticated assessment systems that are integrated with user friendly tools implementing automated quality assurance mechanisms. The quality assurance tools should automate collection, reporting, assessment, and evaluation of outcomes information and offer digital traceability of the subsequent corrective actions performed by several academic and administrative committees. These tools would systematically automate the most difficult phase of CQI for engineering programs by providing easy access to objective evidence for confirming the ‘closing the loop’ process in CQI PDCA cycles Therefore, engineering programs seeking simultaneous enhancement of quality of education and automation of accreditation processes have challenges to develop guidelines and frameworks for implementing integrated CQI systems using practical digital solutions. The desired digital Integrated Quality Management Systems (IQMS) should seamlessly integrate LMS, Outcomes Assessment and Quality Assurance to achieve required levels of automation for practical and effective management of CQI efforts. The various processes of the IQMS should be based on authentic OBE frameworks, employ best practices for assessment and automate data collection and reporting mechanisms to establish comprehensive CQI efforts for the attainment of SOs and fulfill the requirements of international engineering quality standards such as those stipulated by the IEA or ABET.

ii. An Accreditation Experience that Helped to Conceptualize this Research

In 2012, I was commissioned as the manager of quality assurance efforts for the Electrical Engineering and Technology programs at the King Fahd University of Petroleum and Minerals (KFUPM), Hafr Al Batin branch in Saudi Arabia. The management at KFUPM made this selection due to my high profile engineering background in the electronics manufacturing industry which was coupled with significant ISO quality experience working for the Application Specific Standards products (ASSP) group at LSI Corporation in Milpitas, California. Specifically, the Electrical Engineering and Technology programs were pursuing accreditation efforts to fulfill international quality standards of the ABET. To achieve this, the programs were required to maintain CQI processes based on an OBE model and prepare self-study evaluation reports to be reviewed in an audit visit scheduled for the end of 2013. For accreditation, ABET required engineering programs to fulfill 9 criteria [9]. The most significant of these were the PEOs, SOs, Program Criteria and CQI [9]. As observed in the research literature and stated earlier, most programs in the US and internationally indicated that the most difficult criteria to fulfill for ABET accreditation was criteria 4, CQI. The CQI criteria 4 required programs to track quality improvement resulting from corrective actions for students' performance failures extracted from assessment and evaluation of outcomes at the course and program level. ABET's evaluators require programs to implement 6 years of quality cycles with at least 2 years of well documented data as display material during audit visits. Actually, the prevalent culture of the evaluator community requiring programs to present massive amounts of display data during audits is drawn from the standards of a global quality agency, the International Engineering Alliance (IEA), of which ABET is a founding member [8]. The Washington, Dublin and Sydney Accords of the IEA clearly articulate the frameworks which define the paradigm for this existent culture of the engineering and technology evaluator community [8]. A detailed study of an accreditation effort in Canada, in 2011, estimated how the University of Alberta, Edmonton engineering programs spent more than a million dollars, collected more than a ton of display data and exhausted more than 16,000 work hours of preparation time for the Canadian Engineering Accreditation Board (CEAB) accreditation visit [19].

At the KFUPM, Hafr Al Batin, Electrical Engineering and Technology programs, a similar experience emerged as I managed a traumatic manual assessment, evaluation, reporting and documentation exercise for the preparation of 70 folders of display data with each folder ranging between 600-1000 pages. The data consisted of course information, direct and indirect assessments, course and program evaluations, administrative committees' meeting minutes, corrective actions based on SOs and their follow up to closure. The most difficult part was the reverse engineering efforts in linking corrective actions with outcomes data to prove the existence of a systematic CQI process. However, this exercise proved less of a strain than what the KFUPM main branch was advocating for data collection and reporting. The consultants at the main branch in Dammam advocated an obsolete and redundant assessment model where generic performance indicators and their rubrics were used to assess the Course Outcomes (COs).

This was the common model most engineering programs adopted across the US and globally. The problem with this model was that independent raters would take a set of these rubrics and apply them to student work in past course portfolios. A significant rescoring effort would take place to obtain outcomes assessment data which could never be formative and apply to cohorts on a real-time basis for remedial action and improvement. The actual instructors of the courses would be missing from this CQI process thereby creating a deficiency in the efforts for root cause failure analysis to accurately create appropriate remedial actions for quality improvement. I conducted an exhaustive literature review to search for alternative solutions and learnt about the embedded assessments model, an emerging methodology that rearranges class room based assignments to align with learning outcomes. So, any tests of classrooms assignments would result in outcomes related performances. Embedded assessments build on the daily work (assignments, exams, course projects, reports, etc.) of students and faculty members. These assessments help avoid the use of external independent raters that are usually employed for rescoring past course portfolios for accreditation purposes. According to Ammons and Mills (2005), the major benefit of course embedded assessment is that "the instruments can be derived from assignments already planned as part of the course, data collection time can be reduced" [45]. Gerretson and Golson (2004) stated that the advantage of assessment at the classroom level is that it "*uses instructor grading to answer questions about students learning outcomes in a nonintrusive, systematic manner*" [46]. A composite advantage of course embedded assessments in regards to the fulfillment of accreditation requirements are that they can be used at the course level to help instructors determine attainment of COs, and can be used at the program level to assist in measuring to what degree the program level SOs are being met. Embedded Assessments is not just of interest to the instructor teaching the course, but also to other faculty members in the program whose courses build on the knowledge and skills learned in the course [45]. John K. Estell's Faculty Course Assessment Report (FCAR) and EAMU vector methodology won a top award at the BAP symposium, facilitated embedded assessments and seemed to address the problem with independent raters and additional assessments. The basis of the embedded assessment model in FCAR is the EAMU performance vector [47,48]. The EAMU performance vector [48,49] counts the number of students that passed the course whose proficiency for that outcome was rated *Excellent, Adequate, Minimal*, or *Unsatisfactory* as defined by: *Excellent*: scores >= 90%; *Adequate*: scores >= 75% and < 90%; *Minimal*: scores >= 60% and < 75%; and *Unsatisfactory*: scores < 60%. Program faculty report failing COs, SOs, PIs, comments on student indirect assessments and other general issues of concern in the respective course reflections section of the FCAR. Based upon these course reflections, new action items are generated by faculty. Old action items are carried over into the FCAR for the same course if offered again. Modifications and proposals to a course are made with consideration of the status of the old action items [47,48].

Since ABET had recently introduced Performance Indicators (PIs) in its SOs assessment model, engineering programs felt that the Estell basic FCAR model was deficient since it provided alignment with just the COs and did not cover the PIs. After a careful study of the FCAR EAMU methodology, I made some adjustments to the original model by modifying the language of COs to align with the relevant generic PIs to achieve measurement of student course activity by directly using PIs [32]. Now, rubrics corresponding to the generic PIs could also be applied directly to existing assessments. This significantly enhanced the capability of the basic FCAR methodology to adequately address the evolving ABET assessment model. The enhanced FCAR + PIs model with course and program evaluations implemented using MS Excel supported the embedded assessments concept to significantly reduce the amount of time and faculty resources which were otherwise spent in allocating independent raters for collection and reporting of outcomes data from additional assessments besides routine curricular assessment activity. In 2014, our engineering technology programs successfully achieved a full 6 years' accreditation from ABET Inc.

iii. Problem Statement

My industrial background taught me some very practical lessons of life which may not be understood or realized to a full extent from a total academic stand point. The optimum use of resources, precision of models, accuracy of final results, sustainability and level of attainment of goals are very crucial aspects of any process, the deficiency of which could render gigantic efforts useless and an entire project completely worthless. The accreditation experience at KFUPM helped me gauge the contemporary quality assurance systems firsthand.

In summary, the problem statement for this continued research is as below:

"*Accreditation being the prime driver of outcomes assessment in most engineering campuses across the US and internationally, means that most programs have adopted a macro approach to applying outcomes to student learning. Assessment is rarely aligned to learning models measuring all three domains of Bloom's taxonomy and their learning levels. Generic language of outcomes and rubrics does not effectively support valid and reliable assessment and evaluation of engineering learning activity. Manual systems further exacerbate the situation by forcing programs to sample small sets of students, assessments and courses that do not reflect the full spectrum of student performances. Accurate root cause failure analysis followed by on time remedial actions for real-time improvement of students' performance failures, rarely happen. Prevalent engineering assessment processes utilize independent raters who apply these generic rubrics on past course portfolios render formative assessments for real-time improvement an impossibility. Program evaluations generally do not incorporate any weighting scheme to aggregate outcomes data corresponding to varying skills, knowledge and course levels. Resulting in an inaccurate aggregation involving pure averaging without appropriate prioritization of outcomes data corresponding to their varying skills, knowledge and course levels. Most essential principles of Spady's (2020) authentic OBE theory are not targeted or achieved. A critical and fundamental component of the education process, academic advising, is rarely based on outcomes information, but rather on overall transcript grades. Higher education is now faced with* *a challenge on how to implement the paradigm, philosophy and principles of OBE using manual quality processes. The question is, whether Digital Technology and embedded collation of assessments can help programs implement 'authentic' OBE and achieve realistic CQI*."

iv. Major Issues of Prevalent Manual CQI, Assessment and Evaluation Mechanisms

The real-time accreditation experience coupled with consulting work and an intense literature survey helped me identify several major issues with the prevalent manual CQI, assessment and evaluation mechanisms. These issues have been repeatedly cited from research literature in my publications and listed below for better comprehension of the problem statement for this thesis:

a) Prime driver for outcomes assessment in engineering for most campuses in the US and worldwide is accreditation [59,60].
b) Realistic CQI is difficult to achieve in engineering by using manual systems since processes related to collection, reporting and documentation of quality data cannot be easily implemented and lack sustainability [20,32,33,34,38,39,40,41].
c) Most essential principles of authentic OBE philosophy and paradigm are either not targeted or achieved in engineering programs [16,17,18,19,20,21,22].
d) CQI information for all students is not collected, documented or reported [32,38,39,40].
e) Learning models are generally not understood and used comprehensively as the founding framework for CQI efforts [3,16,42].
f) Course evaluations do not incorporate appropriate weightage for various types of assessments [22,32,35,39].
g) Language of learning outcomes is deficient and lacking alignment with actual activity [3,5,16].
h) PIs are mostly generic and lack the required specificity to achieve required validity and reliability in assessment and evaluation [3,16,21,22,23,28,29,51].
i) Majority of assessment models just target learning activity in the cognitive domain. Learning activity related to psychomotor and affective domains are mostly not assessed [3,16,21,22,23, 27,28,30,31,32,51].
j) Course delivery is not systematically aligned with flow of course outcomes to implement Bloom's Mastery Learning [3,4,5,16,25,32,36,37,38,39,51]
k) Real-time corrective actions with formative assessments are rarely implemented [22,24,28,36,37,40].
l) Most rubrics are generic, simplistic and vague and lack the necessary detail to accurately assess several hundred complex student learning activities of any engineering specialization [16,21,50,51].
m) Independent raters are used to apply generic rubrics to past course portfolios [32,35,39].
n) Most program evaluations are based on a small set of random samples of student activity rather than utilizing large data sets of outcomes [22,27,28,33,36,38,43].

o) Many program evaluations do not incorporate appropriate weightage to course and skill levels. Advanced course and skills levels should be prioritized by accurate weighting schemes [20,33,35,39,40].
p) Many program evaluations do not analyze the coverage of student learning in all the three domains of Bloom's taxonomy and their learning levels [27,28,30,31,32,39,41].
q) Academic advising systems and consequent advice are not based on student outcomes information [53-57].
r) Industrial Training courses cannot be managed and assessed remotely by training advisors [61,62].
s) CQI efforts are not realistic and programs mostly employ reverse engineering to link corrective actions to outcomes evaluations results [30,31,32,39,41]
t) Quality assurance, monitoring and control processes at course or program level are not well defined, aggressive and properly distributed to dedicated staff to ensure standards of outcomes, rubrics, their alignment with learning activity, assessment, feedback, and improvement, and on time completion of accurate data collection and reporting efforts [35,36,37,38,39,40,41,42].
u) Quality cycles do not necessarily integrate with each other making causal links difficult to identify. The underlying assumptions of some quality cycles are not based on authentic OBE frameworks or best assessment practices [3,30,31,32,39,].
v) The frequency and time period of some quality cycles do not present effective CQI actions since they do not cover all the SOs in a practically manageable evaluation and realistic improvement effort [30,31,32,51].

Another key and practical principle of life which I learnt from the industry in Silicon Valley is to never reinvent the wheel, and whenever possible, build on what already exists. Therefore, I began to search intensively for tools that support automation, embedded assessments and are flexible enough to allow enhancement to evolve into integrated Learning Management (LMS), Outcomes Assessment (OAS) and Continuous Improvement Management (CIMS) Systems that comprehensively implement authentic OBE principles by effectively streamlining the massive manual efforts for CQI to achieve quality and accreditation. The exhaustive search ended up with one digital web-based software EvalTools ® that employed Estell's basic FCAR and was managed by MakTeam Inc. from Erie in Pennsylvania, USA. EvalTools ®, at the time in 2013, was being used by Gannon University, Frostburg State University and Bethune-Cookman University. I came in touch with Prof. Fong K. Mak who was the chair of the Electrical and Computer Engineering program at Gannon University. I explained the enhanced FCAR+ PIs methodology in detail. Prof. Mak was delighted to work with me and incorporate the enhanced FCAR into the EvalTools ® suite.

A proposal to KFUPM for shifting to automation was rejected by the consultants in Dammam since they were resistant to any kind of change to existing manual processes. At the end of 2014, I moved to the Islamic University in Madinah, as Director of Quality and Accreditation to implement CQI efforts at the Faculty of Engineering for ABET accreditation. By November 2014, we implemented the first digital platform in Saudi Arabia for quality and accreditation work at the Faculty of Engineering, Islamic University. From the very inception until now in 2020, I worked with Prof. Mak aggressively pursuing development of modules, enhancement of features, implemented beta testing and research. This has resulted in the use of a cloud-based environment at the Islamic University, that collates thousands of outcomes, PIs, hundreds of hybrid rubrics and millions of digital documents related to engineering students' work and CQI activities. During 2017-2018, we gained ABET accreditation for the Computer Science, Information Science, Information Technology, Civil, Mechanical and Electrical Engineering programs.

v. Research Statement

a) Title of the Thesis

"*Implementing Digital Integrated Quality Management Systems for Achieving Quality and Accreditation of Engineering Programs*"

b) Raison D'être

Experiences in accreditation at the Hafr Al Batin, KFUPM campus that required using manual CQI processes for data collection and reporting were traumatic and lacked realistic opportunities for cycles of quality improvement. Many actions were reverse engineered to connect to outcomes evaluations that were too generic to point to any specific student failures. Printed Excel worksheets, student outcomes and CQI objective evidence folders, course portfolios, lab manuals, advising records etc. were the display materials that amounted to hundreds and thousands of pages and many hours of work for an ABET visit in 2013. Even after the visit, several hundred transcript corrections and a full 1 year of accreditation data was required since just 1 year of data was shown during the visit. Another challenge was to collect and effectively report this data for the final accreditation decision in July 2014. All this effort could have been avoided by using sophisticated digital technology and organized quality management processes.

c) Aim

To study the benefits and challenges of application of essential theory of the authentic OBE model using digital technology for delivering a holistic and comprehensive educational process that maximizes opportunities for the attainment of successful student learning and evaluating CQI processes that are required to be reported for accreditation purposes.

d) Objectives

To achieve OBE quality standards and ABET accreditation by implementing state of the art digital Integrated Quality Management Systems (IQMS) for automation at the Islamic University civil, electrical and mechanical engineering programs using comprehensive methodology based on authentic outcome-based frameworks.

To apply a novel eight phase meta framework for mixed methods theory-based impact evaluations [63] of state of the art Integrated Quality Management Systems implemented at the Faculty of Engineering that provides electrical, civil and mechanical programs (2014-20) to achieve ABET accreditation.

e) Statement of Purpose

The purpose of the intervention [2014 – to date] at the Faculty of Engineering was to develop and implement the IQMS to seamlessly automate data collection, reporting, and other QA processes for ABET accreditation and achieve high standards of educational quality by fulfilling essential OBE frameworks in engineering education.

f) Methodology for Development and Implementation of the IQMS

The development and implementation of state of the art outcome-based Integrated Quality Management Systems using cutting edge digital technology was not a trivial affair but a complex one that involved a prolonged group effort. Therefore, the development and implementation of the IQMS was incremental involving systematic actions for both research and quality management.

The developmental research in all its phases, therefore, consists of two aspects for attainment of the purpose and objectives:

1. Study of issues of manual quality systems and processes with reference to authentic OBE frameworks, best assessment practices, resource requirements and time expenditure, and quality of data.
2. Systematic development and incremental implementation of digital solutions and associated quality processes based on authentic OBE frameworks, best assessment practices, ABET criteria for enabling automation, accurate data and credible program evaluations.

The Faculty of Engineering had studied various options for developing its assessment methodology and systems [19,20,21,22,27,28,30,31,32,33,34,36,39,40,41,43] to establish actual CQI and not just fulfill ABET accreditation requirements [9]. The following points summarize the essential elements chosen by the faculty to incrementally develop and implement an authentic outcome-based IQMS employing state-of-the-art assessment systems and quality processes for achieving realistic CQI in engineering education:

1. OBE assessment model

Justification: The OBE model is selected due to its 'success for all' student centered learning approaches [1,2,3,4,5] which are adopted by IEAs' Washington Accord signatories globally for delivering world class engineering education [8]

2. ***ABET, EAC outcomes assessment model employing PEOs, 11/7 ABET EAC SOs and PIs to measure COs***

Justification: The Faculty of Engineering programs seek ABET accreditation for their global quality standards and therefore the IQMS assessment model should align fully with that of ABET [9].

3. Selection of appropriate Learning Model, learning domains and learning levels

Justification: Achieve accurate application and alignment of Bloom's Taxonomic and Mastery Learning to curriculum, pedagogy and assessment by appropriate selection of learning domains such as cognitive, affective and psychomotor domains and their learning levels. Grouping the learning levels of each domain in elementary, intermediate and advanced levels for ease of application of outcomes to curriculum development, instruction, course level activity and assessments [3,4,5,24,25].

4. ***Measurement of outcomes information in all course levels of a program curriculum:***

Justification: In order to achieve comprehensive and realistic CQI, outcomes data should be a heterogeneous sample collected from all course levels *Introductory, Reinforced* and *Mastery* and not just from the final level courses [20,32,35,40]. This enables formative approaches that facilitate on time remedial actions for failures observed in earlier phases of curriculum delivery and are not too late for corrective actions.

5. The FCAR utilizing the EAMU performance vector methodology

Justification: FCAR using the EAMU performance vector methodology enables embedded assessments and collection of outcomes data for all students in a cohort [32,39,47,48,49]. This saves immense faculty time and resources by using tightly aligned routine course work for assessments and supports a crucial principle of OBE, which is providing outcomes information to all enrolled students.

6. Well-defined performance criteria for course and program level evaluation

Justification: Well defined and detailed performance criteria facilitate valid and reliable assessment [1,2,20,24]. They support accurate development and application of rubrics to learning activities. At the program level, they enable accurate evaluation of outcomes attainment and precision corrective actions.

7. Standard COs and PIs Design Rules

Justification: Combining Spady's (2020,1994 a, b) fundamental guidelines related to the language of outcomes [3,4,5], key concepts from Adelman's work (2015) on verbs and nominal content [16], and some essential details on the hierarchical structure of outcomes from Mager's work

(1962) [52] led to a consistent standard for learning outcome statements that were accurately aligned to the course delivery using a structured format for COs and specific PIs.

8. *A digital database of specific PIs and their hybrid rubrics classified as per Bloom's 3 domains*
Justification: Since an engineering undergraduate student has to learn several hundred learning activities of ranging domains and skills levels during a typical course of study, it is pertinent that the IQMS captures all these range of performances in multiple courses throughout the engineering curriculum using digitally indexed outcomes and performance indicators information properly stored in an easily accessible digital database. Every Performance Indicator consists of a corresponding hybrid rubric accessible to both students and faculty. The hybrid rubric is a combination of analytic and holistic rubrics' models and has topic specific detail for accurate assessment of student learning activity [50,51].

9. Unique Assessment mapping to one specific PI
Justification: Avoiding redundant alignment is a crucial practice of good assessment. It ensures no two outcomes measure the same learning activity [2,5,16,24,50]. Therefore, unique assessments mapping to a specific performance indicator ensure outcomes are computed correctly and are a hall mark of accurate assessment models.

10. Scientific Constructive Alignment
Justification: To be able to design assessments with tight alignment to intended student learning activity for obtaining realistic outcomes data representing information for one specific PI per assessment [2,5,24].

11. Comprehensive Course Evaluations
Justification: Integration of direct, indirect, formative, and summative outcomes assessments for full spectrum comprehensive course evaluations [32,39].

12. Accurate Computations of Outcomes Information
Justification: Calculation of program and course level ABET SOs, COs data based upon weights assigned to type of assessments, PIs and course levels [20,32,35,39]. This ensures pure averaging is not applied directly to student performances corresponding to varying skills and course levels.

13. Systematic Program Evaluation Process
Justification: Systematic Program Evaluation process consisting of 3 parts supporting full spectrum step-by-step approach for failure analysis and subsequent corrective actions: a) *Learning Domains Evaluation*: for evaluation of coverage of learning distribution of Bloom's 3 domains and their learning levels b) *PIs Evaluation*: that provides detailed results collected from corresponding assessments in various courses and c) *ABET SOs Evaluation:* that provides an overall program level SOs attainment by weighted aggregation of the results of corresponding PIs and assessments

14. Digital Developmental Advising System

Justification: A student academic advising module based on measured learning outcomes and skills data collected for each individual student and not just based on academic transcripts and GPA information [53-57].

15. Continuous Improvement Management System

Justification: Electronic integration of AIs generated from program outcomes term reviews with the Faculty of Engineering standing committees' meetings, tasks, lists and overall CQI processes (CIMS feature).

16. Integrated Quality Management Systems

Justification: Electronic integration of the Administrative Assistant System (AAS), the Learning Management System (LMS), the Outcomes Assessment System (OAS) and the Continuous Improvement Management System (CIMS), facilitating faculty involvement for realistic CQI [32,34].

17. Total Quality Management Processes

Justification: Technology driven highly organized operational processes that follow well defined PDCA cycles based on principles of total quality management to ensure faculty adherence to quality standards in all phases of education.

18. Remote Evaluator Module

Justification: A good number of accreditation agencies have been introducing articles in their accreditation policy to indicate provisions for engineering programs to collect, and report digital data as objective evidence for accreditation audits. Specifically, ABET introduced article (*I.E.5.b.(2))* in their Accreditation Procedure and Policy Manual (APPM) manual to accommodate engineering programs that choose to maintain digital display materials for accreditation audits [9]. Objective evidence in digital form enables great savings in terms of time, money and other resources for programs which are otherwise spent to collect and organize massive amounts of information as display materials for onsite visits. Remote audits can make life easier for evaluators since the digital data is typically made available for an extended period of time and web-based software can organize the display data efficiently to make the otherwise traumatic accessibility and review of specific documentation a seamless and convenient affair.

19. Customizable Software

Justification: Customizable web-based software EvalTools® employing ABET criteria, FCAR embedded assessments methodology and facilitating development of all of the above additional features [34]

g) Selection of Software

Selection of a web-based software for development and implementation of the IQMS entailed consideration of multiple factors as listed below:

1. Affordable or open source software
2. Degree of customizability
3. Technical support
4. Embedded assessments methodology
5. ABET criteria

For the Islamic University, being a government funded institution, the choices for software selection were primarily based on allocated budget and available technical support. Blackboard® was a paid LMS software provided to all government institutions in Saudi. Moodle® was another option, since it was open source. Unfortunately, both these popular options did not offer embedded assessment methodology, did not implement ABET criteria (consisting of an outcomes hierarchical structure of SOs, COs, PIs), and were not customizable. On the other hand, EvalTools® presented by CEO of Makteam Inc. Dr. Fong Mak became a viable solution since it incorporated ABET criteria directly and employed embedded assessment methodology using the FCAR. The key selling point of EvalTools® was Dr. Fong's offer to provide full scale technical support for massive customizations to the version 5 of the software to integrate the CIMS module to LMS and expand the existing outcomes assessment capabilities to incorporate all the essential elements of the intended digital IQMS. Finally, since costs of subscription and development played a major role for government institutions in Saudi, the management of the Faculty of Engineering decided to select EvalTools® for development of the IQMS when Dr. Fong offered the Islamic University a one-year free subscription followed by discounted pricing and full scale customizations.

B. PRIOR PUBLICATIONS TO BE INCLUDED AS PART OF THE THESIS

i. Publications

a) 2nd International Conference on Outcomes Assessment (ICA), QIYAS, National Center of Assessment, Intercontinental Hotel, Riyadh, Saudi Arabia (2015)

Hussain, W. and Addas, M., F. (2015), "*A Digital Integrated Quality Management System for Automated Assessment of QIYAS Standardized Learning Outcomes*", 2nd International Conference on Outcomes Assessment (ICA), 2015, QIYAS, Riyadh, KSA

b) National Institute for Learning Outcomes Assessment (NILOA), Lumina, Teague Foundation, University of Illinois, Urbana Champaign (2016)

Hussain, W. and Addas, M. F. (2016, April), "*Digitally Automated Assessment of Outcomes Classified per Bloom's Three Domains and Based on Frequency and Types of Assessments*". National Institute for Learning Outcomes Assessment (NILOA), Lumina, Teague Foundation, University of Illinois, Urbana Champaign.
http://www.learningoutcomesassessment.org/documents/Hussain_Addas_Assessment_in_Practice.pdf

c) 123rd Annual Conference & Exposition, American Society for Engineering Education (ASEE), New Orleans Convention Center, New Orleans, Louisiana (2016)

Hussain, W., Addas, M. F. and Fong, M., "*Engineering Program Evaluations Based on Automated Measurement of Performance Indicators Data Classified into Cognitive, Affective, and Psychomotor Learning Domains of the Revised Bloom's Taxonomy*," 123rd Annual Conference & Exposition, ASEE, 2016.
https://www.asee.org/public/conferences/64/papers/14792/view

d) 46th Annual Frontiers in Education Conference (FIE), Bayfront Convention Center, Erie, Pennsylvania (2016)

Hussain, W., Addas, M. F. and Fong, M., "*Quality Improvement with Automated Engineering Program Evaluations Using Performance Indicators Based on Bloom's 3 Domains*," in Frontiers in Education Conference (FIE), 2016 IEEE, 2016, pp. 1-9.
https://ieeexplore.ieee.org/document/7757418/fie-conference.org/sites/fie-conference.org/files/FIE-2016-Proceedings.pdf

e) 124th Annual Conference & Exposition, American Society for Engineering Education (ASEE), Columbus Convention Center, Columbus, Ohio (2017)

Hussain, W., and Spady, W., "*Specific, Generic Performance Indicators and Their Rubrics for the Comprehensive Measurement of ABET Student Outcomes*," 124th Annual Conference & Exposition, ASEE 2017.
https://peer.asee.org/specific-generic-performance-indicators-and-their-rubrics-for-the-comprehensive-measurement-of-abet-student-outcomes

f) Rex Publishers, Manila, Philippines, February 2018

William Spady, Wajid Hussain, Joan Largo, Francis Uy; Book Chapters - 7 & 8, "*Beyond Outcomes Accreditation*," - Rex Publishers, Manila, Philippines, February 2018
https://www.rexestore.com/home/1880-beyond-outcomes-accredidation-paper-bound.html (paper bound)
https://www.rexestore.com/e-books/1906-beyond-outcomes-accreditation-exploring-the-power-of-real-obe-practices-e-book-pdf-.html (e-book)

g) 9th International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2020, Takamatsu, Japan, Dec 8-11 (2020)

Hussain, W., and Spady, W., *"Industrial Training Courses – A Challenge During the COVID19 Pandemic,"* in 9th International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2020, IEEE Education Society, Takamatsu, Japan, Dec 8-11, 2020.
http://tale2020.org/
https://ieeexplore.ieee.org/abstract/document/9368455

h) IEEE Open Access Journal 2020

Hussain, W., Spady, W., Naqash, T., Khan, S., Z., Khawaja, B., A., Conner, L., "ABET Accreditation During and After the COVID19 pandemic – Navigating the Digital Age", 2020, IEEE Open Access.
https://ieeexplore.ieee.org/document/9274316

i) IEEE Open Access Journal 2021

W. Hussain, W. G. Spady, S. Z. Khan, B. A. Khawaja, T. Naqash and L. Conner, "IMPACT EVALUATIONS OF ENGINEERING PROGRAMS USING ABET STUDENT OUTCOMES," in IEEE Access, doi: 10.1109/ACCESS.2021.3066921
https://ieeexplore.ieee.org/document/9380632

ii. Research Contribution and Impact

Table 1: Research Contributions

Pub. No.	Title	Contributions
Pub (a)	Hussain, W. and Addas, M., F. (2015), "*A Digital Integrated Quality Management System for Automated Assessment of QIYAS Standardized Learning Outcomes*", 2nd International Conference on Outcomes Assessment (ICA), 2015, QIYAS, Riyadh, KSA.	✓ Led Publication Process ✓ Write up initial draft, editing and final draft ✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection, Analysis and Reporting ✓ Development, Implementation and Management of State of the Art Quality Processes ✓ Software Development: Integral part of technological conceptualization, deployment, data base management, testing, monitoring, improvements or enhancements
Pub (b)	Hussain, W. and Addas, M. F. (2016, April), "*Digitally Automated Assessment of Outcomes Classified per Bloom's Three Domains and Based on Frequency and Types of Assessments*". National Institute for Learning Outcomes Assessment (NILOA), Lumina, Teague Foundation, University of Illinois, Urbana Champaign.	✓ Led Publication Process ✓ Write up initial draft, editing and final draft ✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection, Analysis and Reporting ✓ Development, Implementation and Management of State of the Art Quality Processes ✓ Software Development: Integral part of technological conceptualization, deployment, data base management, testing, monitoring, improvements or enhancements
Pub (c)	Hussain, W., Addas, M. F. and Fong, M., "*Engineering Program Evaluations Based on Automated Measurement of Performance Indicators Data Classified into Cognitive, Affective, and Psychomotor Learning Domains of the Revised Bloom's Taxonomy*," 123rd Annual Conference & Exposition, ASEE, 2016.	✓ Led Publication Process ✓ Wrote up initial draft, editing and final draft ✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection, Analysis and Reporting ✓ Development, Implementation and Management of State of the Art Quality Processes ✓ Software Development: Integral part of technological conceptualization, deployment, data base management, testing, monitoring, evaluation of improvements or enhancements
Pub (d)	W. Hussain, M. F. Addas and F. Mak, "Quality improvement with automated engineering	✓ Led Publication Process ✓ Write up initial draft, editing and final draft

	program evaluations using performance indicators based on Bloom's 3 domains," 2016 IEEE Frontiers in Education Conference (FIE), Erie, PA, USA, 2016, pp. 1-9, doi: 10.1109/FIE.2016.7757418.	✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection and Reporting ✓ Development, Implementation and Management of State of the Art Quality Processes ✓ Software Development: Integral part of technological conceptualization, deployment, data base management, testing, monitoring, improvements or enhancements
Pub (e)	Hussain, W., and Spady, W., "*Specific, Generic Performance Indicators and Their Rubrics for the Comprehensive Measurement of ABET Student Outcomes*," 124th Annual Conference & Exposition, ASEE 2017.	✓ Led Publication Process ✓ Write up initial draft, editing and final draft ✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection and Reporting ✓ Development, Implementation and Management of State of the Art Quality Processes
Pub (f)	William Spady, Wajid Hussain, Joan Largo, Francis Uy; Book Chapters - 7 & 8, "Beyond Outcomes Accreditation," - Rex Publishers, Manila, Philippines, February 2018.	✓ Led Publication Process ✓ Write up initial draft, editing and final draft ✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection and Reporting ✓ Development, Implementation and Management of State of the Art Quality and Evaluation Processes ✓ Software Development: Integral part of technological conceptualization, deployment, data base management, testing, monitoring, improvements or enhancements
Pub (g)	W. Hussain and W. G. Spady, "Industrial Training Courses: A Challenge during the COVID19 Pandemic," 2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE), Takamatsu, Japan, 2020, pp. 189-196, doi: 10.1109/TALE48869.2020.9368455	✓ Led Publication Process ✓ Write up initial draft, editing and final draft ✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection and Reporting ✓ Development, Implementation and Management of State of the Art Quality and Evaluation Processes ✓ Software Development: Integral part of technological conceptualization, deployment, data base management, testing, monitoring, improvements or enhancements
Pub (h)	W. Hussain, W. G. Spady, M. T. Naqash, S. Z. Khan, B. A. Khawaja and L. Conner, "ABET	✓ Led Publication Process ✓ Write up initial draft, editing and final draft

	Accreditation During and After COVID19 - Navigating the Digital Age," in IEEE Access, vol. 8, pp. 218997-219046, 2020, doi: 10.1109/ACCESS.2020.3041736.	✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection, Analysis and Reporting ✓ Development, Implementation and Management of State of the Art Quality and Evaluation Processes ✓ Software Development: Integral part of technological conceptualization, deployment, data base management, testing, monitoring, evaluation for improvements or enhancements
Pub (i)	W. Hussain, W. G. Spady, S. Z. Khan, B. A. Khawaja, T. Naqash and L. Conner, "Impact Evaluations of Engineering Programs Using ABET Student Outcomes," in *IEEE Access*, doi: 10.1109/ACCESS.2021.3066921.	✓ Led Publication Process ✓ Write up initial draft, editing and final draft ✓ Research Conceptualization ✓ Implementation of OBE Frameworks ✓ Development and Implementation of Novel Assessment Methodology ✓ Management of Data Collection, Analysis and Reporting ✓ Development, Implementation and Management of State of the Art Quality and Evaluation Processes ✓ Software Development: Integral part of technological conceptualization, deployment, data base management, testing, monitoring, evaluation for improvements or enhancements

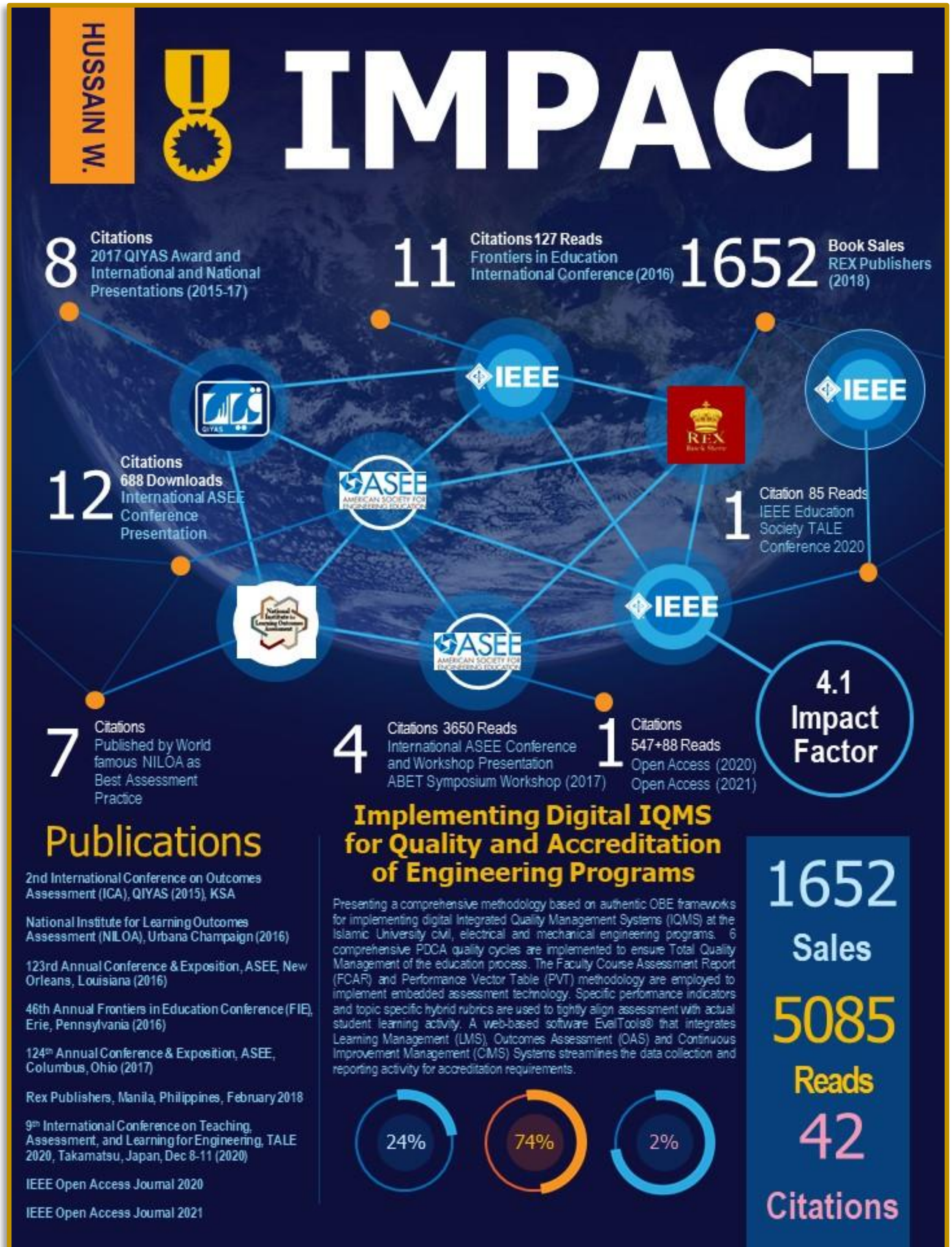

Figure 1: Impact of Research Publications

iii. Timeline and Milestones

a) Timeline for Implementing Digital IQMS and Associated Research Activity

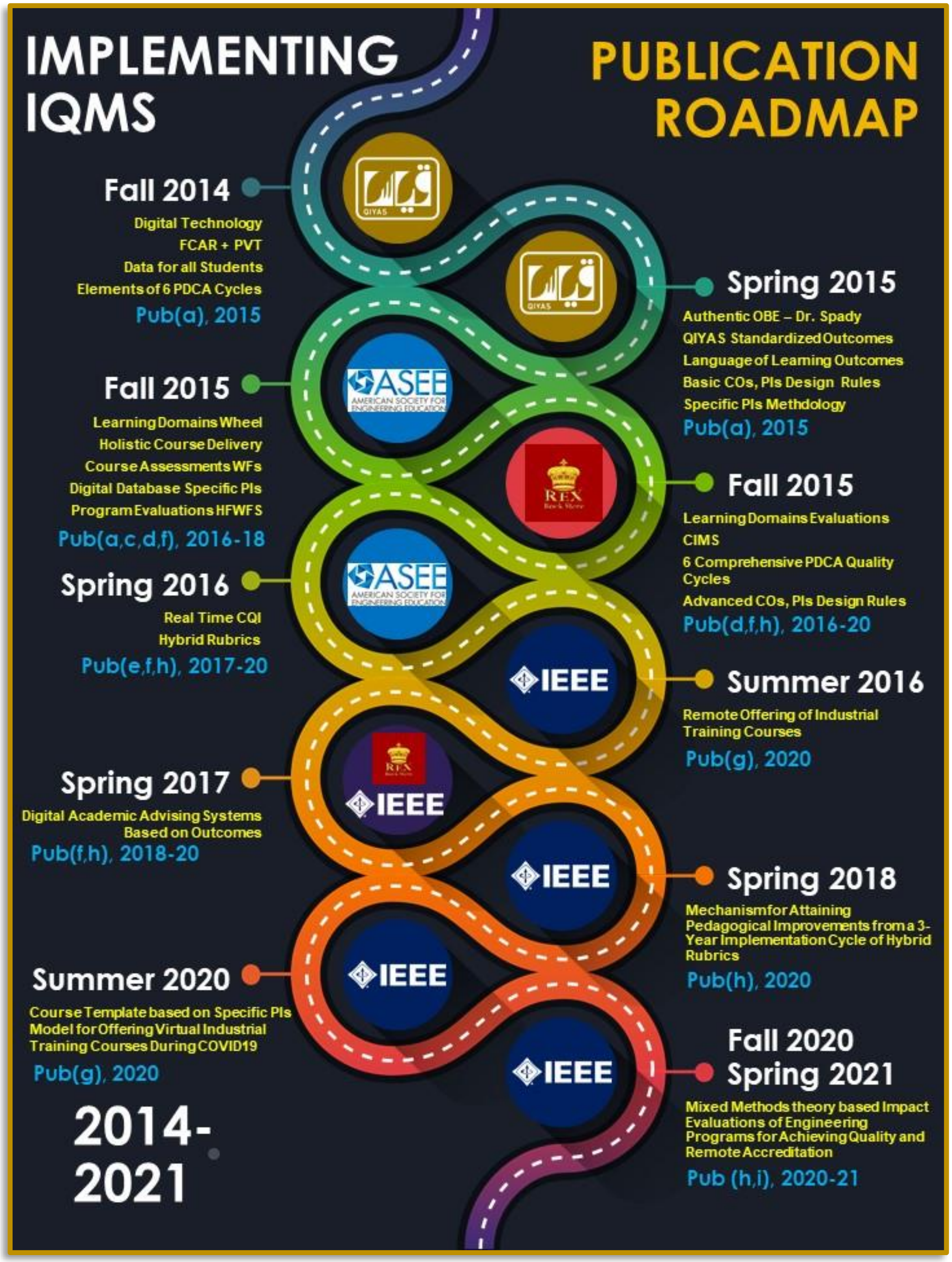

Figure 2: Timeline for Implementing Digital IQMS and Publication Road Map

b) Milestones for Establishing the IQMS

The specific milestones achieved for fulfillment of the purpose of this intervention are shown in the Table 2 below:

Table 2: Milestones, Studied Issues, Developed and Implemented Solutions for Establishing IQMS

Milestones		Study Issues	Develop and Implement Solutions
Fall 2014	**Digital Technology**	Realistic CQI is difficult to achieve in higher education by using manual systems since processes related to collection, reporting and documentation of quality data cannot be easily implemented and lack sustainability **[Pub(a), 2015]**	▪ Implemented initial rev 5 of EvalTools® which employed the *FCAR basic* and did not provide a specific PIs database, weighting factors for course and skills levels **[Pub(a), 2015]**
Spring 2015	**Authentic OBE**	Most essential principles of authentic OBE philosophy and paradigm are either not targeted or achieved. **[Pub(a), 2015]**	▪ Establishing a close consultation and collaboration for review of philosophy, paradigm, principles and premises of authentic OBE with Dr. William Spady, 'Father of OBE' (student of Benjamin Bloom) **[Pub(a), 2015]**
Fall 2014	**Data Collection for ALL Students**	CQI information for all students is not collected, documented or reported. **[Pub(a), 2015]**	▪ Implemented EvalTools® FCAR+PVT technology that enabled outcomes data collection for ALL enrolled students **[Pub(a), 2015]**
Fall 2015	**Learning Model**	Learning models are generally not understood and used comprehensively as the founding framework for curriculum delivery and CQI efforts. **[Pub(a), 2015; Pub(c), 2016]**	▪ Developed the Learning Domains Wheel to validate the selection of Bloom's domains instead of the SQF 5 domains. ▪ Specified regulations for selection of learning domains categories and classification of outcomes based on learning domains and their levels **[Pub(c), 2016]**
Spring 2015	**Language of Outcomes Scientific Constructive Alignment**	Language of learning outcomes is deficient and lacking alignment with actual activity. **[Pub(a), 2015; Pub(c), 2016]**	▪ Established fundamental framework for *language of outcomes* with implementation using embedded assessments employing *FCAR + PVT methodology*. ▪ Developed and implemented *Scientific Constructive Alignment* methodology to be used in conjunction with the Setup Assignment Module of *EvalTools®* for achieving enhanced alignment with actual student learning activity. **[Pub(a), 2015; Pub(c), 2016]**

Spring 2015 - Fall 2017	**COs and PIs Design Rules Specific PIs Methodology**	PIs are mostly generic and lack the required specificity to achieve required validity and reliability in assessment and evaluation. **[Pub(a), 2015; Pub(c), 2016; Pub(e), 2017]**	▪ Incorporated the Saudi Ministry of Education's *National Standardized Learning Outcomes* for engineering disciplines; ▪ Developed and implemented '*Design Down'* mapping model to align Program Educational Objectives (PEOs) to program Student Outcomes (SOs), Course Outcomes (COs) and specific Performance Indicators (PIs); ▪ Developed and implemented improved version of COs and PIs design rules based on consistent framework extracted from work done by *Spady, Adelman* and *Mager.* **[Pub(a), 2015; Pub(c), 2016. Pub(e), 2017]**
Fall 2015	**Course Level WFs**	Course evaluations do not incorporate proper weightage for various types of assessments. **[Pub(a), 2015; Pub (b), 2016; Pub(c), 2016]**	▪ Developed 4 course formats based on course offerings with lab and/or project for computing weighting factors for various types of assessments; ▪ Implemented customized modifications to EvalTools® **[Pub(a), 2015; Pub (b), 2016; Pub(c), 2016]**
Fall 2015 – Fall 2017	**Holistic Course Delivery Mastery Learning**	Course delivery is not systematically aligned with flow of course outcomes to implement Bloom's Mastery Learning **[Pub(c), 2016; Pub(e), 2017; Pub(f), 2018]**	▪ Developed the *Ideal Learning Distribution Model* for holistic curriculum delivery to implement essential concepts of *Bloom's Mastery Learning*; ▪ Developed and implemented a thorough mechanism of holistic course delivery using structured format of COs and their PIs, thereby achieving *Ideal Learning Distribution*. **[Pub(c), 2016; Pub(e), 2017; Pub(f), 2018].**
Fall 2015 – Fall 2020	**Digital Database of Specific PIs**	PIs are not classified as per the three learning domains of Bloom's and their learning levels. **[Pub(c), 2016; Pub(d), 2016; Pub(e), 2017; Pub(f), 2018]**	▪ Developed and implemented a digital database of thousands of specific PIs corresponding to the ABET SOs and classified as per Bloom's three learning domains and their learning levels. **[Pub(c), 2016; Pub(d), 2016; Pub(e), 2017; Pub(f), 2018]**
Spring 2016 – Spring 2020	**Real Time CQI**	Real-time corrective actions with formative assessments are rarely implemented. **[Pub(e), 2017; Pub(f), 2018]**	▪ Course delivery implemented *Ideal Learning Distribution* and *Mastery Learning* with specific PIs achieved real-time corrective actions **[Pub(e), 2017; Pub(f), 2018]**

Spring 2016 – Spring 2020	**Hybrid Rubrics**	Evaluation of type of rubrics employed by several programs indicated that most rubrics are generic, simplistic and vague and lack the necessary detail to accurately assess several hundred complex student learning activities of any engineering specialization. **[Pub(e), 2017; Pub(f), 2018]**	▪ Developed the *Hybrid Rubric*. A combination of analytic and holistic rubrics with descriptors providing details of method, techniques, steps of solution. **[Pub(e), 2017; Pub(f), 2018].** ▪ 3-year Rubrics implementation quality cycle was established in 2018. **[Pub(i), 2020]**
Spring 2018 – Spring 2020	**Scoring Rubrics by Course Instructors**	Independent raters are used to apply generic rubrics to completed portfolios **[Pub(e), 2017; Pub(f), 2018]**	▪ Development and implementation of data collection processes including scoring assessments using rubrics that are performed by just course instructors, thereby enabling formative assessments and real-time CQI. Since ABET does not mandate any benchmarking based on inter-program comparisons Independent raters are not required. **[Pub(e), 2017; Pub(f), 2018]**
Fall 2015	**Program Evaluations Aggregating Outcomes Data from All Course & Skills Levels**	▪ Most program evaluations as referred to in the literature reviews are based on a small set of random samples of student activity. ▪ Program evaluations do not incorporate appropriate weightage to course and skill levels. **[Pub(d), 2016; Pub(f), 2018]**	Development and implementation of program evaluations using EvalTools® FCAR + Specific PIs PVT methodology enabling aggregation of heterogeneous outcomes data set, collected for all students, in all courses, combining skills in three levels, by using a scientific weighting system called *Hierarchy-Frequency Weighting-Factor Scheme* (HFWFS) that incorporates the counts of assessments in each course and skills level. **[Pub(d), 2016; Pub(f), 2018]**
Fall 2015	**Learning Domains Evaluations**	Program evaluations do not analyze the coverage of student learning in all the three domains of Bloom's taxonomy and their learning levels. **[Pub(d), 2016; Pub(f), 2018]**	Development and implementation of SOs, PIs and Learning Domains Evaluations of EvalTools® to provide a full spectrum coverage of analyses of student learning in all 3 domains of Bloom's taxonomy and their learning levels. **[Pub(d), 2016; Pub(f), 2018]**
Fall 2015	**CIMS**	CQI efforts are not realistic and programs mostly employ reverse engineering to link corrective actions to outcomes evaluations results. **[Pub(f), 2018; Pub(h), 2020]**	Development, deployment and implementation of the CIMS module of EvalTools®. 20 administrative committees communicate with each other using the CIMS. Action items have electronic indices, remarks, history and time stamps resulting in high level of credibility thereby, totally eradicating any kind of reverse engineering of CQI processes. **[Pub(f), 2018; Pub(h), 2020]**

Spring 2017 – Spring 2020	**Digital Academic Advising Systems Based on Outcomes**	Academic advising systems are not based on student outcomes information. **[Pub (f), 2018; Pub(h), 2020]**	Development, deployment and implementation of digital academic advising systems based on outcomes using EvalTools®. Implemented developmental advising using a mixed methods approach for evaluating students' skills performances. **[Pub (f), 2018; Pub(h), 2020]**
Summer 2016 – Summer 2020	**Remote and Virtual Industrial Training Courses**	Industrial Training courses cannot be managed and assessed remotely by training advisors. [**Pub(g), 2020]**	▪ Development, deployment and implementation of remote training employer surveys and digital bi-weekly reports fully integrated with all the COs for systematic guidance of offsite student training. ▪ Developed a novel course template using EvalTools® for offering off site remote and virtual industrial training courses during global COVID19 pandemic conditions. A viable alternative to onsite industrial training courses during social distancing or lockdown conditions. [**Pub(g), 2020]**
Fall 2015 – Spring 2020	**6 Comprehensive PDCA Quality Cycles**	Quality assurance, monitoring and control processes at course or program level are not well defined, rigorous and properly allocated to dedicated staff to ensure standards of outcomes, rubrics, their alignment with learning activity, assessment, feedback, and improvement, and on time completion of accurate data collection and reporting efforts. **[Pub(h), 2020]**	6 PDCA quality cycles with comprehensive QA processes were developed and implemented by a dedicated quality team to ensure all aspects of the IQMS are fully compliant to accreditation criteria and established quality standards. **[Pub(h), 2020]**

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Fall 2014 – Spring 2020	**Comprehensive Mixed Methods Theory Based Impact Evaluations Using an Eight Phase Meta-framework**	▪ Quality cycles involving assessment, evaluation and improvement processes do not properly integrate with each other making if difficult to establish a causal link. ▪ The underlying assumptions of some quality cycles are not based on authentic OBE frameworks or best assessment practices. ▪ The frequency and time period of some quality cycles do not enable effective CQI actions since they do not cover all the SOs that can be practically managed for evaluation and realistic improvement effort. **[Pub(h), 2020; Pub(i), 2021]**	▪ Managed execution of 6 PDCA quality cycles seamlessly over a period of 6 years, till date, using the digital IQMS. ▪ Millions of documents stored in a cloud environment as objective evidence. ▪ Comprehensive mixed methods theory based impact evaluations using an eight phase meta-framework involving: 1. Detailed evaluation of construct of interventions. 2. Detailed analyses of underlying assumptions of all elements of the causal links. 3. Meta-analyses of the process and product. 4. Multi-term SOs trend analyses using regression methods. 5. Sustainability analyses of data collection and reporting processes. 6. Evaluation of all assessment and evaluation activities in each PDCA quality cycle. 7. Evaluation of statistical power and quality of data ▪ Achieved highly successful ABET accreditation results using the IQMS and remote Evaluator Module. ▪ ABET reported just strengths and no weakness or concerns. **[Pub(h), 2020; Pub(i), 2021]**

iv. Coherence of Research Publications

Coherence of the listed publications is established through their strong link with the objectives of this continued research. The study of issues and development and implementation of solutions for establishing IQMS are extracted from items (a-v) of *Section A.iv Major Issues of Prevalent Manual CQI, Assessment and Evaluation Mechanisms*.

The issues (a-v) are reproduced below in concise form for easy understanding and quick review:

a) Prime driver for outcomes assessment is accreditation.
b) Realistic CQI is difficult to achieve with manual systems.
c) Most principles of authentic OBE philosophy are not targeted or achieved.
d) CQI information for all students is not collected.
e) Learning models are generally not used as the founding framework for CQI efforts.
f) Course evaluations do not apply weightage to various types of assessments.
g) Language of learning outcomes is deficient and lacking alignment.
h) PIs are mostly generic and lack the required specificity.
i) Majority of assessment models just target learning activity in the cognitive domain.
j) Course delivery is not aligned with flow of COs.
k) Real-time corrective actions with formative assessments are rarely implemented.
l) Most rubrics are generic, simplistic and vague.
m) Independent raters are used to apply generic rubrics to past course portfolios.
n) Program evaluations use small set of random samples of student work.
o) Program evaluations do not apply appropriate weightage to course and skill levels.
p) Program evaluations do not analyze student learning in Bloom's three domains
q) Academic advising systems are not based on SOs data.
r) Industrial Training courses cannot be managed and assessed remotely.
s) Reverse engineering is employed to link corrective actions to outcomes evaluations results.
t) Quality management of course or program level activity are not well defined and properly distributed to dedicated staff.
u) Processes in PDCA cycles are not based on authentic OBE frameworks.
v) Frequency and time period of quality cycles are not manageable and sustainable.

The mapping of my listed publications with the overall objectives of the continued research is provided in the Table 3 below.

Table 3: Coherence of Publications Proved by Mapping to Study of Issues, and Development and Implementation of Solutions for attainment of Overall Objectives of Continued Research

Pub	Organization	Aspects of Continued Research that Fulfill its Objectives	
		Study Issues	**Develop & Implement Solutions**
(a)	QIYAS, ICA, Riyadh, 2015	b c D f g h q	b c d f g h q
(b)	NILOA, IL, 2016	a b D e f g h n o p	b d e f g h n o p
(c)	FIE, Erie, PA, 2016	a b E g i j k n o p t	b e g i j k n o p t
(d)	ASEE, New Orleans, LA, 2016	a b C d e f g h i j k n o p	b c d e f g h i j k n o p
(e)	ASEE, Columbus, OH, 2017	a b c d e f g h i j k l m o p q s t	b c d e f g h i j k l m o p q s t
(f)	REX, Manila, Philippines, 2018	a b c d e f g h i j k l m o p q s t u v	b c d e f g h i j k l m o p q s t
(g)	TALE, Takamatsu, Japan, 2020	a b c d f g h i j k l r	b c d f g h i j k l r
(h)	IQMS (IEEE+Thesis)	a b c d f g h i j k l m o p q s t u V	b c d f g h I j k l m o p q s T u V
(i)	SOs Multi-term Impact Evaluations (IEEE+Thesis)	a b c d f g h i j k l m o p q s t u v	b c d f g h I j k l m o p q s T u v

C. SYNOPSIS OF PRIOR PUBLICATIONS AND PRESENTATIONS

i. Publication(a): Hussain, W. and Addas, M., F. (2015), "A Digital Integrated Quality Management System for Automated Assessment of QIYAS Standardized Learning Outcomes", 2nd International Conference on Outcomes Assessment (ICA), 2015, QIYAS, Riyadh, KSA

Conference: 2nd International Conference on Outcomes Assessment (ICA), 2015, QIYAS, Riyadh, KSA

Theme of Conference:
The Second International Conference on Measurement and Evaluation, which will be held in Riyadh, aims to benefit from global experiences and trends in the field of measuring learning outcomes, studying and evaluating local efforts and practices, and enriching scientific aspects in the field of measuring learning outcomes. The conference includes four main axes, the first of which is contemporary knowledge systems for education, the second axis is a discussion of issues and trends in measuring learning outcomes, the third axis is a review of international and local experiences in measuring learning outcomes, and finally, the applications of measuring learning outcomes in improving the quality of public education and higher education, accountability and responsibility in Education, and improving the quality of programs and courses.

https://etec.gov.sa/en/Media/News/Pages/Measurecalls.aspx
https://www.youtube.com/watch?v=CdZLFgGmCIg
https://www.youtube.com/watch?v=JaQ0trgk6YE

Summary:
In November 2014, QIYAS had rolled out a national standardized list of learning outcomes for assessing various aspects of computing and engineering knowledge and skills. They initially mandated engineering and computing programs to utilize these outcomes for assessment, evaluation and subsequent student and program improvement. The approach adopted for this research involved a qualitative review of literature covering issues regarding manual systems for engineering accreditation followed by study of existing digital solutions and best assessment practices for implementation or development of CQI models or processes. The approach involved the development of a consistent framework for the generation of COs and their specific PIs for course delivery. Specifically, weighting schemes for course evaluations considering types of assessments were developed and implemented. Program and student evaluations were implemented using quantitative SOs and PIs data using this weighted course assessment information. A qualitative review of literature on engineering accreditation topics revealed several issues with prevalent manual CQI systems. Further, search of available tools indicated EvalTools® provided embedded assessment capability and specialized customizations. At the Faculty of Engineering, automation of the assessment, evaluation and CQI processes was therefore, implemented using web-based software EvalTools® that employed embedded

assessments methodology of the FCAR. Several hundred QIYAS indicators were studied and integrated into a PIs digital database for eventual application to instruction, assessment and evaluation. A weighting scheme incorporating various course assessment types was implemented to overcome inaccurate aggregation of outcomes data that does not prioritize final exams over a homework or quiz. Automated student, course and program level evaluations utilizing quantitative SOs and specific PIs data were implemented. However, our almost two-year research involving application of QIYAS indicators revealed that several faculty members could not easily apply many of these indicators to instruction, assessment or evaluation. Several of the indicators were futuristic, whereas many others could not be appropriately aligned with the pedagogical aspects related to course topics and their assessment. The findings of this research provided significant insight to the various stakeholders and eventually the Ministry of Education recalled the mandate for application of the QIYAS national standardized indicators. The author also identified the need for classification of PIs and application of a weighting scheme for implementing accurate program evaluations. The Faculty of Engineering was able to successfully accomplish implementation of an initial version of the digital IQMS achieving high levels of automation for assessment, evaluation and CQI activity yielding enhanced alignment, accuracy and traceability of objective evidence.

Table 4: Publication (a) Research Contributions

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Assessment Methodology	Embedded Assessments using the FCAR and specific PIs
	Software Development, Deployment, Testing	EvalTools® FCAR (EAMU and PVT); SOs/PIs evaluations; CIMS;
	Course Delivery Framework	Consistent framework for the development of COs and their specific PIs based on Spady and Mager principles
	PIs Digital Database	Digital database of hundreds of PIs for alignment with instruction, assessment and evaluation
	QIYAS Indicators	Implemented into a digital PIs database for alignment with instruction, assessment and evaluation
	CQI Course Evaluation	Course level aggregation of outcomes data for ALL students using the EAMU PVT methodology with weighted averaging of various assessment types for 4 course formats. Scientifically color coded flagging system based on well-defined performance criteria.
	CQI Program Evaluation	Program level quantitative evaluation of SOs and their PIs based on a pure averaging aggregation scheme
	CQI CIMS	An automated interface, CIMS, that connected course and program evaluations to the activity of administrative committees with capability for generation of electronically indexed action items.

Findings	Feasibility of Applying QIYAS Indicators	QIYAS indicators were either futuristic or were difficult to align with the actual student learning activity. Validity or reliability of assessments was affected and instructors did not find majority of the QIYAS indicators useful for actual application to teaching.
	Benefits of Automation	✓ All students' outcomes assessment data seamlessly collected and reported. ✓ Course evaluations were automated and accurate due to use of weighted assessments and clear performance criteria. ✓ Program evaluations based on quantitative SOs and PIs information aggregated using detailed course assessment information. ✓ The CIMS significantly alleviated the documentation, reporting, follow up and tracking process for several CQI actions
Future Work	Classification of PIs	The specific PIs would be classified following the *Bloom's Taxonomic* and *Mastery Learning* models
	Program Evaluations	Program evaluations would be accurately aggregated with weighting factors applied for course and skills levels

ii. Publication(b): Hussain, W. and Addas, M. F. (2016, April), "Digitally Automated Assessment of Outcomes Classified per Bloom's Three Domains and Based on Frequency and Types of Assessments". National Institute for Learning Outcomes Assessment (NILOA), Lumina, Teague Foundation, University of Illinois, Urbana Champaign.

About NILOA: The National Institute for Learning Outcomes Assessment (NILOA), established in 2008, is a research and resource-development organization dedicated to documenting, advocating, and facilitating the systematic use of learning outcomes assessment to improve student learning. NILOA supports institutions in designing learning experiences and assessment approaches that strengthen the experience of diverse learners within a variety of institutional contexts. NILOA works in partnership with a broad range of organizations and provides technical assistance and research support to various projects focused on learning throughout the U.S. and internationally.
https://www.learningoutcomesassessment.org/about/niloa-mission/

NILOA Assessment in Practice Publications:
NILOA invites faculty, staff, and administrators to author Assessment in Practice (AiP) pieces. These short and informative examples showcase meaningful assessment processes and practices from the field that can inform assessment activities at other institutions.

The Assessment in Practice publications are organized by topic area:

- General Education
- Engagement and Professional Development Activities
- Student Affairs and Administrative Units Reporting and Assessment
- Assessment Frameworks and Approaches

https://www.learningoutcomesassessment.org/wp-content/uploads/2019/04/AiP_HussainAddasApril2016.pdf

Summary:
In this *Assessment in Practice, NILOA* publication, several crucial elements of the Faculty of Engineering's outcomes assessment methodology are outlined that fully support automation and digital technology. The article covers a qualitative review of automated assessment, documentation and reporting systems that collect, analyze and utilize outcomes data to establish meaningful CQI and not just fulfill accreditation requirements. Specifically, key points of the assessment technology and methodology that support automated CQI efforts to achieve high levels of faculty buy-in are indicated. Seamless operations, active faculty involvement and lack of complaints were the main observations regarding faculty collaboration recorded by the *Quality and Accreditation Committee* to gauge faculty buy-in. The importance of massive data collection was especially highlighted for informed quality improvement decisions. Data was collected from

ALL students in courses in all levels of the program curriculum using the FCAR PVT methodology and EvalTools®. References were made to cutting edge research publications regarding a *Learning Wheel Model* for selection of Learning Domains and their learning levels; a comprehensive digital database of several hundred PIs classified per Bloom's 3 domains and their learning levels; and a program level evaluation system where SOs and PIs data are aggregated using weighted averaging based on the frequency and counts of assessments. The study qualitatively reviewed benefits and limitations of a Continuous Improvement Management System (CIMS) that provided faculty members with efficient streamlining mechanisms for quality improvement efforts by attaining high levels of automation of several QA processes using paper-free digital documentation and electronic tracking. Instant electronic access to thousands of digital records consisting of single or multi-term outcomes assessment information from program term review evaluations; detailed meeting minutes; and status of action items of 17 standing committees; were essential for conducting seamless CQI operations and compelling reasons for an eventual, almost 100% faculty buy-in of the implemented digital systems and outcomes assessment methodologies.

Table 5: Publication (b) Research Contribution

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Assessment Methodology	Embedded Assessments using the FCAR and specific PIs
	Software Development, Deployment, Testing	EvalTools® FCAR (EAMU and PVT); SOs/PIs evaluations; CIMS; Advising based on outcomes;
	Learning Model	An introductory reference to the use of a novel *Learning Domains Wheel* for appropriate selection of Learning Domains and their learning levels for the accurate assessment and evaluation of learning outcomes. An introduction to a novel *3-Levels Skills Grouping Methodology* for a simplified classification of outcomes as per Bloom's 3 learning domains and their learning levels.
	PIs Digital Database Based on Bloom's 3 Domains	Digital database of hundreds of specific PIs classified as per Bloom's 3 domains and their learning levels for accurate alignment with instruction, assessment and evaluation
	CQI Course Evaluation	Course level aggregation of outcomes data for ALL students using the *EAMU PVT* methodology with weighted averaging of various assessment types for 4 course formats. Scientifically color coded flagging system based on well-defined performance criteria.
	CQI Program Evaluation	An introductory reference to program level quantitative evaluation of SOs and their PIs based on a weighted averaging aggregation scheme

	CQI Integration of AAS, OAS and CIMS	Electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS) with Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI
Findings	Learning Models	Appropriate learning models should be used to avoid redundancy in classification of outcomes based on learning domains and enable automation of assessment.
	Classification of Specific PIs and Benefits for Assessment	An accurate and practical classification of PIs based on Bloom's 3 domains and their learning levels is achieved by utilizing a simplified model that groups learning levels into the elementary, intermediate and advanced skills levels.
	CQI Faculty Buy-in	The benefits of automation for comprehensive and massive CQI efforts were realized with a maximum rate of faculty buy-in (based on full faculty involvement and operations without complaints as observed by the Quality and Accreditation Committee) that resulted with streamlined CQI processes using digital technology that integrated FCAR embedded assessments and the CIMS module.
	CQI Weighted Program Evaluations	An introductory reference to an accurate program level evaluation of SOs and their PIs based on a weighted averaging aggregation scheme for assessment data collected from all courses in all levels of a program curriculum.
Future Work	Automated Remote Scoring System	The current approach for manual scanning of paper documents was the only aspect that required automation and the article concluded with a suggestion for development of an automated remote digital scoring system for marking assessments online.

iii. Publication(c): Hussain, W., Addas, M. F. and Fong, M., "Engineering Program Evaluations Based on Automated Measurement of Performance Indicators Data Classified into Cognitive, Affective, and Psychomotor Learning Domains of the Revised Bloom's Taxonomy," 123rd Annual Conference & Exposition, ASEE, 2016

Conference: American Society for Engineering Education (ASEE) 123rd Annual Conference & Exposition, New Orleans, LA, June 26 - 29, 2016

Conference Overview:
The ASEE Annual Conference and Exposition is the only conference dedicated to all disciplines of engineering education. It is committed to fostering the exchange of ideas, enhancing teaching methods and curriculum, and providing prime networking opportunities for engineering and technology education stakeholders such as deans, faculty members and industry and government representatives. The conference features more than 400 technical sessions, with peer-reviewed papers spanning all disciplines of engineering education.
https://www.asee.org/public/conferences/64/papers/14792/view

Summary:
The approach adopted for this research involved a qualitative review of literature covering issues regarding manual systems for engineering accreditation followed by development of learning models and assessment practices based on authentic OBE frameworks. The literature review indicated that most engineering programs generally focused on assessing outcomes related to the cognitive domain. A novel *Learning Domains Wheel* was implemented for appropriate selection of learning domains followed by development and implementation of a 3- *Level Skills Grouping Methodology* for classification of specific PIs. A *Hierarchy-Frequency Weighting-Factors Scheme* was developed and implemented for establishing accurate program level SOs and PIs evaluations resulting from quantitative analyses of specific outcomes data aggregated using this skills level based weighting scheme. Learning domains SOs evaluations were also implemented employing skills levels based weighted aggregation using a web-based software EvalTools®. Learning distribution information for 11 ABET SOs for various course and skills levels were obtained for the electrical, mechanical and civil engineering programs and compared to an ideal hypothetical learning distribution model to verify results. Observed deficiency in learning distributions helped to identify specific improvement actions for alignment of curriculum, instruction and assessment to attain holistic engineering education.

The literature review of this research highlights the influence of accreditation on quality of assessment and evaluation. A special emphasis on the deficiencies of manual CQI systems are explained thoroughly. In specific, the study explains the scope of learning outcomes assessment prevalent in the global engineering education disciplines. The limitations of contemporary models assessing learning activity aligned only with the cognitive domain and lack of coverage of the affective and psychomotor domains and their learning levels are adequately covered. A hypothetical model for the SOs coverage of Bloom's three learning domains based on the semantic analysis of their language is presented. A novel methodology based on Venn Diagrams called the *Learning Domains Wheel* is presented for the accurate selection of learning domains to classify PIs. The methodology explains how redundancy is avoided due to accurate selection of learning domains categories for assessment of outcomes. A novel *3-Level Skills Grouping Methodology* was developed for each learning domain with a focus on grouping activities which are closely associated to a similar degree of skills complexity. Usage of specific PIs classified per Bloom's 3 learning domains and their learning levels to achieve scientific constructive alignment and *Ideal Learning Distribution* for program curriculum are discussed. ABET SOs coverage using COs and their PIs is explained. A comprehensive assessment methodology with 15 essential elements is explained. An OBE assessment model integrating key aspects of the ABET accreditation criteria is implemented. A detailed Learning Domains Evaluation of ABET SOs comprehensively presents the learning distribution coverage of each SO for the Introductory, Reinforced and Mastery level courses. The *3-Level Skills Grouping Methodology* is applied effectively to classify PIs at each of the three course levels to obtain an accurate coverage of assessment for skills aligned to all learning levels of the Bloom's 3 domains. The learning distribution in every course and skills level for each SO is finally obtained by measuring the counts of PIs assessments in their respective levels. The SOs and PIs evaluations are aggregated using a *Hierarchy-Frequency Weighting-Factors Scheme* for multiple learning and course levels is computed using the counts of assessments extracted from the Learning Domains Evaluations results. The weighted averaging helps obtain accurate program level SOs and PIs evaluations since it helps implement a hierarchy of skills by giving prevalence to those assessments that measure skills of the highest order over others. For example, mastery-advanced level PIs will have a higher prevalence than those for the intermediate-advanced level. Finally, the learning distribution results achieved for the Electrical Engineering program's ABET SOs for term 361 (Fall 2015) were compared with the hypothetical model to evaluate the learning domain coverage of assessments for each SO and derive actions for improvement of the program's term wise SO assessment plan. In conclusion, the selection of accurate learning domains, scientific skills grouping methodology, and skills based weighted averaging significantly enhance the accuracy of program evaluations by incorporating a prioritized aggregation of valid and reliable PIs assessment data for making informed improvement decisions for attaining holistic engineering education.

Table 6: Publication (c) Research Contributions

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Assessment Methodology	Embedded Assessments using the FCAR and specific PIs; 15 essential elements of assessment methodology.
	Software Development, Deployment, Testing	EvalTools® FCAR (EAMU and PVT); SOs/PIs and Learning Domains evaluations; CIMS; Advising based on outcomes;
	Learning Model	A novel *Learning Domains Wheel* for appropriate selection of Learning Domains and their learning levels for the accurate assessment and evaluation of learning outcomes. An introduction to a novel *3-Levels Skills Grouping Methodology* for a simplified classification of outcomes as per Bloom's 3 learning domains and their learning levels.
	PIs Digital Database Based on Bloom's 3 Domains	Digital database of hundreds of specific PIs classified as per Bloom's 3 domains and their learning levels for accurate alignment with instruction, assessment and evaluation
	CQI Course Evaluation	Course level aggregation of outcomes data for ALL students using the *EAMU PVT* methodology with weighted averaging of various assessment types for 4 course formats. Scientifically color coded flagging system based on well-defined performance criteria.
	CQI SOs/PIs and Learning Domains Evaluation	A detailed Learning Domains Quantitative Evaluation of ABET SOs comprehensively presents the learning distribution coverage of each SO for the Introductory, Reinforced and Mastery level courses. The *3-Level Skills Grouping Methodology* is applied effectively to classify PIs at each of the three course levels to obtain an accurate coverage of assessment for skills aligned to all learning levels of the Bloom's 3 domains. The learning distribution in every course and skills level for each SO is finally obtained by measuring the counts of PIs assessments in their respective levels. The SOs and PIs quantitative evaluations are aggregated using a *Hierarchy-Frequency Weighting-Factors Scheme* for multiple learning and course levels is computed using the counts of assessments extracted from the Learning Domains Evaluations results.
	CQI Integration of AAS, OAS and CIMS	Electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS) with Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI

Findings	Learning Models	Bloom's learning domains and learning levels can be applied for classification of PIs and achieve valid and reliable assessment information.
	Classification of Specific PIs and Benefits for Assessment	An accurate and practical classification of PIs based on Bloom's 3 domains and their learning levels is achieved by utilizing a simplified model that groups learning levels into the elementary, intermediate and advanced skills levels.
	CQI Evaluation of Learning Distribution	The quantitative learning distribution results achieved for the Electrical Engineering program's ABET SOs for term 361 (Fall 2015) were compared with the hypothetical model to evaluate the learning domain coverage of assessments for each SO and derive actions for improvement of the program's term wise SO assessment plan
Future Work	Automated Remote Scoring System	The current approach for manual scanning of paper documents was the only aspect that required automation and the article concluded with a suggestion for development of an automated remote digital scoring system for marking assessments online.
	CQI Real-time Learning Distribution Attainment in Course Offerings	Course learning distributions shall be studied for real-time improvement actions to achieve intended ideal learning distribution for a specific course level

iv. Publication(d): Hussain, W., Addas, M. F. and Fong, M., "Quality Improvement with Automated Engineering Program Evaluations Using Performance Indicators Based on Bloom's 3 Domains," in Frontiers in Education Conference (FIE), 2016 IEEE, 2016, pp. 1-9, Erie, PA.

Conference: The 46th Annual Frontiers in Education (FIE) Conference is a major international conference focusing on educational innovations and research in engineering and computing education. We welcome submissions related to educational issues in electrical and computer engineering, energy engineering, software engineering, computing and informatics, engineering design, and in other engineering disciplines. FIE 2016 continues a long tradition of disseminating results in these areas. It is an ideal forum for sharing ideas, learning about developments and interacting with colleagues in these fields. FIE welcomes full papers up to eight-pages and work-in-progress papers up to four-pages that address the broad tracks of (1) innovative practice, (2) research-to-practice, and (3) research. Work-in-progress papers are typically in frontier areas where it is understood the work is in an early or intermediate stage and authors are seeking feedback from the community. Additional information may be found on the FIE 2016 Web site: http://fie-conference.org/sites/fie-conference.org/files/FIE-2016-Proceedings.pdf

https://ieeexplore.ieee.org/document/7757418

Summary:
The research method adopted in this study involved a qualitative review of literature covering issues regarding manual CQI systems for engineering accreditation. Several issues were identified regarding validity and reliability of outcomes data; alignment with actual student learning activity; and lack of course and program evaluations that incorporate aggregation prioritizing advanced skills levels and comprehensive assessments. Therefore, 16 essential elements of an authentic OBE assessment methodology were implemented to help achieve accuracy of outcomes data and automated CQI. Details of a *Hierarchy-Frequency Weighting-Factors Scheme* and its application to weighted aggregation for program evaluations was explained. Specifically, the study focused on reviewing CQI efforts resulting from quantitative learning domains evaluations of the learning distributions for the 11 ABET SOs at the program and course level. At the program level, the learning domains evaluations quantitative results included a) composite learning domains coverage information for all ABET SOs showing details of three skills levels for all course levels and b) learning distributions covering all course levels for the individual cognitive, affective, and psychomotor learning domains. The program level CQI efforts involved generation of actions based on quantitative review of past term's deficiencies in achieved SOs learning distributions to improve the holistic coverage of a future term's ABET SOs assessment plan. At the course level, real-time CQI was achieved by employing quantitative analyses of learning distributions based on the coverage of PIs assessments thereby helping instructors adjust or design assessment activity to attain the intended course level *Ideal Learning Distribution*. The study presents actual program and course level quantitative evaluation samples from the Civil, Electrical and Mechanical engineering programs. The program and course level quantitative

learning domain evaluations produce CQI actions that result in holistic course and curriculum delivery thereby attaining progressive learning as prescribed by Bloom' Mastery Learning.

Table 7: Publication (d) Research Contributions

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Assessment Methodology	Embedded Assessments using the FCAR and specific PIs; 16 essential elements of assessment methodology.
	Software Development, Deployment, Testing	EvalTools® FCAR (EAMU and PVT); SOs/PIs and Learning Domains evaluations; CIMS; Advising based on outcomes;
	PIs Digital Database Based on Bloom's 3 Domains	Digital database of hundreds of specific PIs classified as per Bloom's 3 domains and their learning levels for accurate alignment with instruction, assessment and evaluation
	CQI Course Learning Domains Evaluation	Real-time CQI is achieved by employing evaluation of learning distributions based on the coverage of PIs assessments thereby helping instructors adjust assessment activity to attain the intended course level *Ideal Learning Distribution*
	CQI Program Level Learning Domains Evaluation	Learning domains evaluations results include a) composite learning domains coverage information for all ABET SOs showing details of three skills levels for all course levels and b) learning distributions covering all course levels for the individual cognitive, affective, and psychomotor learning domains
	CQI Integration of AAS, OAS and CIMS	Electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS) with Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI
Findings	Classification of Specific PIs and Benefits for Assessment	Bloom's learning domains and learning levels are applied for classification of PIs to achieve valid and reliable assessment information. The assessment coverage is used to compute the learning distribution at the course and program level.
	CQI Course Level Evaluation of Learning Distribution	Actual sample of real-time CQI achieved by designing assessments to attain Ideal Learning Distributions for a sample course such as Electronics-I from the Electrical Engineering program.

	CQI Program Level Evaluation of Learning Distribution	Composite and Individual domain learning distribution results were quantitatively evaluated for the Electrical Engineering program's ABET SOs for term 361 (Fall 2015). The mechanism for analyzing and evaluating any deficiency in intended learning distribution for the ABET SOs is explained in detail and the documentation, reporting systems for verification of fulfillment of the term wise SO assessment plan and any subsequent CQI actions are shown.
Future Work	CQI Cycles, Processes and Actions	A complete set of CQI actions were generated and implemented following course level and program level Learning Domains, SOs and PIs evaluations. A comprehensive study and reporting of the CQI quality cycles and processes needs to be covered in future research articles.

v. Publication(e): Hussain, W., and Spady, W., "Specific, Generic Performance Indicators and Their Rubrics for the Comprehensive Measurement of ABET Student Outcomes," 124th Annual Conference & Exposition, ASEE 2017, Columbus, OH.

Conference:

124th Annual Conference & Exposition! Where Engineering Education Takes Flight - From P-12 Through Life June 25 - 28, 2017, Columbus, Ohio

Conference Overview:

The ASEE Annual Conference and Exposition is the only conference dedicated to all disciplines of engineering education. It is committed to fostering the exchange of ideas, enhancing teaching methods and curriculum, and providing prime networking opportunities for engineering and technology education stakeholders such as deans, faculty members and industry and government representatives. The conference features more than 400 technical sessions, with peer-reviewed papers spanning all disciplines of engineering education.

https://www.asee.org/public/conferences/78/papers/17900/view

Summary:

The research method involves a qualitative review of the application and use of generic rubrics for teaching and assessment. The literature review covered issues related to vague and generic language of outcomes and rubrics. Specifically, samples from ABET training materials were qualitatively examined in detail. The detrimental effects of generic outcomes on the validity and reliability of assessments were explained and a synopsis of research literature and opinions of experts in the field of assessment and use of rubrics were comprehensively cited. The CQI process flow for the FCAR + Specific PIs methodology to achieve enhanced alignment with student learning activity was explained. A novel '*design down'* approach to achieve accurate alignment of program goals, objectives, SOs, COs and specific PIs was presented. This mapping model illustrates trends in levels of breadth, depth, specificity and details of technical language related to the development and measurement of the various components of a typical OBE 'design down' process. A brief clarification of goals, objectives, outcomes and PIs was provided. The importance of specificity in assessment of learning activity in technical education and the use of specific PIs for accurate alignment to learning activity in the three learning domains was emphasized. Specific examples were provided to elaborate the deficiency in achieving alignment by qualitative comparison of the application of generic or specific analytic rubrics to engineering course learning activity. A qualitative examination of a novel hybrid rubric, a combination of the holistic and analytic rubrics was presented, it is developed to address the issues related to validity: precision, accuracy of assessment alignment with outcomes, PIs; and inter, intra-rater reliability: detail of specificity of acceptable student performances; when dealing with assessment of complex and very specialized engineering activities. The development and implementation process for specific PIs and hybrid rubrics using the four power principles of authentic OBE applied as guidelines was thoroughly explained. The benefits of rubrics and their contribution to the overall program, course and student level CQI actions were examined qualitatively. Some samples of course and student level assessment and evaluation activity were also presented.

Table 8:Publication (e) Research Contributions

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Assessment Methodology	Embedded Assessments using the FCAR and specific PIs; 16 essential elements of assessment methodology.
	Software Development, Deployment, Testing	EvalTools® FCAR (EAMU and PVT); SOs/PIs and Learning Domains evaluations; CIMS; Advising based on outcomes;
	'Design Down' Mapping Model	A novel 'design down' approach to achieve accurate alignment of program goals, objectives, SOs, COs and specific PIs is presented
	Development & Implementation of Specific PIs and their Hybrid Rubrics	The development and implementation of specific PIs and hybrid rubrics using the four power principles of authentic OBE applied as guidelines is thoroughly explained.
	PIs & Hybrid Rubrics Digital Database Based on Bloom's 3 Domains	Digital database of hundreds of specific PIs and their hybrid rubrics classified as per Bloom's 3 domains and their learning levels for accurate alignment with instruction, assessment and evaluation
	CQI Course Reflections & Improvement Actions	FCAR + Specific PIs and Hybrid rubrics significantly enhance validity and reliability of assessments and enable accurate root cause failure analysis. The COs, specific PIs and SOs indices are used as standard nomenclature for generation and tracking of failures and their improvement actions. The nomenclature developed from the outcome indices helps implement electronic porting features for course actions deferred to the following term for completion.
	CQI Program Level Evaluations	Program Term Review module of EvalTools® 6 using accurate specific PIs assessment data by the application of hybrid rubrics and consists of three parts i) Learning Domains Evaluation ii) PIs Evaluation and iii) ABET SOs Evaluation. The PIs and SOs evaluation is focused on failing SOs and PIs for analysis and discussions relating to improvement.
	CQI Student Evaluations	Student developmental advising system based on detailed and accurate outcomes and assessment information resulting from the application of specific PIs and their hybrid rubrics.

Findings	Assessment of Specific PIs by Application of Hybrid Rubrics	The Hybrid Rubrics provide instructors with detailed steps, descriptor dimensions, distinct scoring distribution, specific performance criteria and scales to significantly enhance validity and reliability of assessments
	CQI Course Level Evaluations	The specific PIs and Hybrid Rubrics based indices help implement standards of nomenclature formats for course failure reflections and corrective actions enabling quick root cause analysis, electronic porting and traceability of actions.
	CQI Program & Student Level Evaluations	The quality of assessment data used for program and student level SOs and PIs evaluations is significantly enhanced by the use of Hybrid Rubrics
Future Work	CQI Cycles, Processes and Actions	A complete set of CQI actions were generated and implemented following course level and program level Learning Domains, SOs and PIs evaluations. A comprehensive study and reporting of the CQI quality cycles and processes needs to be covered in future research articles.

vi. Publication(f): William Spady, Wajid Hussain, Joan Largo, Francis Uy; Book Chapters - 7 & 8, "Beyond Outcomes Accreditation," - Rex Publishers, Manila, Philippines, February 2018.

About the Book:
Exploring the Power of 'Real' OBE Practices: Outcomes Accreditation is not Outcome-Based Education, even though it represents itself as such. The philosophy, fundamentals, authentic practices, and implications of 'real' OBE are carefully spelled out in the first section of the book by Dr. William Spady, who then carefully documents their conspicuous and total absence within OA's requirements, guidelines, and processes. Dr. Spady's fifty years of experience as the clarion voice and champion of OBE worldwide speaks for itself, and it speaks loudly for the empowering vision and transformational power that OBE projects for those with the insight and willingness to open their hearts and minds to it.

The wisdom of pursuing OBE is persuasively portrayed in chapters by Dean of Law Joan Largo and Dean of Civil Engineering Dr. Francis Uy. They describe the major benefits for both students and faculty that resulted from their departments' implementation efforts with authentic OBE thinking and practice. These include a 100% pass rate for Dean Largo's graduates on the recent Law Bar Examinations in the Philippines, an unrivaled Filipino success story!

Second, Beyond Outcomes Accreditation exposes and pinpoints over a dozen of the most glaring weaknesses in standard Outcomes Accreditation practices; and third, it shows how university departments can move beyond each of those weaknesses with focused recommendations, correctives, and examples. These two related issues are insightfully and capably handled by Wajid Hussain. His exacting expertise in applying the operational principles of OBE to the challenges posed by Outcomes Accreditation's many requirements and procedures, is unrivaled internationally.

Hence, Beyond Outcomes Accreditation is a gold mine of invaluable insights and knowledge for those wanting to improve the effectiveness of their programs and expand the current and future success of their students – all at the same time!

Summary:
The two chapters (Chs. 7 and 8) of this popular book (with over 1652 copies sold in three years) focus on major accreditation issues related to outcomes alignment with education processes and establishing student centered CQI and their proposed practical solutions. The research method applied used qualitative analyses of prevalent assessment and CQI practices in engineering education based on authentic OBE frameworks, best assessment practices and essential quality management theory. Chapter 7 presents a qualitative review of several issues and practical solutions related to lack of guiding frameworks for incorporating life performance roles into education; lack of standards of outcomes statements and their assessment; lack of guiding frameworks for proper selection of learning domains and their learning levels for the classification of outcomes; outcomes, PIs and their rubrics are generic and vague not resulting in assessment accuracy; the design and use of assessment results in marginal scientific constructive

alignment; lack of guiding frameworks for developing outcomes to result in appropriate developmental levels for holistic curriculum delivery; and lack of application of OBE principle design down to curriculum design and instruction delivery. In chapter 8, we discuss practical solutions by qualitatively examining several issues related to establishing effective CQI and shifting from program to student centered CQI processes; lack of accurate assessment models; insufficient outcomes data and lengthy quality cycles; delayed corrective actions that do not implement formative assessments; cumbersome manual processes for data collection and analysis; use of independent raters; inaccurate results stemming from pure averaging used for aggregation for program evaluations; and outcomes that do not strictly drive CQI efforts.

Table 9: Publication (f) Research Contributions

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Incorporating Life Performance Roles	Guiding frameworks for incorporating life performance roles into education (Ch. 7)
	Standards of outcomes statements	Standards of outcomes statements and their assessment (Ch. 7)
	Learning Model	Clear guiding frameworks for proper selection of learning domains and their learning levels for the classification of outcomes (Ch. 7)
	Development & Implementation of Specific PIs and their Hybrid Rubrics	The development and implementation of specific PIs and hybrid rubrics using the four power principles of authentic OBE applied as guidelines is thoroughly explained. (Ch. 7)
	Scientific Constructive Alignment	Design and use of assessment to achieve scientific constructive alignment with student learning activity (Ch. 7)
	Curriculum Delivery	Guiding frameworks for developing outcomes to result in appropriate developmental levels for holistic curriculum delivery (Ch. 7)
	‘Design Down’ Mapping Model	A novel ‘design down’ approach to achieve accurate alignment of program goals, objectives, SOs, COs and specific PIs is presented (Ch. 7)
	Development & Implementation of Specific PIs and their Hybrid Rubrics	The development and implementation of specific PIs and hybrid rubrics using the four power principles of authentic OBE applied as guidelines is thoroughly explained. (Ch. 7)
	Assessment Model	Accurate assessment models that utilize specific PIs to measure program level SOs through assessments measuring COs (Ch. 8)
	Software and Automation	EvalTools® FCAR (EAMU and PVT); SOs/PIs and Learning Domains evaluations; LMS, AAS, OAS, CIMS; Advising based on outcomes;

	CQI Student Centered Processes	CQI model focusing on heterogeneous student outcomes assessment data collected for all students in all courses. (Ch. 8)
	CQI Weighted Program Level Evaluations	The program level SOs and PIs evaluations are aggregated using a *Hierarchy-Frequency Weighting-Factors Scheme* for multiple learning and course levels is computed using the counts of assessments extracted from the Learning Domains Evaluations results. (Ch. 8)
	CQI Student Evaluations	Student developmental advising system based on detailed and accurate outcomes and assessment information resulting from the application of specific PIs and their hybrid rubrics. (Ch. 8)
	CQI Integration of AAS, OAS and CIMS	Electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS) with Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI (Ch. 8)
	CQI CIMS	An automated interface, CIMS, that connects course and program evaluations to the activity of administrative committees with capability for generation of electronically indexed action items. (Ch. 8)
Findings	Authentic OBE Frameworks	Several aspects of authentic OBE frameworks such as outcomes data for all students, accurate language of outcomes, specificity of PIs, topic-specific analytic rubrics, assessment models, formative assessments etc. are not implemented in outcomes accreditation criteria
	CQI Models	CQI Models are not based on accurate outcomes data, small sample sizes, consist of lengthy quality cycles, do not support real-time improvements
	Manual Vs. Automated CQI Systems	Automated digital CQI systems that integrate LMS, AAS, OAS and CIMs streamline data collection, analysis, reporting and provide digital traceability of quality improvement efforts
Future Work	CQI Cycles, Processes and Actions	A complete set of CQI actions were generated and implemented following course level and program level Learning Domains, SOs and PIs evaluations. A comprehensive study and reporting of the CQI quality cycles and processes needs to be covered in future research articles.

vii. Publication(g): Hussain, W., and Spady, W., "Industrial Training Courses – A Challenge During the COVID19 Pandemic," in 9th International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2020, IEEE Education Society, Takamatsu, Japan, Dec 8-11, 2020.

Conference:
IEEE TALE is the IEEE Education Society's flagship Asia-Pacific conference series, catering to researchers and practitioners with an interest in engineering, technology, and integrated STEM education as well as those interested in the innovative use of digital technologies for learning, teaching, and assessment in any discipline. The conference target audience is diverse and includes those working in the higher education, vocational education and training (VET), K-12, corporate, government, and healthcare sectors. All accepted peer-reviewed papers presented at TALE conferences will be published in the conference proceedings and will also be submitted to the IEEE Xplore Digital Library. TALE is held in December each year in the Asia-Pacific region (IEEE Region 10), complementing the other events in the IEEE Education Society's suite of conference offerings, including Frontiers in Education in North America (IEEE Regions 1–7), EDUCON in Europe/Middle East/Africa (IEEE Region 8), and EDUNINE in Latin America (IEEE Region 9). (1000 engineering institutional attendees, 400 full papers, work in progress and posters).

Wajid Hussain presented ONE out of the TWO invited workshops and Full Paper - Dec 11 2020 11:20-11:45 (F) 219 Industrial Training Courses – A Challenge During the COVID19 Pandemic.
https://ieeexplore.ieee.org/abstract/document/9368455

Summary:
This research paper involves study of implementation of state of the art digital technology with cutting edge OBE assessment methodology to remotely deliver holistic industrial training courses. The research method adopted for this study involves a qualitative literature review of the need for integrating both technical and transversal skills in engineering curricula and the role of industrial training courses in achieving that. This is followed by a qualitative examination of a course template for remote offerings of industrial training courses. Specific features and modules of a web-based software EvalTools® that enable remote course offerings are studied. Students are guided throughout the various phases of the industrial work by their training advisors using a versatile online Biweekly Reporting tool which is tightly aligned with the COs, PIs and hybrid rubrics. This helps students to remain focused on key learning areas aligned with the intended COs at industrial sites while continuously gauging their performance using rubrics related to each learning activity. The FORUM tool effectively facilitates communication of individual and group experiences across industrial sites to catalyze collaborative work. The performance data for COs and PIs is collected using direct and indirect assessments. The FCAR summative and formative data is quite detailed and for brevity samples of COs, PIs and CQI FCAR data are presented for quantitatively evaluating attainment of student learning in remote industrial training courses. We then examine a novel course template specially designed and implemented in summer of

2020 for virtual offerings of industrial courses during the COVID19 pandemic. In conclusion, a qualitative comparison of the two course models is made based on the coverage of learning distributions in Bloom's three learning domains to determine attainment of holistic delivery and limitations of industrial training course offering during current pandemic conditions and some plausible recommendations for enhancing holistic learning are discussed

In the literature review of this publication, we begin with an explanation of technical and transversal skills required of engineering graduates. The definition and need of industrial training is explained from literature. The international engineering accreditation requirements for industrial training courses to be included in curriculum are cited. The essential authentic OBE frameworks, assessment and evaluation practices, and web-based software EvalTools® are introduced. The FCAR + Specific PIs methodology is used for the development of the COs and PIs template for establishing the format for industrial training course delivery. The rules for COs and PIs design are adequately explained and a sample hybrid rubric is also displayed. 12 Essential elements of the assessment methodology are presented and the benefits of use of remote Bi-weekly reporting Tool and FORUM communication module are explained. A novel industrial training course template for remote virtual offerings is introduced. The assessment criteria are modified to accommodate the changes in evaluations previously related to employers or site visits. The template involves a comprehensive training plan consisting of 11 phases. A top down approach is adopted to instill a holistic industrial learning experience blended with key elements of entrepreneurship as per the Saudi Vision 2030. The students begin with reviewing the history of the industry, organization, organizational structure, business model and target markets. They then select a department and virtual engineering role to work in. Students construct the operational structure and process flow of their department using information either directly from the organization's website or extracted from other sources on the public domain such as research literature, technical blogs or YouTube videos. The professional engineering experience I & II involve problem solving, design, experimentation, teamwork activity for which students employ remote labs or virtual training roles to simulate relevant activity approved by advisors. Several options for remote, simulation and virtual laboratories offered by either established universities or other private and governmental initiatives are referred. In phase 10, students critically analyze their virtual engineering experience by comparing key aspects of the work environment for their organization, with that of a competitor. Finally, they submit a final report as per given template and make remote streaming video presentations in defense of their training experience. The Office of Quality and Accreditation performed a qualitative analysis of the learning distribution coverage in Bloom's 3 domains for COs related to onsite and virtual offerings of industrial training courses by collecting feedback from two leading international OBE and assessment experts. The results of this analysis show that excepting for a medium (M) coverage for COs learning distribution in the cognitive domain, both psychomotor and affective domains exhibit a low (L) learning distribution. Therefore, adequate development of skills in the affective and psychomotor learning domains would be difficult to achieve in virtual training. However, engineering programs can still consider a virtual role as a viable, but temporary alternative to onsite training if the course plan would help students remotely achieve acceptable levels of cognitive learning related to problem solving, design, experimentation, professional ethics, and collaborative work at state of the art industrial sites

Table 10: Publication (g) Research Contributions

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Assessment Methodology	Embedded Assessments using the FCAR and specific PIs and their hybrid rubrics; essential elements of assessment methodology.
	Software Development, Deployment, Testing	EvalTools® FCAR (EAMU and PVT); BI-weekly Reporting Tool; FORUM Communication Module; Remote Employer Surveys;
	Learning Model	A novel *Learning Domains Wheel* for appropriate selection of Learning Domains and their learning levels for the accurate assessment and evaluation of learning outcomes. An introduction to a novel *3-Levels Skills Grouping Methodology* for a simplified classification of outcomes as per Bloom's 3 learning domains and their learning levels.
	'Design Down' Mapping Model	A novel 'design down' approach to achieve accurate alignment of program goals, objectives, SOs, COs and specific PIs is presented
	PIs & Hybrid Rubrics Digital Database Based on Bloom's 3 Domains	Digital database of hundreds of specific PIs and their hybrid rubrics classified as per Bloom's 3 domains and their learning levels for accurate alignment with instruction, assessment and evaluation
	Bi-weekly Reporting Tool	Students are guided throughout the various phases of the industrial work by their training advisors using a versatile online Biweekly Reporting tool which is tightly aligned with the COs, PIs and hybrid rubrics. This helps students to remain focused on key learning areas aligned with the intended COs at industrial sites while continuously gauging their performance using rubrics related to each learning activity
	FORUM Communication Module	The FORUM tool is an effective communication and collaboration platform for integrating feedback from industrial training students to course assessment. Students post individual and group experiences and communicate with their colleagues, other teams and their advisors. Advisors are able to post comments, activity, follow up on any query and congratulate student achievements. A

		comprehensive rubric for grading posts on the FORUM is available for view and application to both students and their advisor
	Industrial Training Course Template for Remote Offering	A course template using COs and PIs that covers problem solving, design, experimentation, use of new tools, techniques, software etc., teamwork, safety regulations and professional ethics
	Industrial Training Course Template for Remote Virtual Offering	The template involves a comprehensive training plan consisting of 11 phases. A top down approach is adopted to instill a holistic industrial learning experience blended with key elements of entrepreneurship as per the Saudi Vision 2030. The students begin with reviewing the history of the industry, organization, organizational structure, business model and target markets. They then select a department and virtual engineering role to work in. Students construct the operational structure and process flow of their department using information either directly from the organization's website or extracted from other sources on the public domain such as research literature, technical blogs or YouTube videos. The professional engineering experience I & II involve problem solving, design, experimentation, teamwork activity for which students employ remote labs or virtual training roles to simulate relevant activity approved by advisors. In phase 10, students critically analyze their virtual engineering experience by comparing key aspects of the work environment for their organization, with that of a competitor. Finally, they submit a final report as per given template and make remote streaming video presentations in defense of their training experience.
	CQI Course Assessment and Evaluation	FCAR presents several comprehensive reports displaying scientifically color coded, consolidated COs, SOs, PIs histogram plots, summative learning distribution data, and CQI information. Detailed students' EAMU performance results for various assessments linked to each CO are listed sequentially. Specific PIs and hybrid rubrics enable accurate outcomes data and evaluation results resulting in precision CQI.
Findings	Industrial Training Course Remote Offering	FCAR + Specific PIs methodology employed by web-based software EvalTools® and remote learning management and collaboration tools like the Bi-weekly Reporting Tool and FORUM Communications and Remote Surveys support remote management of on-site Industrial Training Courses.

	Industrial Training Course Remote Virtual Offering	A novel course template presented in this publication offers a viable alternative for comprehensive learning focusing on entrepreneurship while using virtual lab and practice tools.
	Virtual Training Courses Cannot Replace On-site Training	A qualitative analysis of coverage of learning distribution for a virtual offering of Industrial Training courses indicates a deficiency in the psychomotor and affective domains of learning suggesting that on-site industrial training experiences cannot be attained by virtual courses.
Future Work	Simulation, Virtual and Remote Labs	Further research should significantly expand the list of available simulation, virtual and remote lab tools and solutions whether open source or paid to supplement the existing virtual industrial course template.

viii. Publication(h): Hussain, W., Spady, W., Naqash, T., Khan, S., Z., Khawaja, B., A., Conner, L., "ABET Accreditation During and After the COVID19 pandemic – Navigating the Digital Age", 2020, IEEE Open Access.
https://ieeexplore.ieee.org/document/9274316

Summary:
In general, engineering programs worldwide have adopted short cut approaches to collate learning outcomes information for accreditation purposes. Manual CQI systems have exacerbated the situation with limited sampling of outcomes data, lengthy assessment cycles, lack of tight alignment resulting from generic and vague outcomes and rubrics, pure averaging for aggregation of outcomes information for program or course evaluations etc. Several digital solutions and models have been referred to in the literature review of this research. The COVID19 global pandemic and social distancing norms have resulted in accreditation agencies worldwide announcing either deferred on virtual audits in the upcoming accreditation cycles. This raises the bar for accreditation agencies to enhance requirements for credible remote evaluation of engineering programs globally. In this study, we examine a novel meta-framework to qualify state of the art digital Integrated Quality Management Systems for three engineering programs seeking accreditation. The digital quality systems utilize authentic OBE frameworks and assessment methodology to automate collection, evaluation and reporting of precision CQI data. The philosophy, paradigm, premises and principles of Authentic OBE form the basis for theoretical frameworks that lead to the development of crucial models which act as the foundation of the IQMS implemented at the Faculty of Engineering. Several essential concepts are then induced from OBE theory, best practices for assessment and ABET criterion 4, CR4 on continuous improvement. Essential techniques and methods based on this conceptual framework are then used to construct a practical framework consisting of automation tools, modules and digital features of a state of the art, web-based software, EvalTools®. The theoretical, conceptual and practical frameworks are discussed in detail. EvalTools® facilitates seamless implementation of CQI processes based on an authentic OBE model and consisting of 6 comprehensive Deming-Shewart (1993), PDCA quality cycles:
Q_1: COs, PIs and hybrid rubrics development
Q_2: Course evaluation, feedback and improvement
Q_3: Program term review
Q_4: PIs 3-year multi-term review
Q_5: SOs Multi-term review
Q_6: PEOs 5-year review.

Essential aspects, inputs/outputs, processes and underlying frameworks of each quality cycle are discussed in detail. Detailed description of assessment process and activities in each quality cycle are provided. Fifteen essential elements of digital technology and assessment methodology are presented. A quantitative analysis provides evaluation of the sustainability of course and program level CQI processes. This is followed by an elaborate presentation of the tabs, features

and reports of the EvalTools® Remote Evaluator Module that collects, organizes and reports massive amounts of CQI data for enabling remote accreditation audits. This section shows a summary of a qualitative comparison of various types of CQI data and key aspects for manual and automated systems.

A theory-based mixed methods approach is applied for evaluations. Detailed results and discussions show how 8 phases of the meta-framework help to qualify the context, construct, causal links, processes, technology, data collection and outcomes of comprehensive CQI efforts. In this study, we discuss various aspects of relevant phases of this meta-framework and utilize key elements of the 8 phases as indicators to examine the CQI processes implemented at the Electrical Engineering (EE), Civil Engineering (CE) and Mechanical Engineering (ME) programs of the Islamic University in Madinah.

The eight phases for the Mixed Methods Theory Based Impact Evaluation (MMTBIE) are outlined as below:

- Phase 1: understand the local and broader context;
- Phase 2: understand the construct(s) of interest;
- Phase 3: map out the causal chain that explains how the intervention is expected to produce the intended outcomes;
- Phase 4: collect quantitative and qualitative data to test the underlying assumptions of the causal links;
- Phase 5: determine the type and level of generalizability and transferability;
- Phase 6: conduct a rigorous evaluation of impact;
- Phase 7: conduct a rigorous process analysis of links in the causal chain; and
- Phase 8: conduct a meta-evaluation of the process and product of the MMTBIE.

Credibility and rigor of evaluation rest on many aspects such as using mixed methods for analyses, accurate theoretical and conceptual frameworks, appropriate context for evaluations, constructs of interest, well defined causal links, meta-analyses of processes and products, and quality of outcomes data. The evaluation results and K tables reported in this study that provide evidence for all of these aspects using 8 phases of a comprehensive meta-framework. This also provides detailed guidelines for a multi-dimensional mixed methods research approach to achieve credible MMTBIEs. Essential elements that ensure the quality of CQI data such as sampling schemes, data and theoretical saturation for qualitative analyses, statistical power of quantitative data, generalizability and transferability, sustainability, data collection and reporting methods etc. have been discussed in this research. We also show how embedded assessment methodology, using the FCAR and PVT with specific PIs and hybrid rubrics, presents significant efficiencies for instructors and helps ensure outcomes data is valid, reliable and tightly aligned to learning activities. The documentation and reporting features of EvalTools® could help programs actively facilitate social distancing norms since both faculty and students can interact remotely and exchange digital versions of necessary educational information such as outcomes results, advising notes, syllabi, lessons, online assessments, assignments, gradebook results etc. The most arduous task of maintaining a trail of CQI history, all the way up to closed corrective actions, is transformed into a seamless and totally manageable digital system with the help of the CIMS Module. The Remote Evaluator Module provides accreditation auditors with an all in-one remote display dashboard with tabs to conveniently access a wealth of evidential information such as course portfolios, curriculum maps; performance criteria and heuristics rules; course and program evaluations results; PEOs, SOs, PIs and rubrics databases; single term and multi-term SOs, executive summary reports; SOs based objective evidence; complete CQI history including detailed committee activity; and advising records. The results of evaluation and discussions provide valuable insights on conducting credible program interventions by showing how various phases of a novel meta-framework help to qualify comprehensive digital CQI systems. In conclusion, the findings of this study offer both accreditation agencies and engineering programs significant exposure to the overwhelming benefits of an outcome-based digital IQMS for seamless management of automated data collection and reporting to enable credible remote accreditation audits during the COVID19 global pandemic and beyond.

Table 11: Publication (h) Research Contributions

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Assessment Methodology	Embedded Assessments using the FCAR and specific PIs and their hybrid rubrics; essential elements of assessment methodology.
	Software Development, Deployment, Testing	EvalTools® FCAR (EAMU and PVT); BI-weekly Reporting Tool; FORUM Communication Module; Remote Employer Surveys; Specific PIs classification & database; Advising based on outcomes; Program Level SOs, PIs and Learning Domains Evaluations; CIMS; Remote Evaluator Module;
	'Design Down' Mapping Model	A novel 'design down' approach to achieve accurate alignment of program goals, objectives, SOs, COs and specific PIs is presented
	Course Delivery Framework	Consistent framework for the development of COs and their specific PIs based on Spady, Adelman and Mager principles
	Development & Implementation of Specific PIs and their Hybrid Rubrics	The development and implementation of specific PIs and hybrid rubrics using the four power principles of authentic OBE applied as guidelines is comprehensively explained.
	PIs & Hybrid Rubrics Digital Database Based on Bloom's 3 Domains	Digital database of hundreds of specific PIs and their hybrid rubrics classified as per Bloom's 3 domains and their learning levels for accurate alignment with instruction, assessment and evaluation

CQI Course Evaluation	Course level aggregation of outcomes data for ALL students using the *EAMU PVT* methodology with weighted averaging of various assessment types for 4 course formats. A color coded flagging system based on well-defined performance criteria. FCAR presents several comprehensive reports displaying color coded, consolidated COs, SOs, PIs histogram plots, summative learning distribution data, and CQI information. Detailed students' EAMU performance results for various assessments linked to each CO are listed sequentially. Specific PIs and hybrid rubrics enable accurate outcomes data and evaluation results resulting in precision CQI.
CQI SOs/PIs and Learning Domains Evaluation	A detailed Learning Domains Evaluation of ABET SOs comprehensively presents the learning distribution coverage of each SO for the Introductory, Reinforced and Mastery level courses. The *3-Level Skills Grouping Methodology* is applied effectively to classify PIs at each of the three course levels to obtain an accurate coverage of assessment for skills aligned to all learning levels of the Bloom's 3 domains. The learning distribution in every course and skills level for each SO is finally obtained by measuring the counts of PIs assessments in their respective levels. The SOs and PIs evaluations are aggregated using a *Hierarchy-Frequency Weighting-Factors Scheme* for multiple learning and course levels is computed using the counts of assessments extracted from the Learning Domains Evaluations results.
CQI Integration of AAS, OAS and CIMS	Electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS) with Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI (Ch. 8)
CQI CIMS	An automated interface, CIMS, that connects course and program evaluations to the activity of administrative committees with capability for generation of electronically indexed action items. (Ch. 8)
CQI Quality Cycle Q_1	COs, PIs and hybrid rubrics development based on authentic OBE theory and consistent frameworks
CQI Quality Cycle Q_2	Course evaluation, feedback and improvement; Syllabi Checklist, FCAR Checklist, End Of Term (EOT) Checklist.
CQI Quality Cycle Q_3	Program term review; SOs, PIs and Learning Domains Evaluations.

	CQI Quality Cycle Q_4	PIs 3-year multi-term review; the Faculty of Engineering programs conduct a PIs multi-term review every 3 years to check the validity of PIs in regards to technical content, learning level classification, relevancy to industry, alignment to program SOs, COs, curriculum and student learning activity.
	CQI Quality Cycle Q_5	SOs Multi-term review; The Faculty of Engineering programs' assessment model includes a culminating PDCA Quality Cycle Q5, a multi-term program SOs review which is conducted every three years. This review entails a thorough trend analysis of all program SOs by the program faculty. Almost 6 terms of outcomes data are collected and reviewed for overall improving trends of performance
	CQI Quality Cycle Q_6	PEOs 5-year review; The PEOs review and improvement process consists of internal and external components. The various phases of this process are listed below in chronological order: 1. Definition and Development of PEOs 2. Review of Undergraduate Student Skill Sets 3. Review of Attainment of PEOs - using Alumni Surveys (External Review). 4. Review of Relevancy of PEOs - using a) alignment to University Mission and SOs mapping tables, b) PEOs attainment data based on well-established rubrics and c) feedback of EAC and Faculty members (a combination of Internal and External Review processes). 5. Generate Corrective Actions - for improvement of PEOs, SOs, curriculum, teaching and learning strategies (combination of Internal and External Review processes).
Findings	Remote Virtual Accreditation Audits	EvalTools® Remote Evaluator Module helped conduct a remote ABET accreditation audit of CQI data in 2019.
	Phase 1: Understand The Local and Broader Context	From Table K1, it is evident that the local and broader context of the MMTBIE adequately incorporates regional and international standards for quality in education by examining attainment of the ABET SOs during and upon completion of study and attainment of PEOs a few years after graduation during employment.
	Phase 2: Understand The Construct(S) of Interest	Table K2 (Appendix K) presents details on the relevant frameworks, construct(s) of interest and variables with references to corresponding subsections of Section IV of this research paper.
	Phase 3: Map Out The Causal Chain That Explains How The Intervention is	Table K3 (Appendix K) presents the requirements of the framework proposed by Onwuegbuzie and Hitchcock (2017) to validate the mapping of causal links of the IQMS implemented at the Faculty of Engineering EE, CE and ME

Expected to Produce The Intended Outcomes	programs. Brief responses with appropriate sectional references are provided for a thorough understanding of the fulfillment of required conditions of the extracted framework
Phase 4: Collect Quantitative and Qualitative Data to Test The Underlying Assumptions of The Causal Links	In Table K4 (Appendix K), we provide a summary of data collection activity for qualitative or quantitative evaluations occurring in each PDCA quality cycle with references to the various sections of this research paper. Extensive distribution of comprehensive qualitative and quantitative analyses are presented in Table K4 for assessing underlying assumptions in each PDCA cycle thereby qualifying the program interventions at the Faculty of Engineering as credible MMTBIEs that fulfill mixed methodological approach requirements for phase 4 of the meta framework proposed by Onwuegbuzie and Hitchcock (2017)
Phase 5: Determine The Type and Level of Generalizability and Transferability	In Table K5 (Appendix K), we explain some fundamental aspects related to the Sample size (Planned vs. Actual), Course /Program Level Data, Theoretical Saturation Statistical Power, Response Rate, Generalizability & Transferability, and Sustainability of CQI and outcomes data related to course and program level evaluations.
Phase 6: Conduct A Rigorous Evaluation of Impact	Multi-term executive summary reports (refer Section 5.ii ME Program Sample - Multi-Term Executive Summary Report for ABET SOs [a-k], Appendix J) showed detailed reflections, corrective actions (refer Section IV.D.4 Practical Framework – Digital Platform EvalTools® - SOs, PIs Evaluations); and the CIMS system recorded achieved improvements with thousands of actions and evidentiary CQI documentation (refer Section IV.D.7. CIMS). Multi-term SOs trend analyses with forecasted results showing improved SOs performances reinforced the decision of program committee reviewers (refer Section 5.vii Summary of Results of Trend Analysis for ABET SOs (a-k) ME, CE and EE programs; Figures J31, J32 and J33, Appendix J), EAC members and other stake holders (refer Section 6.iii EAC Review Meeting; Figure J50 of Appendix J) to qualify the ME, CE and EE programs' implementation of IQMS as Meeting Expectations in regards to attainment of SOs (refer Section 5.vii Summary of Results of Trend Analysis for ABET SOs (a-k) ME, CE and EE programs; Tables J25, J26 and J27, Appendix J) and PEOs (refer Section 6.ii PEOs Assessment Data; Tables J55, J56 and J57, Appendix J).

	Phase 7: Conduct A Rigorous Process Analysis of Links in The Causal Chain	Process analysis for PDCA quality cycles Q1 to Q6 for MMTBIEs conducted at Faculty of Engineering programs showing the various qualitative and quantitative analyses employed in the 6 quality cycles are shown in Table K6 (Appendix K). Therefore, from process analysis conducted in phase 7, as shown in the Table K6, we find that all elements of the causal links assiduously follow the mentioned theoretical, conceptual and practical frameworks, plus work in a tightly cascaded connection to directly contribute to an overall improvement in the attainment of EE, ME and CE program SOs
	Phase 8: Conduct A Meta-Evaluation of The Process and Product of The MMTBIE	Table K7 (Appendix K) shows qualitative and quantitative process analyses employed for PDCA quality cycles Q1 to Q5. The last portion of Table K7 shows the PDCA quality cycle Q6 which is the meta-analyses phase 8 of the MMTBIE of the Faculty of Engineering EE, ME and CE programs involving both process and product evaluations. The product evaluation deals with aspects related to the attainment of the PEOs a few years after graduation. The process analyses cover qualitative review of the curriculum, Capstone project design work, industrial training experience, teaching/learning process, CQI systems, lab and other infrastructure matters. The quantitative analyses involve a review of multi-term SOs executive summary reports and trend analyses along with COs, PIs and SOs data for capstone design and industrial training courses. The qualitative and quantitative analyses conducted for the process and product evaluations in the PDCA quality cycle Q6 involve multiple levels of audits that include the program committee, QA office, QD supervisor and finally, the External Advisory Committee. The rigorous QA procedures based on authentic frameworks and coupled with an exhaustive array of qualitative and quantitative analyses for both the process and product evaluations of the Faculty of Engineering IQMS qualify the MMTBIE in phase 8 as credible since they adequately fulfill the criteria presented by Onwuegbuzie and Hitchcock (2017).
Future Work	Automated Assessments and Remote Marking	Future research can target the development of state-of-the-art digital systems that automate outcomes assessment development and scoring processes. This technology would integrate with and enhance existing digital systems to significantly reduce the overhead related to the overall time spent by faculty in the outcomes assessment process and

	scanning work done by lecturers. Specifically, the Faculty of Engineering, QA office intends to pursue ground-breaking automation technology to push the frontiers in outcomes assessment by including optical character recognition features in remote online marking and scoring tools to assess digital versions of hard copies of student exam sheets fed into high-end large scale scanners with barcode reading capability. The bar coding on digital copies of students' exams would help align with corresponding exam templates that automatically map to the COs, specific PIs, rubrics and SOs. This technology would automate the outcomes mapping, manual score entry, file scan and upload of documents, thereby resulting in enormous savings of effort and other resources. Additionally, Zoom video conferencing shall be integrated in version 7 of EvalTools R to roll out early 2021, supporting virtual tours of lab facilities, and faculty/student interviews, that could significantly enhance remote audit capabilities. The cutting edge innovations in digital technology can dramatically revolutionize the implementation of OBE quality systems for higher education and accreditation, especially during the COVID19 global pandemic and beyond.

ix. Publication(i): Hussain, W., Spady, T., Khan, S., Z., Khawaja, W., Naqash, B., A., Conner, L., "Impact Evaluations of Engineering Programs Using ABET Student Outcomes", 2020, IEEE Open Access.

https://ieeexplore.ieee.org/document/9380632

Summary:

Engineering programs collect student outcomes information for conducting program evaluations for fulfillment of accreditation requirements. Quality agencies like ABET and International Engineering Alliance (IEA's) Washington Accord require that programs collect at least few years of student outcomes information. Most engineering programs employing manual quality systems collect outcomes information from select or random samples of students from small set of courses for fulfilment of minimal accreditation requirements. This results in non-heterogeneous samples of outcomes data with low statistical power rendering the multi-term data inadequate for conducting any type of credible retrospective impact evaluations. In this study, we present essential elements of an authentic outcome based assessment model that used web-based software EvalTools® and FCAR with Specific PIs embedded assessment technology to collect and report accurate cohort outcomes for credible multi-term evaluations. Essential elements that ensure the quality of CQI data such as sampling schemes, data and theoretical saturation for qualitative analyses, statistical power of quantitative data, generalizability and transferability, sustainability, data collection and reporting methods etc. have been discussed in this research. The philosophy, paradigm, premises and principles of Authentic OBE form the basis for theoretical frameworks that lead to the development of crucial models which act as the foundation of the IQMS implemented at the Faculty of Engineering. Several essential concepts are then induced from OBE theory, best practices for assessment and ABET criterion 4, CR4 on continuous improvement. Essential techniques and methods based on this conceptual framework are then used to construct a practical framework consisting of automation tools, modules and digital features of a state of the art, web-based software, EvalTools®. EvalTools® enables seamless implementation of CQI processes based on an authentic OBE model and consisting of 6 comprehensive Deming-Shewart (1993), PDCA quality cycles:

A non-experimental approach employing regression analyses were used to identify trends in student outcomes and evaluate the impact for three engineering programs. The Faculty of Engineering programs' assessment model includes a culminating Plan Do Check Act (PDCA) Quality Cycle Q5, a multi-term program SOs review which is conducted every three years. This review entails a thorough trend analysis of all program SOs by the program faculty. Almost 6 terms of outcomes data are collected and reviewed for overall improving trends of performance. Detailed rubrics provide criteria to accurately classify multi-year student outcomes. If more than 80% of the SOs displays a positive trend, then the program multi-term SO review results in an *Exceeding Expectations* decision. If 60% to 80% of the program SOs display an improving trend, then the decision is *Meeting Expectations*. When more than 60% of program SOs display a

negative trend in overall performance, then the multi-term SO review results in a *Below Expectations* decision. The *Below Expectations* decision necessitates an examination of language, content and scope of the failing SOs besides several other corrective actions. A detailed report of recommendations for improvement, including any modifications to SOs is sent to the External Advisory Committee or Industrial Advisory Board for review and approval. The findings of this study present practical steps for engineering programs to effectively collect and report accurate cohort outcomes data and perform credible evaluations of program interventions based on multi-year outcomes data.

Table 12: Publication (i) Research Contributions

	Category	Research Contributions to the Body of Knowledge
Pedagogical Solutions	Assessment Methodology	Embedded Assessments using the FCAR and specific PIs and their hybrid rubrics; essential elements of assessment methodology.
	Software Development, Deployment, Testing	EvalTools® Multi-term SOs evaluation, trend analyses and reporting module;
	‘Design Down’ Mapping Model	A novel ‘design down’ approach to achieve accurate alignment of program goals, objectives, SOs, COs and specific PIs is presented
	Course Delivery Framework	Consistent framework for the development of COs and their specific PIs based on Spady, Adelman and Mager principles
	Development & Implementation of Specific PIs and their Hybrid Rubrics	The development and implementation of specific PIs and hybrid rubrics using the four power principles of authentic OBE applied as guidelines is comprehensively explained.
	PIs & Hybrid Rubrics Digital Database Based on Bloom’s 3 Domains	Digital database of hundreds of specific PIs and their hybrid rubrics classified as per Bloom’s 3 domains and their learning levels for accurate alignment with instruction, assessment and evaluation
	CQI SOs Multi-term Evaluations	Multi-term ABET SOs evaluation using regression based trend analyses. Application of detailed rubrics to classify forecasted SOs performance.
	CQI Integration of AAS, OAS and CIMS	Electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS) with Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI (Ch. 8)
	CQI CIMS	An automated interface, CIMS, that connects course and program evaluations to the activity of administrative committees with capability for generation of electronically indexed action items. (Ch. 8)

	CQI Quality Cycle Q_5	SOs Multi-term review; The Faculty of Engineering programs' assessment model includes a culminating PDCA Quality Cycle Q5, a multi-term program SOs review which is conducted every three years. This review entails a thorough trend analysis of all program SOs by the program faculty. Almost 6 terms of outcomes data are collected and reviewed for overall improving trends of performance using detailed rubrics.
Findings	Multi-term SOs Review Results	EE, ME and CE programs indicated *Meeting Expectations* results with majority of SOs showing positive trends (Section VI.B Tables 5,6 and 7)
	External Advisory and Program Committee Review	Multi-term executive summary reports showing detailed reflections, corrective actions and other evidentiary CQI documentation were reviewed by the External Advisory Committee. Valid and reliable quantitative multi-term ABET SOs data collected by employing sixteen essential elements of an authentic OBE assessment methodology supported credible Multi-term SOs trend analyses with forecasted results showing improved SOs performances thereby reinforcing the decision of program committee reviewers (refer Section VI.F and Section VI.G) to approve transition to revised ABET SOs based on an overall *Meeting Expectations* decision.
Future Work	Detailed Study of PDCA Quality Cycles	Future research will entail a comprehensive and detailed study of each of the other 5 PDCA quality cycles that include all the process and product evaluation of the IQMS implemented in these Engineering programs by applying a comprehensive meta-framework proposed by Onwuegbuzie and Hitchcock (2017). Future work would provide elaborate guidelines for engineering programs regarding practical difficulties and advantages, procedural details to be dealt with in the implementation of a comprehensive digital quality management system.

D. CONCLUSION

Student achievement and accountability pose the biggest challenges to improving the quality of higher education in the world today. In order to meet these challenges, an OBE model for student learning, along with several quality standards in higher education, have been adopted by engineering accreditation agencies and educational institutions globally over the past two decades. The Washington Accord lays down international quality standards based on learning outcomes for engineering accreditation. Graduate attributes, knowledge and problem-solving profiles specify technical and transversal knowledge and skills which students should attain during and after completion of engineering education. Engineering Accreditation standards require programs to demonstrate student learning outcomes with established and sustainable CQI processes based on clearly defined performance criteria. ABET's criterion 4, is regarded by many educators as the most challenging for engineering programs to fulfill. To drive the point home, instead of citing several sources, we quote Fergus (2012), chair of ABET's Engineering Accreditation Commission, ABET fellow and chairperson of accreditation committee at the Minerals, Metals and Materials Society (TMS),

> "Establishing, implementing and documenting processes to determine if graduates are meeting expectations and if students are attaining student outcomes is a significant challenge. For a continuous improvement process to be effective, it must be sustainable. Collecting assessment data at a rate that cannot be maintained and in amounts that cannot be properly evaluated is counterproductive. Data should be collected continuously at rates that do not detract from educating students and in amounts that can be evaluated to provide useful information on the effectiveness of the program. If data is being collected that is not providing useful information, then the process should be modified to obtain useful data—improvement of the process is part of continuous quality improvement."

Two essential points arise from this statement as confirmed through findings of this research and more than a decade of intensive consultation and accreditation experiences of the author. Firstly, continuous improvement based on outcomes assessment is, by far, the most challenging aspect of accreditation. Secondly, both accreditation agencies and programs have to decide how to proceed when precariously balancing the need for data quality and the type and amount of data, sampling models, frequency and methods of collection. According to OBE, assessment and quality experts referred to in the publications mentioned in this thesis, the two aspects related to data are interchangeable. Sufficient amounts of relevant and valid data have to be sampled appropriately, collected using precision methods and evaluated accurately. Without collecting data in all courses and for multiple assessments in various phases of course and curriculum delivery, programs can never attain real-time CQI, since they do not have sufficient data to be able to indicate failures for timely remedial action. Any CQI model which does not solve problems at hand, but relies on a deferment plan, does not fulfill the requirements of CQI at all. Such a CQI model does not address the urgent learning needs of enrolled cohorts but rather, is based on a program-centered model. Another major challenge for accreditation agencies is to substantiate the claims of "OBE" if all student outcomes data is not included. Washington Accord and ABET have announced student-centered education systems employing Bloom's Mastery Learning Model and Taxonomy, but they do not seem to fulfill the gold standard of OBE viz. to establish educational systems, in which "all students can learn and succeed". Students cannot learn and succeed, especially if they cannot access basic information relating to their attainment of outcomes, which is an essential requirement for gauging student achievement and establishing accountability for engineering programs. Obviously, and as per the literature cited in the introductory sections of the various publications used for this thesis, most accredited programs using manual CQI systems and processes do not use assessment data for all students in program evaluations due to the massive amounts of data involved and the huge costs in terms of time and other resources needed for data collection and reporting.

The literature review of this research highlighted several issues with manual CQI systems and also cited references to digital solutions adopted by several programs. ABET has also been show-casing digital solutions in their symposia for almost a decade. But, probably due to commercial and practical reasons, there has not been a mandate for digital platforms since thousands of programs in the US and across the globe are still using manual CQI systems. Additionally, the looming international crisis due to the COVID19 global pandemic, which seems like it will be a prolonged affair, with severely limited regional and international movement and travel, has resulted in drastic changes to the format of education delivery globally. The COVID19 global pandemic conditions, by force majeure, have also affected the normal protocol for onsite accreditation visits. Many accreditation bodies, including ABET, have either deferred or announced virtual audits for upcoming accreditation cycles. The limitations of manual CQI systems coupled with the global crisis conditions caused by the COVID19 pandemic have forced both accreditation agencies and engineering programs to rethink about the role of digital solutions as a panacea for remote and virtual audits. The key question is whether digital solutions would be the necessary or preferred choice for engineering programs pursuing renewal or initial accreditation. Obviously, the answer to this question would unfold in the coming years based upon the spontaneity of engineering programs in collectively responding to accreditation requirements with digital solutions.

In this research work conducted since 2014 to date, and as per the aims and objectives mentioned earlier, a state of the art, digital IQMS was gradually developed with significant ingenuity, hard work, management and collaboration. Several practical challenges were met throughout the timeline of this project and addressed accordingly. Spady's authentic OBE philosophy and principles were integrated into learning models, assessment, evaluation and CQI processes. The biggest challenge was to develop a database of thousands of PIs and hundreds of associated hybrid rubrics followed by their implementation ensuring alignment to actual student learning activities. I personally led all the 'tuning' efforts by spending thousands of hours with each faculty member and glossing over even the minutest of details regarding their lessons and intended assessments. Several state of the art assessment instruments were developed to manage educational activity such as Capstone design projects, multi-disciplinary teamwork and collaboration, meta-cognitions and lifelong learning, lab experimentation and industrial training. The Capstone assessment instrument and hand book took the Capstone committee 700 hours of development time, were presented at the ASEE 2018, Salt Lake City, UT and got the top prize at the International Conference of Education Evaluation ICEE 2018 in Riyadh. In August 2020, the ABET Engineering Accreditation Commission provided excellent comments noting the comprehension and coverage of the instrument and process in fulfilling all the international standards of engineering design. The second biggest challenge was to develop and implement the practical frameworks that helped implement the six PDCA quality cycles. The various aspects and processes of the six PDCA cycles were crucial for smooth operation of the IQMS since the outputs of each cycle served as intricate interconnections of the overall causal chain. The outputs of each phase had to be of acceptable quality standards and delivered on time to ensure proper functionality of the IQMS. A well-trained and coordinated quality team was prepared and managed by me to systematically execute the various CQI processes. Over the six-year time frame we managed to develop one of the most sophisticated LMS, OAS, AAS and CIMS systems in the world (the author has not found a similar system with such extensive sophistication elsewhere) with thousands of PIs, hundreds of rubrics and more than a million student and administrative records on a cloud based environment that could be remotely extracted into digital reports using highly organized presentation formats. Lastly, several customized features and modules of EvalTools® were developed, deployed and tested to enable attainment of high level of automation for the collection, reporting and organization of data for seamless CQI efforts. More than 40 regional and international educational events and conferences showcased the novel learning models; cutting edge embedded assessments technology and their best practices; outcomes design and development methodology; development and application of hybrid rubrics; authentic OBE implementation frameworks for holistic curriculum delivery; comprehensive weighted course, program and student level detailed COs, SOs, PIs and Learning Domains Evaluations; digital CIMS features integrating outcomes evaluations data with electronically traceable improvement actions of 20 administrative committees; and an outcomes based digital developmental advising system and process. All the publications since 2014 to date serially examined the progressive development of methodology, technology, CQI processes, and results of their implementation leading up to establishment of the IQMS and successful remote ABET accreditation results. The final publication culminates the scope of the PhD thesis with a thorough examination of the IQMS utilizing a comprehensive eight phase meta-framework for conducting Mixed Methods Theory Based Impact Evaluations (Onwuegbuzie & Hitchcock, 2017) and provide detailed guidelines to both accreditors and engineering programs for conducting credible remote evaluations for accreditation [63].

As suggested by Onwuegbuzie and Hitchcock (2017), credibility and rigor of evaluation rest on many aspects such as using mixed methods for analyses, accurate theoretical and conceptual frameworks, appropriate context for evaluations, constructs of interest, well defined causal links, meta-analyses of processes and products, and quality of outcomes data [63]. The evaluation results and K tables reported in this publication provide thorough evidence for all these aspects using 8 phases of a comprehensive meta-framework and provide detailed guidelines for a multi-dimensional mixed methods approach to achieve credible MMTBIEs. Essential elements that ensure the quality of CQI data such as sampling schemes, data and theoretical saturation for qualitative analyses, statistical power of quantitative data, generalizability and transferability, sustainability, data collection and reporting methods etc. have been adequately discussed in this research. We also show how embedded assessment methodology using the FCAR and PVT with specific PIs and hybrid rubrics presents significant savings to instructors and helps ensure outcomes data is valid, reliable and tightly aligned to learning activities. The documentation and reporting features of EvalTools® could help programs actively facilitate social distancing norms since both faculty and students can interact remotely and exchange digital versions of necessary educational information such as outcomes results, advising notes, syllabi, lessons, online assessments, assignments, gradebook results etc. The most arduous task of maintaining a trail of CQI history, all the way up to closed corrective actions, is transformed into a seamless and totally manageable digital affair with the help of the CIMS Module. The Remote Evaluator Module provides accreditation auditors with an all-in-one remote display dashboard with tabs to conveniently access a wealth of evidential information such as course portfolios, curriculum maps; performance criteria and heuristics rules; course and program evaluations results; PEOs, SOs, PIs and rubrics databases; single term and multi-term SOs, executive summary reports; SOs based objective evidence; complete CQI history including detailed committee activity; and advising records. In summary, the findings of this study offer both accreditation agencies and engineering programs significant exposure to the overwhelming benefits of an outcome-based digital IQMS for seamless management of automated data collection and reporting to enable credible remote accreditation audits during the COVID19 global pandemic and beyond.

With a majority of positive aspects, one limitation of our system, the allocation of resources to scan paper documents, is currently performed by either the lecturers or teaching assistants. Future research can target the development of state-of-the-art digital systems that automate outcomes assessment development and scoring processes. This technology would integrate with and enhance existing digital systems to significantly reduce the overhead related to the overall time spent by faculty in the outcomes assessment process and scanning work done by lecturers. Specifically, the Faculty of Engineering, QA office intends to pursue ground-breaking automation technology to push the frontiers in outcomes assessment by including optical character recognition features in remote online marking and scoring tools to assess digital versions of hard copies of student exam sheets fed into high-end large scale scanners with barcode reading capability. The bar coding on digital copies of students' exams would help align with corresponding exam templates that automatically map to the COs, specific PIs, rubrics and SOs. This technology would automate the outcomes mapping, manual score entry, file scan and upload efforts, thereby resulting in enormous savings of manpower and other resources. Additionally, Zoom video conferencing shall be integrated in version 7 of EvalTools ® to roll out by mid 2021, supporting virtual tours of lab facilities, and faculty/student interviews, thereby significantly enhancing remote audit capabilities. The cutting edge innovations in digital technology can dramatically revolutionize the implementation of OBE quality systems for higher education and accreditation, especially during the COVID19 global pandemic and beyond.

Additionally, as per the UNESCO (2019) report on National Qualification Frameworks, more than 95 countries adopted learning outcomes models in their frameworks following national policy to foster emerging job skills [64]. So we can expect National Qualification Frameworks i.e. Learning domains and their learning levels, playing a dominant role in upcoming accreditation criteria of several developing countries and those of the European Union. The IQMS developed at the Faculty of Engineering can lay down a gold standard for automating accreditation efforts of not only the engineering programs but also for other specializations in higher education given the built in features available to customize to specific learning domains and learning levels of the national frameworks in respective countries. However, the digital web-based software EvalTools® is in itself not sufficient for programs seeking to automate their quality and accreditation efforts, since the primary focus of the IQMS is accuracy of learning models adopted, language of outcomes implemented, best assessment practices and protocols followed, and attainment of tight alignment with student learning activities in various courses. Therefore, for achieving successful and comprehensive automation and attain realistic CQI in education, programs would have to invest efforts in developing a database of outcome-based course portfolios that consist of a hierarchy of outcomes and performance indicators classified per multiple domains and their learning levels of given National Qualification Frameworks, and tightly aligned to various student course learning activities. The digital database would be dynamic due to the flexibility given to course instructors for designing formats for curriculum delivery most suited to their cohorts. Unless, institutions and program take the principles and paradigm of authentic OBE seriously, and are willing to expend additional resources to train faculty, and maintain quality assurance cells to equip the digital databases with accurate outcomes data and associated actions collected based on authentic practice and rigorous quality procedures, we cannot fully realize the benefits of utilization of the digital IQMS in higher education.

The global higher education and accreditation landscape, especially after the COVID19 pandemic, is set to penetrate deeper and faster into exploring various kinds education technology solutions that would impact every aspect of learning. Immersive learning, virtual reality, gaming, artificial intelligence, and use of big data are the key areas that could see explosive growth and use in education technology in the coming decade. Despite the imminent and drastic shift to new and cutting edge technologies in education, we would not be able to dispense with the necessity of using authentic OBE frameworks, learning models, best assessment practice for empowering students with the best possible educational opportunities. Therefore, the discussions in my publications on the limitations of current digital technology, their disparity with authentic OBE frameworks and proposed solutions present an exciting new frontier of research dealing with the integration of automation of development of outcomes based assessments and evaluation with the emerging technologies of the upcoming decade. Given the dynamic shift to newer technologies and navigation of higher education into an unchartered digital age of the upcoming decade, both institutions and accreditation bodies shall be faced with the daunting task of redefining standards and criteria for an acceptable level of quality of blended hybrid education systems. Detailed theoretical and practical frameworks presented in this research can provide multi-dimensional perspectives and valuable insights to various stakeholders on conducting credible program evaluations by showing how various phases of a novel meta-framework help to qualify state of the art technological educational interventions such as comprehensive digital IQMS systems.

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ABOUT THE AUTHOR

i. Industrial and Academic Background

Wajid Hussain is a US scientist and world renowned expert on authentic OBE, QA processes, outcomes assessment and program evaluation for accreditation using digital technology and software. He joined the academic field coming from an intensive Silicon Valley engineering background and more than 20 years' industry experience of mass production expertise of a Billion Dollar Microprocessor Manufacture Life Cycle. Over many years Wajid has managed several projects related to streamlining operations with utilization of state of the art technology and digital systems giving him significant experience working with ISO standard quality systems. He has received specialized Quality Leadership Training at LSI Corporation and also received an award LSI Corporation Worldwide Operations Review 1999 for his significant contributions to the Quality Improvement Systems. He was the lead product engineer supporting the Portal Player processor for *Apple's IPOD* plus many other world famous products at LSI Corporation.

In academics, Wajid has extensive experience supporting and managing outcomes assessment and CQI processes to fulfill regional and ABET accreditation requirements for several EAC, CAC and ETAC programs. Wajid has developed several revolutionary outcomes assessment instruments and evaluated models based on John K. Etsell's FCAR and one of the first to classify specific PIs as per all 3 domains and learning levels of Bloom's taxonomy and implement best assessment practices to support digital technology, automation, streamlining and CQI. He led the first 'tuning' efforts in the Middle East at the Faculty of Engineering, Islamic University by developing a complex database of thousands of outcomes and performance indicators with hundreds of rubrics for the Electrical, Mechanical and Civil Engineering disciplines. A comprehensive automated ISO standards Quality Systems CQI model for program evaluation with precision assessment instruments for capstone design, team work, lifelong learning, ethics etc. was developed and implemented. The Faculty of Engineering, Capstone Committee worked several hundreds of hours with Wajid to produce a revolutionary Capstone Design Course Assessment Instrument. Wajid recently presented this Capstone Design Activity Assessment model at the ASEE International conference 2018 at Salt Lake City, Utah. Wajid also worked closely with Dr. Mak Fong, Director Makteam Inc. to implement ground breaking academic advising systems based on outcomes using digital technology.

Wajid is currently reviewer for several international conferences on topics related to education and research methods, outcomes assessment, quality and accreditation. Wajid has presented multiple world class research papers on outcomes assessment and automation at the ASEE, FIE, IEEE Education Society and other international conferences. The National Institute of Learning Outcomes Assessment (NILOA) has published Wajid's work at the Faculty of Engineering at the Islamic University as an international example of best outcomes assessment practices. Wajid Hussain and William Spady, internationally regarded as the 'Father of OBE', have recently co-authored a book titled 'Beyond Outcomes Accreditation'. Wajid has been invited keynote or presenter in more than 40 international OBE and education conferences. Some notable presentations have been at the ICA 2015, MTN 2016, OBE ICON 2016, FIE 2016, ASEE 2016, ASEE 2017, ICTIEE 2017, ABET Symposium 2017, IICEDubai 2018, QS ASIA 2018, ASEE 2018, EDUTECH 2018, APAC STEM 2018, ICEE 2018, QS ASIA 2019, EDUTECH 2019, QS ASIA 2020, OBE ICON 2020, TALE 2020, EDUTECH ARABIA 2021, QS ASIA 2021.

In 2019, he was opening speaker at the QS ASIA 2019, Shaikh Zayed University, Dubai in Track 2 on Learning & Teaching with topic titled *Integrating Learning Outcomes into Undergraduate Curriculum for Fostering Research Skills.* In Asia's largest education conference, EDUTECH 2019, Singapore with 7000+ participants, Wajid was an invited Expert Panelist on *Learning Outcomes assessment for Program Evaluation*, Round Table Moderator on *Digitizing Learning Outcomes for Higher Education Institutions* and Meet the Mentor for delegations of International Education Ministry and QA agency representatives.

In 2020, Wajid was speaker at the QS ASIA VIRTUAL 2020, Singapore in Topic 3: Preparing the region to become an economic power over the coming decade with session titled *Gaining Essential Technical and Transversal Skills for Jobs in the Digital Age During COVID19 and Beyond.* In Asia's largest education conference, EDUTECH 2020, Singapore with 7000+ participants, Wajid was an Expert Panelist on *Future of Digital Assessments – Challenges and Opportunities* and Town Hall Speaker on *Best Practices for Engaging Students with Blended Learning Models* and Meet the Mentor for delegations of International Education Ministry and QA agency representatives. He was also an invited workshop presenter titled *Specific and Generic Performance Indicators to Measure Learning Outcomes* at TALE 2020 an IEEE Education Society Virtual Conference, Japan.

In 2021, Wajid was speaker at the QS ASIA VIRTUAL 2021, Singapore in *Track 5: Proactive Learning* for theme *Future Today - Sustainable Growth Towards 2030* with session titled *Digital Technology to Foster Lifelong Learning Skills.* In the MENA region's largest education conference, EDUTECH ARABIA 2021, Dubai with 2000+ participants, Wajid was an Expert Panelist on *Key Lessons from Digital Transformation Journey* and Round Table speaker with Juniper Networks on *Powering the Digital Learning Era*. Wajid is also the General Organizing Chair of the *Global OBE Virtual Summit 2021* November 19-22 2021 featuring 20 world famous OBE experts, 25 best proposals speakers in 5 themes.

Wajid featured on an international webinar event organized by the Christ University, Bangalore, India titled *Assessment and Evaluation of Learning Outcomes Using Performance Indicators and Hybrid Rubrics***.** He also conducted a series of workshops in Nov-Feb 2020 on *Implementing Learning Outcomes* for 20 programs at the University of Business and Technology, Jeddah. He made a national presentation on assessment at QIYAS, Aug 2017. On Janury 22, 2018, Prince Muqrin University, Madinah, Saudi Arabia invited Wajid to present on *OBE, Accreditation and Continual Quality Improvement a Global Challenge for Higher Education to* board of trustees, Rector, Vice rectors, deans and 200 faculty members. In August 2018, he was invited as a VIP 3-day presenter at the King Faisal University, Hofuf, Saudi Arabia to several hundred faculty members on the topic titled *Learning Outcomes and Methods of Measurement*. Regionally, William Spady and Wajid were also recognized as international OBE experts in 2017 by Dr. Faisal Al Mishary, CEO National Assessment Center (NAC) QIYAS, Riyadh. Wajid conducted multiple workshops attended by several hundred faculty members such as the ones in 2020, 2019, 2018, 2017 and 2016 for the University of Business and Technology, Prince Muqrin, King Faisal, King Fahd and Islamic Universities.

QS global news announced Wajid's ICEE 2018 Riyadh award on Capstone Assessment Instrument in 2018 and publication of IEEE paper on *ABET Accreditation during and after COVID19* in 2021.

Wajid is a senior member of the IEEE, IEEE Education Society, Association for the Assessment of Learning in Higher Education (AALHE), leading member of the Advisory Board for the International Network of OBE Experts worldwide (IN4OBE) and member of the American Society of Engineers for Education (ASEE). He is alumni of LSI, Texas A&M and Osmania Universities.

ii. Work Experience

- [2014-Present] Director, Quality & Accreditation, Faculty of Engineering, Islamic University of Madinah, Saudi Arabia
- [2012-2014] ABET Coordinator and faculty member, Electrical Engineering and Technology Programs at KFUPM operated colleges of Hafr Al Batin
- [2011-2012] Executive Director, Lattice Companies WLL, Qatar
- [2009-2011] Business Development Manager, HTCC Steel WLL, Qatar
- [2003-2009] Business and Technology Development Manager, Customer Specialists Inc. Miami FL
- [1998-2003] Product Engineer II, LSI Logic Corporation, Milpitas, CA
- [1997] Research Assistant, Department of Computer Science, Texas A&M University, College Station TX
- [1996] Teaching Assistant, Department of Physics, Texas A&M University, College Station TX

➔ **[2014-Present]** Director, Quality & Accreditation, Faculty of Engineering, Islamic University of Madinah, Saudi Arabia.

→ Job Function

- Consult with academic and administrative units to develop and implement plans and strategies to assess course-and program-level student learning outcomes (including core competencies) and to use assessment results for curriculum and instructional improvement.
- Continue to establish a culture of assessment where learning outcomes and data regarding them are continuously used to improve learning.
- Continuously assess the assessment process to ensure that it provides useful information to improve student learning while also uses human and fiscal resources wisely.

- Help to establish continuous improvement methodology, its monitoring and closing the loop for CQI
- Coordinate and support college-wide planning for student learning outcomes assessment.
- Implement, monitor, and maintain an operational plan for systematically assessing student learning across the curriculum (i.e., all credit and noncredit academic/instructional departments), across all sites, and in all instructional delivery modes (i.e. e-learning courses).
- Collaborate with chairs, directors and deans to develop, implement and manage a systematic process for curricular review and redesign focusing on outcomes assessment.
- Manage and lead the program term and multi-term review process.
- Consult with academic and administrative units to develop, implement, and evaluate plans and strategies to support student success and retention initiatives.
- Work closely with faculty in the design of outcomes-based curriculum. Assist faculty in the development or selection of strategies, assessment instruments/tools, data collection methodologies, and data analysis techniques appropriate for assessing student learning outcomes.
- Design, facilitate and coordinate ongoing training for faculty on current pedagogies and curriculum design to enhance assessment-as-learning.
- Serve as a resource on best practices and research findings in the areas of student learning assessment and measurement.
- Research and disseminate information on a wide array of educational resources on student learning assessment models, processes, and activities to both internal and external constituents.
- Maintain currency in the teaching-learning process
- Prepare and maintain an operational budget for the Office of Quality & Accreditation.
- Supervise staff as assigned.
- Align assessment of course, program, competency outcomes, and the use of that assessment for the benefit of student learning.
- Develop an assessment plan along with stakeholders that can be used in assessing PEOS, SOS and course learning outcomes.
- Develop all kinds of surveys along with stakeholders (alumni survey, course/senior exit survey, co-op, employer etc.)
- Supervise ABET coordinators/Staff for comprehensive review of status of all student and faculty related ABET work
- Suggest latest material for faculty of engineering website, brochure and other advertising and publicity materials
- Inform management/coordinators of improvements/deficiencies/delinquency in EvalTools related faculty course work

- Inform management/coordinators of improvements/deficiencies/delinquency in EvalTools related program review work
- Inform management/coordinators of improvements/deficiencies/delinquency in EvalTools related ABET/NCAAA report work
- Conduct random student surveys for feedback of e-learning experiences
- Conduct random faculty surveys for feedback on areas of improvement
- Schedule and supervise the completion of term wise course exit surveys
- Conduct research affiliated to the Faculty of Engineering on outcomes assessment
- Represent faculty of engineering quality department by participating in quality /accreditation/outcomes assessment training, conferences, symposiums local and international
- Moderate technical issues in using EvalTools with Makteam
- Suggest efficient ways of documentation, presentation, recording, mapping course or program related information on EvalTools
- Inform faculty of operational details of new modules implemented in EvalTools for utilization
- Organize individual or group training on utilization of the various modules of EvalTools
- Organize individual or group training on learning & teaching strategies
- Moderate setup of faculty, course and student portfolios on EvalTools
- Propose cost effective EvalTools® 6 modules with practical on time implementation
- Develop supplemental modules if required with Makteam and analyze any additional budget or cost requirement
- Propose, develop additional technology for streamlining teaching/learning, outcomes data collection, administrative processes, reporting for accreditation or intra university purposes
- Submit annual report to the deanship of quality and accreditation
- Add course specific PIS upon faculty request by investigating language, coverage of bloom's domains of learning and avoidance of any redundancy in the database
- Prepare analytical reports for work loads, passing, failing patterns, or any other analysis based on collected outcomes information
- Verify the logistic implementation of formally proposed committee suggestions for outcomes assessment methodology, implementation
- Train program ABET coordinators and arrange periodic audit and review of their work
- Inform ABET coordinators, program coordinators or management regarding areas for ABET coordinator improvement

→ Achievements:

✓ Established state of the art digital Integrated Quality Management Systems

✓ Attainment of very successful ABET accreditation for full 6 years with several strengths and no concerns or weakness

- ✓ Paper free LMS, OAS, CIMS with millions of documents (objective evidence) in a cloud based environment
- ✓ Multiple years of seamless clockwork operations for several quality processes in 6 PDDCA quality cycles
- ✓ Developed and implemented state of the art pedagogical and assessment models
- ✓ Led the development of massive self-study reports (1100 pages+ for each program)
- ✓ Developed assessment instruments for capstone design projects, teamwork, lab work, lifelong learning
- ✓ Cutting edge research and book publications
- ✓ QS Global News announcements in 2018 and 2021
- ✓ International and regional recognitions, presentations and consultancy
- ✓ Established 20 administrative committees and defined their scope and responsibilities.
- ✓ Developed a state of the art web based recruitment system specific to the Saudi academic system listing 22 states of recruitment process, salary calculator, job offer generator, highly advanced multi-inbox administrative role based email system with storehouse of information for 10000+ applicants

International Presentations, Activity, Honors and Affiliations

i. Tuning Efforts

- 568 COs, 1457 PIs and 339 Hybrid Rubrics (Faculty of Engineering)
- 300 COs, 352 PIs, 15 Hybrid Rubrics (Faculty of Computing)
- State of the Art, *Capstone Design Course Management and Assessment Instrument* featuring comprehensive Outcomes, PIs, Rubrics, Assessment Forms, Peer Evaluation Forms (500 hours spent for development leading Capstone Design Course Committee)
- *Vocational Training Course Management and Assessment Instrument* featuring comprehensive Outcomes, PIs, Rubrics, Assessment Forms, Peer Evaluation Forms
- Assessment models and process for enhancing student metacognition skills for lifelong learning
- COs, PIs, rubrics and assessment tables for experimental laboratory work for the EE, ME and CE programs

ii. International Presentations

- Facilitator and Speaker Inauguration of the IN4OBE Bangladesh chapter on April 18th 2021, featuring 518 attendees and key governmental representations from University Grants Commission (UGC), Bangladesh Accreditation Council (BAC), Board of Accreditation for Engineering and Technical Education (BAETE)
  https://www.facebook.com/watch/live/?v=206133397655483&ref=notif&notif_id=1618750724302941&notif_t=live_video
  https://www.jugantor.com/todays-paper/news/413455
  https://www.ittefaq.com.bd/education/238754/
  https://www.dailynayadiganta.com/city/576843

https://bonikbarta.net/home/news_description
https://epaper.dainikamadershomoy.com/files/e-paper/2021/04/20/images/11_120.jpg
https://www.ejjdin.com/2021/04/20/images/05_107.jpg?v=1
https://www.jaijaidinbd.com/todays-paper/education-arena
https://www.thedailystar.net/city/news/uiu-hosts-outcome-based-education-network-launching-2081685?amp
https://epaper.newagebd.net/detail/271989/5673
https://www.newagebd.net/article/135935/in4obe-opens-chapter-in-bangladesh
https://www.tbsnews.net/bangladesh/education/international-network-obe-inaugurates-uiu-233983
https://dailyasianage.com/news/259867/inauguration-of-intl-network-for-obe-at-uiu
https://campuslive24.com/private-university/41581/
https://www.risingbd.com/campus/news/403911
https://careertimes24.com/archives/33137
https://bdtone24.com/archives/5293
https://www.odhikar.news/education/184406

- IN4OBE International OBE Virtual Summit 2021, Organizing Chair and Key Speaker for world class events. 20 top OBE speakers from the US, Canada, Australia, South Africa, Philippines. 25 proposals selected speakers in 5 themes.
  https://in4obe.org/
- Key presenter, international Webinar organized by Christ University, Bangalore, India April 17th 2021, Titled "Assessment and Evaluation of Learning Outcomes Using Performance Indicators and Hybrid Rubrics"
  View the presentation at the following link and using the given password:
  https://christuniversity.webex.com/christuniversity/lsr.php?RCID=8a78a4285ef04727ad1ebe30c8b2581b
  Recording password: AwyW3ys9
- QS ASIA MARCH 23-25, Theme *Future Today - Sustainable Growth Towards 2030*, Track 5 Panel Speaker - *Proactive Learning: Digital Technology to Foster Lifelong Learning Skills*
  https://qsmaple.org/
- EDUTECH ARABIA March 15-16, Theme - *Driving the future of education in MENA*, expert panelist on topic titled "*Key Lessons from Digital Transformation Journey*".
  https://www.terrapinn.com/virtual/edutech-digital-summit/index.stm
- 9th International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2020, Takamatsu, Japan, Dec 8-11 (2020), Hussain, W., Workshop presenter, '*Specific and Generic Performance Indicators for Measuring Learning Outcomes,*' Japan.
  http://tale2020.org/workshop-2/
- 9th International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2020, Takamatsu, Japan, Dec 8-11 (2020), Hussain, W., Sessions speaker, '*Industrial Training Courses – A Challenge During the COVID19 Pandemic,*' Japan.

http://tale2020.org/

- QS ASIA 2020 under Patronage of Ministry of Education, Building World-Class Universities in the Middle East, 1-3 March 2020, ART Rotana Amwaj Islands, Bahrain, Opening Speaker, Research Knowledge and Skills Track 3, '*A Mixed Method Approach for Building a State of the Art Digital Advising Systems based on Learning Outcomes*,' Manama, Bahrain. https://qsmaple.org/agenda/ (rescheduled due to COVID19)
- IN4OBE International OBE Educational Conference 2020, Organizing Chair and Key Speaker for world class events in 4 major cities in India with 10000 attendants. (rescheduled due to COVID19)
- EDUTECH 2019, Suntec Convention Center, Wajid Hussain – Invited Expert Panelist on *'Learning Assessment Challenges and Program Evaluation for Accreditation,'* Mentor and Moderator for topics related to outcomes assessment, evaluation, accreditation and digital automation, Singapore, Nov 4-6, 2019.
- Invited by Rector Osama Bin Ahmed Junadi as OBE expert for series of workshops organized by Faculty Development for 20 Programs at the University of Business and Technology, Jeddah (Sep 2019)
- QS ASIA, Dubai 2019 under Patronage of Minister of Culture and Knowledge Development, Shaikh Zayed University, Opening Speaker Research Knowledge and Skills Track '*Integrating Learning Outcomes Into Undergraduate Curriculum For Fostering Research Skills.*' https://qsmaple.org/dubai-2019/programme-schedule/
- Launch of '*Beyond Outcomes Accreditation,'* Book publication with Dr. William Spady, Joan Largo and Dr. Francis Uy Februray 2018. https://www.rexestore.com/e-books/1905-beyond-outcomes-accreditation-exploring-the-power-of-real-obe-practices-e-book-epub.html
- IICE Dubai, IAFOR 2018 at Dubai (Feb 16-18), "*Automated Student Outcomes Assessment & Evaluation Based on Bloom's Three Domains of Learning Levels: Utilizing State of the Art Web-Based Software*"; Workshop speaker, Wajid Hussain. http://iafor.org/archives/conference-programmes/iicedubai/iicedubai-draft-programme-2018.pdf
- QS Asia 2018 8th International Summit at Bahrain (March 4-6); "*Accreditation and Ranking or Continual Quality Improvement, Which One?*"; Opening Sessions Speaker, Wajid Hussain. http://qsmaple.org/qsmaple2018/wp-content/uploads/2018/03/QS-MAPLE-2018-Conference-Program.pdf
- American Society for Engineers in Education, ASEE 2018, International Conference at Salt Lake City, UT (June 24); U214G·SUNDAY WORKSHOP: *Management and Assessment of Capstone Design Made Easy Using Specific and Generic Performance Indicators*; workshop speaker, Wajid Hussain. https://www.asee.org/public/conferences/106/registration/view_session?session_id=9105
- ICEE 2018, International Conference on Education Evaluation, Four Seasons Hotel, Riyadh Received Top Award presented by HRH Prince Dr. Faisal Al Mishary for BEST Scientific Poster

from 60 posters for '*Capstone Design Course Management and Assessment*', Saudi Arabia, 2018.
http://icee.eec.gov.sa/en/index.html

- Asia Pacific Stem Roundtable 2018, APAC STEM 2018, Malaysia, Intercontinental Hotel, Invited Key Speaker on OBE and STEMpreneurship presided by Member of Parliament, Hon'ble Nurul Izzah. November 6-8, 2018, Kuala Lumpur, Malaysia.
  https://apacstem2018.wixsite.com/home
- EDUTECH Singapore 2018, Invited Key Speaker on '*Automated Student Outcomes Assessment for Enhanced Student Learning*', Round Table Panel Expert on '*CQI or Accreditation Which One?*' https://www.terrapinn.com/exhibition/edutech-asia/Past-speakers.stm
- Invited by HRH Rector Dr. Mohammed Al Ohali (Ex Deputy Minister of Education) King Faisal University as expert OBE workshop presenter in Faculty Enrichment Program (July 30 - Aug 2 2018). Presented to 300 faculty members over 4 days in four 4 hour sessions on '*Learning Outcomes and Methods of Measurement*', 2018, Hofuf, Saudi Arabia.
- Invited VIP Speaker, University of Prince Muqrin, *'OBE, Accreditation, Continual Quality Improvement a Global Challenge for Higher Education'*, presentation to Rector, V. Rectors, top management and 200 faculty members, main auditorium, Madinah, Saudi Arabia Jan 22 2018
- ABET symposium 2017 at Baltimore (April 20-21), '*Specific or Generic PIs to Measure ABET SOs',* 2 hour Sessions speaker, Wajid Hussain.
- American Society for Engineers in Education, ASEE 2017, Workshop Presenter on '*Specific and Generic Performance Indicators for the Comprehensive Measurement of ABET Student Outcomes*', Columbus, Ohio (June 26-28), 2017.
  https://www.asee.org/public/conferences/78/registration/view_session?session_id=7065
- American Society for Engineers in Education, ASEE 2017 at Columbus, Ohio (June 26-28) Sessions speaker, Full research paper on '*Specific, Generic Performance Indicators and Their Rubrics for the Comprehensive Measurement of ABET Student Outcomes'* with Dr. William Spady, Father of 'OBE'.
  https://peer.asee.org/specific-generic-performance-indicators-and-their-rubrics-for-the-comprehensive-measurement-of-abet-student-outcomes
- ICTIEE, '*Automation of Outcomes Assessment Using State of the Art Digital Technology*', Invited VIP Speaker, Wajid Hussain, Hyderabad, India 2017 (Jan 6-8).
  http://www.iucee.org/ictiee2017/confirmed-vips-and-international-speakers/
- National presentation at QIYAS, Invited VIP speaker, '*Digital automation of Outcomes Assessment Using Specific Performance Indicators and Hybrid rubrics for Maximizing Student Learning to Achieve Vision 2030*', William Spady and Wajid Hussain were recognized as international OBE experts by Dr. Faisal Al Mishary, CEO, National Assessment Center (NAC) QIYAS, Riyadh, August, 2017.
  https://etec.gov.sa/ar/Researchers/AnnualReports/Documents/Summary%20of%20the%20annual%20achievements%20report%20for%20the%20year%201438_1439.pdf

- American Society for Engineers in Education, ASEE 2016, Sessions speaker on '*Engineering Program Evaluations Based on Automated Measurement of Performance Indicators Data Classified into Cognitive, Affective, and Psychomotor Learning Domains of the Revised Bloom's Taxonomy',* New Orleans, LA (Jun 26-28). https://www.asee.org/public/conferences/64/papers/14792/view
- Frontiers in Education, Sessions and workshop presenter full research paper on '*Quality Improvement with Automated Engineering Program Evaluations Using Performance Indicators Based on Bloom's 3 Domains'*. FIE 2016, Erie, PA. http://fie-conference.org/sites/fie-conference.org/files/FIE-2016-Proceedings.pdf
- OBE ICON 2016, Keynote speaker on '*Accreditation and OBE'*, Special Note of thanks received from President of Philippines - Rodrigo Duterte, Secretary Department of Education – Leonor Briones and President Commission of Higher Education – Patricia B. Licuanan. Taagtay, Philippines. https://www.facebook.com/watch/live/?v=399058823817161&ref=watch_permalink
- Moving the Needle conference 2016 at St. Petersburg College, Invited Sessions Speaker on '*Automated Student Outcomes Assessment and Evaluation Based on Bloom's 3 Domains of Learning Levels Utilizing State of the Art Web-based Software, and Methodology*', St. Petersburg, FL, (Nov 8-9), 2016. http://movingtheneedleconference.com/2016-conference/2016-presentations/
- 2nd International Conference on Assessments (ICA), National Assessment Center, QIYAS, Riyadh, Sessions speaker, '*A Digital Integrated Quality Management System for Automated Assessment of QIYAS Standardized Learning Outcomes'*, Intercontinental Hotel, Riyadh, Saudi Arabia (Dec 1-3), 2015. https://www.facebook.com/ica.qiyas/

iii. Workshops

50+ workshops conducted from 2014-2019 on topics such as:

- Strategies of Teaching and Learning
- FCAR and GR Models for program and course evaluations
- Quality Assurance in Higher Education
- ABET and NCAAA Accreditation
- Learning Outcomes Development and Implementation
- Development and Implementation of PIs
- Development and Implementation of Hybrid Rubrics
- EvalTools ®LMS, CIMS, AAS and OAS
- Benefits of ABET accreditation to Students
- Management and Assessment of Capstone Design Course
- Management and Assessment of the Vocational Training Course

iv. YouTube Channel

- Wajid Hussain: Specific Performance Indicators (2017). https://www.youtube.com/watch?v=T9aKfJcJkNk
- Wajid Hussain: Automated Engineering Program Evaluations - Learning Domain Evaluations (2016). https://www.youtube.com/watch?v=HAGaoRUrJlE
- Wajid Hussain: Automated Engineering Program Evaluations - Learning Domain Evaluations – CQI (2016). https://www.youtube.com/watch?v=VR4fsD97KD0
- Wajid Hussain: Hybrid Rubrics Development CE Program (2016). https://www.youtube.com/watch?v=ZemPF7OyhyI
- Wajid Hussain: Hybrid Rubrics Development EE Program (2016). https://www.youtube.com/watch?v=2pjIe8Xk78M
- Wajid Hussain: Hybrid Rubrics Development ME Program (2016). https://www.youtube.com/watch?v=pwK7sSLM6tk
- Wajid Hussain: Continuous Improvement Management System (CIMS) (2016). https://www.youtube.com/watch?v=0hqMiddgQRg

v. Honors and Awards

- QS global news announced Wajid's ICEE 2018 Riyadh award on Capstone Assessment Instrument in 2018 and publication of IEEE paper on ABET Accreditation during and after COVID19 in 2021
- 2019 Excellence in Contributions to Accreditation: Development and Implementation of comprehensive Digital Integrated Quality Management Systems, Leading the Self-Study, QA processes, QA teams for all engineering programs' ABET Accreditation Efforts; Faculty of Engineering, Islamic University, Madinah, Saudi Arabia
- IN4OBE 2018 Advisory Board Member Assessment & Evaluation of Outcomes in Learning
- Top National Award for best scientific poster, "*Management and Assessment of Capstone Design Made Easy Using Learning Outcomes*", International Conference on Educational Evaluation ICEE 2018, Riyadh Saudi Arabia
- QIYAS 2017 National Center of Assessment Award for recognition of regional and international achievements in learning outcomes assessments
- OBE Conference Keynote Presentation & Contributions Award, Spady Center in appreciation of the keynote and other presentations at the OBE ICON 2016, TaagTay Philippines
- 2016 Excellence in Contributions to Accreditation Efforts, in appreciation for immense efforts for the support of ABET accreditation efforts, Faculty of Computer Sciences, Islamic University, Madinah, Saudi Arabia
- 2015 Senior Member IEEE
- Key Contributor Incentive Program (KCIP), LSI Corporation, Milpitas, CA, USA
- 1999 Worldwide Operations Review Award, in appreciation of contributions to the LSI Quality Improvement Systems, LSI Corporation, Milpitas, CA, USA

vi. Funded Research Projects

- Research Project and Publication ASEE proceedings, 2016, Engineering Program Evaluations Based on Bloom's 3 Domains of Learning and their Learning Levels, Ministry of Education, Saudi Arabia.
- Research and develop Tcl/Tk 3.0 Digital Design Layout Toolkit under supervision of CPSC Department Chair, Texas A&M University, Prof. Duncan M. H Walker *(Associate Editor. IEEE Transactions on Computer Aided Design on Circuits and Systems 2010-2011; Vice General Chair, IEEE International Workshop on Defects Based Testing 2006; Program Committee IEEE International Conference on Computer Aided Design, 2003-2005*)
- Galois Field Linear Feedback Built-in Self-Test Shift Registers under supervision of CPSC Department, Texas A&M University, Professor and Endowed Chair Dr. Dhiraj K. Pradhan *(Associate Editor, IEEE Transactions on Computers, 2003)*

vii. Organizations

- Advisory Board Member - International Network for Outcome Based Education Experts (IN4OBE)
- American Society of Engineers for Education (ASEE)
- IEEE Education Society
- Senior Member - IEEE
- Association for Assessment for Learning in Higher Education (AALHE)
- Texas A&M Alumni
- LSI Corporation Alumni
- Osmania University Alumni

APPENDICES

Publication(a): Hussain, W. and Addas, M., F. (2015), "A Digital Integrated Quality Management System for Automated Assessment of QIYAS Standardized Learning Outcomes", 2nd International Conference on Outcomes Assessment (ICA), 2015, QIYAS, Riyadh, KSA

A Digital Integrated Quality Management System for Automated Assessment of Qiyas Standardized Learning Outcomes

Wajid Hussain and M. F. Addas

Islamic University, Madinah Munawarrah

Author Note

Wajid Hussain, Director, Office of Quality & Accreditation, Faculty of Engineering, Islamic University.

M. F. Addas, Dean, Faculty of Engineering, Islamic University

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Abstract

Institutions commonly implement and maintain processes for academic, faculty, curriculum development that are minimally integrated with learning outcomes assessment for accreditation. To address this issue Qiyas has developed an extensive list of standardized learning outcomes for seven engineering specializations with assessments planned for implementation upon student graduation and their results provided to the concerned program for appropriate corrective action and subsequent improvement. Additionally, students are reluctant to participate in such learning outcomes assessments external to their program curriculum. This paper presents a novel performance vector methodology based on a widely adopted Faculty Course Assessment Report (FCAR) integrated with a web based software application EvalTools® 6 resulting in a highly sophisticated digital integrated quality management system for academic development based on Qiyas student learning outcomes assessment data and significant customizations facilitating the Saudi Arabian higher education culture and learning environment. Performance indicator analytics information for a program, course and student for single or multiple terms and FCAR is referenced in the executive summary for seamless continuous improvement process with ABET and Qiyas student learning outcomes data as a benchmark for achievement. EvalTools® 6 also facilitates use of electronic or manual assessments provided by external stakeholders such as Qiyas for extraction of standardized learning outcomes information. Further study of learning outcomes information for assessments developed by Qiyas itself is therefore strongly suggested.

Keywords: Qiyas, ABET, FCAR, Continuous improvement, program, learning outcomes.

This research has referenced past work that major driving force of outcomes assessment initiatives in engineering institutions have been regional and specialized accreditation standards. Actual continuous quality improvement and accreditation based activity at various engineering institutions remain as relatively isolated processes with realistic continuous quality improvement efforts maintaining minimal reference to learning outcomes assessment data measured for accreditation (Provezis, 2010). Lack of utilization of digital technology and appropriate methodologies supporting automation of outcomes assessment are primary reasons that further exacerbate this situation.

In this paper, is presented integration of best practices for outcomes assessment methodology, digital database of specific performance criteria and Qiyas learning outcomes (Qiyas handbook, 2014) with web based streamlining software EvalTools® 6 (www.makteam.com, 2015). The entire process of outcomes assessment, evaluation and closing the loop is streamlined by systematically collecting, compiling and presenting the data at the course and program level for an easy review and analysis. As a result, robust assessment data by multiple raters for ABET student learning outcomes as well as course learning outcomes is collected by comprehensively measuring a significant number of specific performance indicators in comparatively much shorter time frames (more than 60% of ABET student outcomes are measured by a program in just one semester at Faculty of Engineering, Islamic University whereas typical embedded assessments cover only 2 or 3 outcomes per semester about 25% of ABET student outcomes as suggested by Mead, Turnquest & Wallace, 2006) resulting in quicker cycles for measuring all ABET student outcomes and relatively comprehensive program term review leading to establishment of an efficient continuous improvement system.

EvalTools® 6 is chosen as the platform for outcomes assessment instead of Blackboard® (several software applications are cited including TrueOutcomes® for outcomes assessment due to the inadequacy of Blackboard® by Kumaran & Lindquist, 2007) since it employs the unique FCAR and EAMU performance vector methodology (Estell, Yoder, Morrison & Mak, 2012; Mak & Kelly, 2010; Liu & Chen, 2012) which facilitate the use of existing curricular grade giving assessments for outcomes measurement and help in achieving a high level of automation of the data collection process (refer Figure 34), feature-rich pick-and-choose assessment/reporting tools, and the flexibility to provide customized features. EvalTools® 6 FCAR module components available with summative or formative options are: course description, course outcomes indirect assessment, grade distribution, course outcomes direct assessment, assignment list, course reflections, old action items, new action items, student outcomes assessment and performance indicators assessment. The basis of assessment in FCAR (Estell et al., 2012; Mak et al., 2010) is the EAMU performance vector (Liu et al., 2012). The EAMU performance vector (refer Figure 1) counts the number of students that passed the course whose proficiency for that outcome was rated **E**xcellent, **A**dequate, **M**inimal, or **U**nsatisfactory (Liu et al., 2012). Program faculty report failing course outcomes (COs), ABET student outcomes (SOs), performance indicators (PIs), comments on student indirect assessments (refer Figure 31 & Figure 32) and other general issues of concern in the respective *course reflections* section of the FCAR. Based upon these course reflections, new action items are generated by the faculty. Old action items status details are carried over into the current FCAR from the information generated during the previous offering for this specific course. Modifications and proposals to a course are made with consideration of the status of the old action items. The *Program Term Review* module of EvalTools® 6 is focused on failing SOs and PIs for analysis and discussions relating to improvement. Average values of ABET SOs and weighted average values of PIs (Liu et al., 2012) with scientific color coding scheme indicate failures for investigation. Courses contributing to failing PIs and SOs are examined.

Method

The Faculty of Engineering at the Islamic University has studied various options for developing its assessment methodology and systems (Mak et al., 2010; Kumaran et al., 2007; Estell et al., 2012; Eltayeb, Mak & Soysal, 2013) to essentially establish actual Continuous Quality improvement (CQI) and not just fulfill the regional or international accreditation requirements. The following points summarize the essential elements chosen to implement state of the art assessment systems for achieving realistic CQI in engineering education:

1. OBE assessment model
2. ABET, Engineering and Accreditation Commission (EAC) outcomes assessment model employing Program Educational Objectives (PEOs), 11 EAC Student Outcomes (SOs) and Performance Indicators (PIs) to measure Course Outcomes (COs)
3. Faculty Course Assessment Report (FCAR) utilizing the EAMU performance vector methodology
4. Digital database of well-defined specific PIs (elementary to advanced) including 20% implemented from Qiyas handbook, (2014) of nationally standardized learning outcomes for several engineering specializations
5. Unique Assessments mapping to one specific PI
6. Scientific Constructive Alignment for designing assessments to obtain realistic outcomes data representing information for one specific PI per assessment

7. Calculation of program and course level ABET SOs, COs data based upon weights assigned to type of assessments, PIs and course levels
8. Course, program and student level measurement and analysis of ABET SOs
9. Electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS), Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI
10. Electronic integration of Action Items (AIs) generated from program outcomes term reviews with the Faculty of Engineering standing committees' meetings, tasks lists and overall CQI processes (CIMS feature)
11. Web-based software EvalTools® 6 with significant customizations facilitating all of the above

In the continuing section of this paper we will elaborate the major elements of our digital outcomes assessment system and features relating to realistic outcomes collection and utilization for CQI.

I. Design and Measurement of Specific Elementary to Advanced Performance Criteria related to Learning Outcomes at the Course Level and Spanning the Entire Educational Curriculum

A quote is presented related to the importance of design and measurement of specific performance criteria for achieving realistic academic improvement in learning:

> The engineering education in Malaysia underwent a major transformation starting in 2004 due to the requirement imposed by the Washington Accord agreement. Assessment and evaluation of programme outcomes (PO) are now mandatory for all engineering

> programmes in Malaysia. However, the typical PO assessment model practised by many engineering programmes resulted in vague assessment methods and as a result failed to show concrete continual quality improvement. The major issue have been the failure to have clear performance criteria for each of the outcome. A new model which is based on looking at each PO as a major thrust with specific performance criteria is proposed. It is expected that the new model will allow one to objectively evaluate whether the students have achieved the criteria and subsequently facilitate CQI implementation within the programme (quoted from conclusion of Mohammad & Zaharim, 2012; Programme outcomes assessment models in engineering faculties. *Asian Social Science*, Vol . 8, No. 16. ISSN 1911-2017, EISSN 1911-2025. Published by the Canadian Center of Science and Education. doi: 10.5539/ass.v8n16p115).

At the Islamic University (IU) in Madinah, Faculty of Engineering have developed through several sessions of departmental meetings a comprehensive electronic database of specific performance criteria covering all phases of the syllabi for different courses offered within the curriculum. A good percentage of the performance criteria have also been incorporated into the electronic database from the Qiyas handbook, (2014) of nationally standardized learning outcomes for several engineering specializations. However roughly less than 20% of the Qiyas performance criteria were actually utilized for measurement since most of the Qiyas performance criteria are of an advanced level while a minority are futuristic (Qiyas handbook, 2014). Learning outcomes and performance criteria progressing from elementary to advanced levels should be measured at the course level for all courses spanning the entire educational curriculum (outcomes data is inadequate if not measured at all levels of the curriculum as succinctly stated by Mead, Turnquest & Wallace, 2006; Mead & Bennet, 2009;

Moon, 2005). Performance criteria should be specific to collect precise learning outcome information related to various topics, phases of a curriculum while addressing various levels of proficiency of a measured skill (refer to the CLO form in Table 6 measuring 36 specific performance criteria for just one typical electrical engineering course reported by Kalaani & Haddad, 2014; refer to course level outcome assessments explained by McGourty, Sebastian & Swart, 1997, 1998). Figure 33 indicates examples from civil engineering (CE) statics and electrical engineering (EE) electric circuits courses where specific performance criteria are utilized to isolate certain critical skills for measurement which are a subset of the total skills associated with the corresponding course learning outcomes.

A design flow for holistic learning outcomes and their performance indicators is shown at the course level in Figure 2 and spanning the entire curriculum in Figure 3. Measurement of these performance indicators will result in a comprehensive database of learning outcome information which will provide a thorough analysis of each phase of the education process and a comparatively easier mechanism for early detection of the root cause of student performance failures at any stage of student's education. Therefore any performance failure in a course in an advanced or elementary level of education in a given curriculum could be remediated through targeting improvement in some associated or basic skills learning process in the same course or some other related course. This approach would enable scientific and timely regulation of the teaching and learning process for holistic improvement of student performance failures ultimately resulting in a very high degree of learning outcomes achieved by the students. A direct quote:

> Learning outcomes that are systematically assessed at course level can be shown to contribute to program-level outcomes, and thus to information provided to students,

employer groups, professional bodies and so on about graduation standards (Assessment toolkit, University of South Wales UNSW, Australia, https://teaching.unsw.edu.au/printpdf/531 pp. 1)

confirms that course outcomes and their specific performance indicators assessment is crucial for faculty teaching and delivery improvement for enhanced student learning.

II. Unique Assessments for Realistic Measurement of Performance Indicators, Learning Outcomes

Generally curricular grade giving assessments in an engineering curriculum are comprised of single or multiple questions and cover more than one performance criteria (explanation on assessments: Whys and hows of assessments. Eberly Center for Teaching Excellence, Carnegie Mellon University CMU website, 2015). Programs may choose to a) develop new assessments and/or b) use the assessments available in their curriculum for the measurement of specific performance criteria related to their program outcomes. In the first method, additional resources and faculty time would be required to measure the performance criteria of interest. The second method may pose limitations on the number of performance criteria measured in a given time frame and the quality of data collected depending upon the availability of streamlining electronic tools or assessments which possess maximum relative coverage of a single performance criterion (confirmation of limitations of manual systems and learning outcome information collected in a given time frame as stated by Kumaran et al., 2007; Mead et al., 2006). The result of both methods is a comparatively small set of performance criteria finally measured in a given time frame by a program using assessments that may not have maximum relative coverage of the specified criteria. Measurement of program educational objectives, student learning outcomes and performance criteria would therefore be completed in comparatively longer cycles. This minimum number of performance criteria measured with comparatively fewer assessments and obviously lesser number of raters over a given time frame would render the program evaluation term review less comprehensive and result in a deficiency in the eventual realization of its PEOs (concurs with what is said regarding minimal number of institutions implementing comprehensive systems for learning outcomes assessment and measurement by McGourty et al., 1998; Gannon-Slater, Ikenberry, Jankowski & Kuh, 2014).

III. Designing a New Set of Assessments Specifically for Realistic Outcomes Measurement in Addition to Existing Curricular Grade Giving Assessments.

Since grade giving assessments in an engineering curriculum are comprised of single or multiple questions and cover more than one performance criteria, the total score of such an assessment is generally a sum total of individual scores obtained from grading multiple performance criteria corresponding to this assessment. Thus the assessment score does not actually reflect the grading results from a single performance criterion but rather a complex distribution of grading results from multiple performance criteria (explanation on assessments: Eberly Center for Teaching Excellence, Carnegie Mellon University CMU website, 2015). Therefore, the outcomes assessment data resulting from this approach is not realistic and does not reflect precise information relating to specific performance indicators or outcomes for quality improvement. To obtain realistic data for continuous improvement purposes one option available for faculty is to create a new set of assessments specifically for performance criteria, outcomes measurement. Several programs worldwide have chosen this approach for accreditation purposes (McGourty et al., 1997, 1998; Gannon-Slater et al., 2014; Provezis, 2010) but since it is tedious and requires additional faculty time, resources the programs generally collect minimal information for small set of outcomes, performance indicators which are not sufficient for the implementation of a comprehensive academic improvement process (Kumaran et al., 2007; Manzoul, 2007; Mead et al., 2006, 2007). This would finally result in programs spending additional resources for maintaining independent processes for accreditation and realistic continuous improvement.

A noteworthy quote from a foreword echoes the question whether learning outcomes assessment systems motivated by accreditation achieve realistic improvement:

The other major finding of our work that stood out was that chief academic officers pointed out that regional and specialized accreditation standards and expectations were the main drivers of outcome assessment initiatives on their campuses. In some respects, learning that accreditation was the main driver of assessment on most campuses is disappointing. Instead, we would have been elated if institutions themselves, faculty members and academic and administrative leaders and governing boards, driven by the desire to be the best and continuously improve, would have been in the driver's seat.

Still, if accreditation is driving learning outcome assessment in American higher education, where is it taking us? What are the standards? What is the variation among regions? And how are regional accrediting groups guiding and helping institutions meet these rising expectations for outcome evidence? These and other key questions are probed in this NILOA Occasional Paper #6, Regional Accreditation and Student Learning Outcomes: Mapping the Territory. It comes as a result of a year-long effort by Dr. Provezis and the generous cooperation of the seven regional accrediting commissions, all made possible by support from Lumina Foundation for Education, Carnegie Corporation, and The Teagle Foundation. The findings should be of interest to all those concerned with the future of higher education in the United

States and the integrity of the systems of quality control that sustain it (foreword by Stanley O. Ikenberry for National Institute of Learning Outcomes Assessment NILOA, Occasional Paper #6, Regional Accreditation and Student Learning Outcomes: Mapping the Territory, Provezis, 2010, pp.8, www.learningoutcomeassessment.org/documents/Provezis.pdf)

Another quote from a latest study with similar information:

Similar to findings reported in 2009 and the 2013 national report, regional and specialized/program accreditation bodies remain the prime drivers of assessment work at colleges and universities across all regions (Gannon-Slater et al., 2014; Institutional assessment practices across accreditation regions pp. 7. National Institute of Learning Outcomes Assessment NILOA. www.learningoutcomeassessment.org/documents/Accreditation%20report.pdf)

IV. Designing Curricular Grade Giving Assessments to Include Scientific Constructive Alignment for Realistic Learning Outcomes Measurement

Significant reduction of work is achieved by avoiding the creation of additional assessments specifically for outcomes measurement through the design of curricular grade giving assessments that include scientific constructive alignment for realistic learning outcomes measurement. While designing any assessment related to a specific course content the concerned engineering faculty member at IU would consider measurement of the most appropriate performance criteria. For scientific constructive alignment (concept of scientifically designing assessments with multiple performance criteria allocated fixed proportions of the total score is in addition to what is mentioned regarding constructive alignment by Biggs & Tang, 2007; Houghton, 2004) the contribution of various performance criteria to the total score of an assessment would be defined during assessment design. The performance criteria of interest to be measured by a specific assessment would be given a nearly 70% or more share in the total score distribution and the effect of grading results of the other performance criteria on the total score would be thus rendered negligible. Figure 4 shows an example where a sample unique assessment (quiz 2) with high relative coverage (Q2 7 points) is designed with maximum coverage (70%) of a specific PI_5_12 mapping to a CO3, ABET SO5.

For cases where it is not possible to assign a nearly 70% or more share to a certain performance criterion in an entire assessment, the Assignment Setup Module of EvalTools® 6 is used to split a question or sub question of an assessment for achieving 70% high relative coverage of a specific performance criteria. Figure 5 indicates examples of implementation of splitting of assessments to questions, sub questions using EvalTools® 6 Assignment Setup Module to obtain maximum relative coverage and measurement of a specific PI mapping to a certain CO and ABET SO. Such assessments or set of questions are said to be unique since they are just used once for measurement of a certain PI. This methodology of implementing unique assessments with high relative coverage of PIs mapping to COs and ABET SOs would ensure realistic measurement of outcomes assessment data for comprehensive continuous improvement. Refer Figure 34 for comparative study of tools using FCAR + EAMU vector methodology, scientific constructive alignment versus generic rubrics.

V. EvalTools® 6 EAMU Vector Calculation for COs or PIs Employing Weighting Factors for Various Assessments

Various relevant assessments are selected by faculty to measure COs or PIs for a certain course. The EAMU vectors for a CO or PI are calculated from the set of final percentage values obtained for all students after applying the weighted average to the scores for each student in all assessments used for measurement of that specific CO or PI. Discussions below will further elaborate the concepts utilized in obtaining final calculations.

Weighting Factors for Various Assessments. Realistic learning outcomes measurements are achieved by specifying weights (similar to what has been suggested regarding relevance of weights for learning outcomes measurement by Moon, 2007; Liu et al., 2012) to different assessments according to a combination of their course grading policy and type. The first rationale in order of priority is the type of assessment so that higher weight is assigned to laboratory/design related assessments compared to purely theoretical assessments since laboratory/design work cover all three domains of Bloom's taxonomy (Taxonomy of educational objectives: McKay) cognitive, psychomotor and affective (as suggested by Salim, Hussain & Haron, 2013) or final exams over quiz since the final exam is more comprehensive and well-designed than a quiz and the students are generally more prepared for a final exam with many of their skills reaching a higher level of maturity and proficiency by then. The second rationale in priority is to account for the percentage contribution of the given assessment to the final grade which is derived from the course grading scale. Figure 6 shows the 4 course formats developed by the Faculty of Engineering at IU to calculate the weighting factors for different assessment types. Faculty first select the course format which matches their course design to obtain the multiplication factors for different assessment types. Then for a specific assessment type in the given course its final weighting factor % is calculated by obtaining the product of its course grading scale and multiplication factor. Fig 7. And Figure 8 illustrate examples of weighting factor % rationale and calculation applied to various type of assessments.

Steps Employed By Evaltools® 6 to Calculate the EAMU Vectors

Faculty use EvalTools® 6 Assignment Setup Module to identify an assignment with a set of specific questions or split an assignment to use a specific question or sub question with relative high coverage of a certain PI mapping to CO, ABET SO (for EAMU calculation).

2. EvalTools® 6 removes students who received DN, F, W or I in a course from EAMU vector calculations, and enters student scores on the selected assignments, questions for remaining students.

3. EvalTools® 6 calculates for each student the weighted average percentage on the assessments, set of questions selected by faculty. Weights are set according to the product of their percentage in the course grading scale and multiplication factor based on the course format (refer Figure 6) and entered in the weighting factor section of the Assignment Setup Module.

4. EvalTools® 6 uses the average percentage to determine how many students fall into the EAMU categories using the pre-selected assessment criteria (Figure 1).

5. EvalTools® 6 calculates the EAMU average rating by rescaling to 5 for a weighted average based on a 3 point scale (refer to Figure 9 for EAMU average for scale of 3).

Example of PIs EAMU vector calculation employing weighting factors□□In the example shown in Table 1 for PI EAMU vector and its average computation employing weighting factors for various types of assessments, assessments Hw3 and Hw8 are selected for measuring a specific PI ABET_PI_5_3. These assessments are weighted (application of weighting factor according to course grading policy and multiplication factor depending upon the course format; let us say arbitrarily those are 5% for Hw3 and 7% for Hw8), added together and then normalized to 100 for each student. The PI EAMU classification for each student in the class (indicated by data in the second column from the left labeled PI_5_3) is obtained from this weighted and normalized to 100 score (right most column labeled percent-weighted). The PI EAMU vector (3,1,1,2) for the class is obtained from the counts of various individual student PI EAMU classifications which are 3 Excellent: scores >= 90%, 1 Adequate: scores >= 75% and < 90%, 1 Minimal: scores >= 60% and < 75% and 2 Unsatisfactory: scores < 60%. Finally, the average of the EAMU vector for this specific PI_5_3 is 2.86 which is obtained after rescaling to 5 the 3-point scale PI EAMU average value computed as per the equation in Figure 9.

VI. Advanced Digital Continuous Improvement Management System

Various committees with their respective members are setup employing the EvalTools® 6 Continuous Improvement Management System (CIMS) module. Each committee maintains a schedule of action items with details on priority level, discussions, brainstorming, assigned to, creation/closure dates and status information. Any committee can add new action items or review existing ones for status update and closure. The advanced CIMS module provides each committee the functionality to categorize an action item as per the given selection range of priority levels low, normal, medium, high or urgent. The action items are sorted electronically as per their priority levels. Transfer or elevate features allow committees to move those action items which are outside their scope or responsibility to another appropriate department or committee within the Faculty of Engineering or University for fulfilment.

Results

I. Course Outcomes Data

Each course has specified COs which are designed to cover each major topic of the course syllabus sequentially. The FCAR module displays all measured CO information with related assessments sequentially with options for summative or formative analysis. The rationale for this design is to collect summative and formative learning outcomes information from each stage of the course delivery process. Figure 10 shows a list of COs sequentially covering all the course topics. The CO data once measured would help identify weakness in teaching or learning methodology corresponding to a certain area of the course content. This would help provide real time formative information to improve the course by appropriate on time modifications (formative option selected). Faculty of Engineering, IU has decided to use 8-14 COs to cover all the major course topics. Figure 11 shows a case where multiple assessments are used to measure a certain course outcome (labeled key assignments by EvalTools® 6). For this case, Homework 2, quiz 2 and mid-term part-V question-42 are used as key assignments for CO2. Figure 11 also shows the color-coded EAMU vector for each key assignment, green for E, white for A, yellow for M and red for U. The course outcome CO2 group EAMU is (8,12,4,0) (with students failing the course removed due to summative option selected) which gives us an average of 3.61.

Figure 11 is only a subset of the analytical charts of the analytical FCAR module under the heading Course Outcomes Assessment where a sequential list of all the COs with various related assessments and their histogram plots depicting performance of all those students who have not failed the course are shown (summative option selected). At the end of the Course Outcomes Assessment section a consolidated histogram plot displays all the COs data measured as shown in Figure 12. The color-coded visual results give faculty a snapshot summarized view facilitating identification of the COs which need attention (color-code details in Figure 1). Even though COs assessment is not required for ABET program accreditation, aligning COs with ABET SOs will channel teaching, learning process towards the skill sets needed for students.

The information displayed (Figure 10) in the syllabi for COs aligns with the principle of outcome based education quoted below:

Outcome based education emphasizes that course learning outcomes for every course in the program should be stated and made known to the student (quoted from abstract of Salim et al., 2013. An instrument for measuring the learning outcomes of laboratory work. Proceeding of the IETEC'13 Conference. Ho Chi Minh City, Vietnam.)

II. ABET Student Outcomes and Performance Indicators Data

The Faculty of Engineering, IU has adopted ABET SOs for all its programs. Using the PIs EAMU computations, for each SO the EAMU classification is obtained and plain average is calculated. Figure 13 lists all the PIs mapping to ABET SO 1(SO 1 corresponds to ABET student outcome 'a'). All the PIs values mapping to a specific ABET SO are averaged together to give the final average value of the ABET SO. Figure 14 shows the consolidated ABET SOs histogram plot for a specific course. We see that SO 1 has an average value of 2.89 which is computed by taking the average of the weighted average values obtained for abet_PI_1_27 (1.39), abet_PI_1_43 (3.54) and abet_PI_1_44 (3.75).

III. Program Term Review Committee Evaluations Data

A specific program term review committee reviews the measured ABET SOs, related PIs information while considering this as a good indicator scheme and concludes its report with significant analysis and discussions as to whether a certain ABET SO is below, meeting or above expectations for the program in a designated term. The term review process flow for a specific program involves completion of two phases a) PI evaluation and b) ABET SO evaluation.

PI evaluation Figure 15 shows that the PI evaluation phase begins with a snap shot consolidated view of all ABET SOs, measured in the specified term with scientific color coding scheme to indicate failures for investigation. The aggregate value for each measured ABET SO is calculated by averaging its corresponding aggregate PIs data. The aggregate value for each PI measured for this specific ABET SO is calculated by weighted averaging according to class size the PIs data measured by multiple raters across different courses. Performance indicator evaluation is focused on failing SOs and their contributing PIs for analysis and discussions relating to improvement. Courses contributing to failing PIs and SOs are examined by selection. The investigations involve study of the course reflections and generated action items in the respective FCARs and the reviewers enter their comments for the selected failing courses and PIs. Action items in respective FCARs are edited, updated or deleted as per the program chair decision in agreement with review members. Certain action items may be elevated to the program level from course level depending upon the scope of the problem or degree of importance. Figure 16 shows the PI review comments for a specific SO for CE program and term 351.

SO evaluation The ABET SO evaluation phase integrates review information from the PI evaluation module for each listed SO. Overall comments on a specific ABET SO are integrated with the comments of review and analysis of its failing PIs taken from the Performance Indicator Evaluation module of EvalTools® 6. Figure 17 shows detailed PI analysis for a selected ABET SO listing the contributing courses and their group EAMU calculations. The following term review reports are available in printable word or pdf format:

a) SO executive summary

b) Detailed SO/PI executive summary

c) SO/PI Performance Vector Table PVT summary and

d) Course reflections/action items

Figure 18 shows a snapshot of a detailed SO/PI executive summary of a sample program term review. The student outcomes information from multiple term reviews for a program can be consolidated and utilized for review of the Program Educational Objectives. Certain action items in the FCARs which were elevated to the program level during the term review process are appropriately escalated to the responsible departments/committees for closure. The remaining action items in the FCARs are followed up by the concerned faculty for implementation.

Discussion

I. Comprehensive Program, Student Evaluations and Advanced Diagnostics for Realistic Improvement

Very few programs have collected comprehensive learning outcomes information at the student level (as indicated by McGourty et al., 1997, 1998) and also a direct quote:

> Few education systems have a comprehensive system for measuring program results in terms of student learning outcomes. There are some exceptions for example, Alverno College, located in Milwaukee, Wisconsin, has created a system that assesses the degree to which all students can demonstrate specific abilities throughout their education experience (McGourty et al., 1998; Developing a comprehensive assessment program for engineering education. *Journal of Engineering Education*. Volume 87, issue 4, pp 355. October 1998. 1998 American Society of Engineering Education. doi: 10.1002/j.2168-9830.1998.tb00365.x)

In comparison with other similar web-based software applications or digital automation tools (as mentioned by Mak et al., 2010; Kumaran et al., 2007; Estell et al., 2012; Eltayeb, Mak & Soysal, 2013) the Faculty of Engineering, IU make a noteworthy observation that EvalTools® 6 is one of the most advanced toolsets available which integrates learning management, outcomes assessment and continuous improvement management systems together (refer Figure 28 for EvalTools® 6 system architecture) thereby facilitating collection, monitoring, reporting of learning outcomes information and thereby greatly simplifying otherwise complex diagnostic analytics of outcomes assessment information for improvement of students learning. It is also important to note that EvalTools® 6 offers many features but the Faculty of Engineering, IU determine how the features are to be used and which processes are to be followed for continuous improvement in student learning. A quote about Evaltools® as a recommended tool for comprehensively evaluating outcomes information is mentioned below:

> To involve more faculty and in an effort to prepare for the most recent ABET visit, we decided to adopt EvalTools® in fall of 2010. EvalTools® is designed and developed according to ABET standards to provide a mechanism for collecting and analyzing data about the program, students' performance and their learning achievements. In addition, EvalTools® is instrumental in providing a mechanism to simplify the process of inspecting the assessment results as well as identifies strengths and shortcomings of the program before ABET review. More importantly getting faculty members excited about results and involved in the process of program improvement is a major accomplishment. Our experience via first-time implementation of EvalTools® shows very useful results for this model that can be easily disseminated for various programs in various disciplines. In this paper we will show: process of best use of relevant features in aid of streamlining faculty's time in data collection as well as evaluation was achieved; our results and how we succeeded in improving our program quality in an effective, efficient and systematic way; that simple curriculum revisions for multiple programs as a result of using EvalTools® for programs under going ABET is possible (Eltayeb et al., 2013; Work in progress: Engaging faculty for program improvement via EvalTools®: A new software model. *2013 Frontiers in Education conference FIE*, 2012 pp.1-6. doi: 10.1109/FIE.2012.6462443)

At Faculty of Engineering, IU both program and students' performance evaluations are based on considering their respective measured ABET SOs and associated PIs as a relevant indicator scheme. Figure 19, Figure 20 and Figure 21 show results of EE Program ABET SOs collected for terms 351 and 352. The performance indicator related to ABET_SO_1: An ability to apply the knowledge of mathematics, science and engineering; is PI_1_27: Apply basic laws and formulas of circuit theory, such as Ohm's and Kirchoff's laws as well as circuit theorems to analyze/simplify circuits (Thevenin and Norton, superposition principle, max power transfer theorem, transformation etc.). PI_1_27 shows a pattern of underperformance for the two terms 351, 352 in courses such as Circuit Theory-I, Circuit Theory-II and Fundamentals of Electrical Engineering. This is also observed in Figure 23 where individual student evaluations confirm the failing pattern for PI_1_27. Study of student failing patterns in these individual student evaluations will confirm any major weakness observed through the collectively averaged outcome data in program evaluations and further investigations of the respective course FCARs will help determine specific areas such as course content (breadth and/or depth), teaching materials, and/or pedagogical/ assessment methodology for realistic program and student improvement. As a sample case if we investigate PI_1_27 failures from the FCAR for Circuit Theory-I we find as shown in Figure 24 a pattern of failures indicated by multiple unique assessments utilized for measuring the skill relating to the application of basic electrical engineering laws to circuits. This is further substantiated by examining the objective evidence Final Exam Part-III Q45 as illustrated in Figure 25 (All documentation whether faculty submittals to students Figure 29 or graded student work Figure 30 are scanned and available in a digital database for instant access). In Figure 26 the course reflections and action items suggest weakness in fundamental math skills as an underlying cause of underperformance.

By examination of academically weak or strong students' evaluations it is also possible to identify areas of strength in learning which are based on the students' natural affinity to and interest in certain topics. Figure 22 illustrates a list of ABET SOs calculated from PIs measurements for a typical student evaluation. In Figure 23 are highlighted certain areas of comparatively better patterns of learning in a typical underperforming EE student. We observe that PI_1_12: Employ basic electrical power formulations and quantities, such as complex vectors, delta star transformation, network flow matrices (network topology and incidence matrices) and symmetrical components; PI_1_41: Convert a given number from one system to an equivalent number in another system; and PI_1_45: Explain basic semiconductors theory concepts such as applied electrical field, junction capacitance, drift/diffusion currents, semiconductor conductivity, doping, electron, hole concentrations, N-type, P-type semiconductors; show better performance and are at a stark contrast versus majority of the other PIs measured for these two terms. One significant observation is that these three PIs measure elementary math skills and concepts and also cover relatively easier topics such as Boolean algebra. The other PIs dealing with topics such as operating principles of various kinds of electronic devices and components, Application of Gauss's Law, Maxwell's equations etc. require slightly advanced learning of several engineering concepts and understanding of differential, integral calculus.

This information strongly suggests that students have initiated learning with the required level of interest but at later stages of the course they may need other mechanisms of course delivery such as active learning for retention of focus and enhanced learning. Student advising based on this information helps faculty to identify potential areas of strength or weakness in student performance through the observation of patterns of relatively high or low scores for certain ABET SO, CO related PIs.

Most academic or career related failures result from an improper selection of the field of study or industrial career due to delay or lack of availability of the necessary decision making student learning outcome information in a deficient education system. With the availability of such analytical tools and comprehensive diagnostics early identification of weakness and prompt remediation efforts are quite possible. On the other hand, early recognition of strong skills in specific subjects based on well observed patterns followed by professional academic guidance leading to proper selection of an area of specialization in education, research for enhanced learning or in future industry related prospects will produce outstanding performers in their respective fields who will shape the future of the world.

Program, student evaluations, assessments and advising based on measurable ABET SOs, COs and PIs facilitate an outcome based education system and help the students to focus not just on improvement of academic scores but learning outcomes since the academic scores to a good extent reflect performance relative to learning outcomes. A direct quote shown below concurs the same observation:

> But students' and graduates' assessment about what competencies they have gained may be one option in constructing new criteria for quality. We see two possible ways of including such output oriented measurements. The best alternative is to develop tests in line with PISA and similar surveys, an initiative now taken by OECD. This is, however, a very time and resource consuming activity. (Aamodt & Hovdhaugen, 2008; Assessing higher education learning outcomes as a result of institutional and individual

characteristics. *Outcomes of Higher Education: Quality relevance and impact*, September 8-10, Paris, France. pp. 13, http://www.oecd.org/site/eduimhe08/41217853.pdf)

II. Future Work

Program, student evaluations were based upon considering the measured PIs data related to ABET SOs and COs as a relevant indicator scheme. EAMU calculations for PIs data obtained from assessments in a specific course were made by applying weighted averages where weights were assigned to various assessments based upon course grading policy and type of assessment (depending upon multiplication factors as indicated in the Figure 6 depicting the various course formats adopted by Faculty of Engineering at IU). The aggregate PI value for a specific PI's data obtained from various courses and its sections is a weighted average of the PIs data with class size selected as the weight. However, for program and student evaluations the ABET SOs values were calculated by pure average of the aggregate PIs data corresponding to various PIs obtained from single or multiple courses. Future work entails classification of specific PIs into cognitive, affective and psychomotor domains according to Bloom's revised taxonomy. Each domain will be further classified into three levels based on the degree of skill proficiency measured namely the elementary, intermediate and advanced levels. Each level will be assigned a weight with the advanced level allocated the highest weighting. Specific performance indicators corresponding to the three domains for courses at higher level of seniority in the curriculum will utilize verb content relating to advanced levels of proficiency in skills as per the definitions of verb content in the revised Bloom's taxonomy and therefore be allocated higher weights. Courses will also be categorized based on introductory, reinforced and mastery levels with appropriate weights assigned to them. Thus the program, student ABET SOs values will then be calculated by weighted averaging of aggregate PIs data corresponding to various PIs obtained from single or multiple courses with the weights reflecting a combination of the level of proficiency of the skill measured and seniority of the related courses. Figure 27 indicates the areas where pure averaging shall be substituted by the application of weighted averages based on the classification of specific PIs into three domains with corresponding levels and related courses into their respective categories resulting in a comprehensive ABET SOs computation reflecting the level of proficiency of skills measured while taking into account course seniority.

The Faculty of Engineering, IU is also interested in pioneering the implementation of an automated electronic examinations module with built-in constructive alignment to reach an almost 100% automated learning outcomes based digital continuous improvement system.

Conclusion

The tasks completed for regional or international accreditation are typically enormous and costly affair for any academic program. Despite such significant efforts on the part of academic programs, research has shown that the learning outcomes information is minimally integrated into academic CQI processes. One of the primary reasons outcomes information is not utilized for CQI is that the information collected is insufficient to make improvement decisions due to impractical manual processes that are either too exhaustive to complete for timely measurement and reporting, or too minimal for basic fulfillment of accreditation requirements. Massive amounts of outcomes data collected from various stages of curriculum delivery is a critical requirement for informing improvement decisions. Therefore, manual assessment, documentation and reporting systems are major factors that exacerbate the implementation of streamlining activities which are necessary to integrate improvement efforts of several stakeholders in an academic CQI process. In an age of technological advancement, use of digital technology allows for the collection of various evidence sources. The Faculty of Engineering at the Islamic University outlined in this paper crucial elements of their outcomes assessment methodology which fully supports automation and digital technology based assessment/documentation/reporting systems to collect, analyze and utilize realistic outcomes data to establish meaningful CQI and not just fulfill accreditation requirements.

With a majority of positive aspects, one limitation of our system, the allocation of resources to scan paper documents, is currently performed by either the lecturers or teaching assistants. Work is currently in progress to develop state-of-the-art digital systems that automate outcomes assessment development and scoring processes. This technology would integrate with existing digital systems to significantly reduce the overhead related to overall time spent by faculty in the outcomes assessment process and scanning work done by lecturers. Future research work will present details of this ground-breaking technology, which has the potential to dramatically revolutionize OBE implementation philosophy in higher education.

Qiyas has developed an extensive list of standardized learning outcomes for seven engineering specializations or PIs for Qiyas/FE exams with assessments planned for implementation upon student graduation and their results provided to the concerned programs for appropriate corrective action and subsequent improvement. Additionally, students are reluctant to participate in such learning outcomes assessments external to their program curriculum. The Faculty of Engineering, IU can offer a unique academic platform for Qiyas to comfortably enhance research, development and testing of its standardized nationwide learning outcomes with implementation in a live scenario of teaching, learning and willing participation of a maximum pool of students who shall receive grades from an in house, integral part of the curriculum, educational process at the Faculty of Engineering.

A combination of world class best practices for learning outcomes assessment methodology, continually improving digital database of learning outcomes, state of the art web-based digital technology utilizing EvalTools® 6 will provide Qiyas the capability to embed its examinations electronically into various phases of the curriculum at the Faulty of Engineering, IU (refer Figure 3), with the option of grading internally within Qiyas centers or at the Faculty of Engineering thus embarking on a new frontier in outcome based assessments technology. This approach presents a formative mechanism that will benefit programs and students with real-time improvement and feedback received directly from Qiyas targeting deficiencies in specific phases of curriculum delivery versus the other contemporary testing models which provide a summative result lacking information on deficiencies relating to the various phases of any program's educational curriculum.

A standardized nationwide digital outcomes assessment, Continuous Improvement Management System (CIMS) using web-based software and features such as those in EvalTools ® 6 would offer Qiyas several advantages as listed below:

1. An almost 15 years successfully implemented, excellent track record for accreditation and CQI processes with ABET and US regional accreditation agencies
2. Transparent, paperless accreditation processes with total costs including a minimal licensing fee and almost 70% less than the average cost of half a million Saudi Riyals otherwise spent by Saudi Arabian educational institutions per program for manual processes related to accreditation
3. Options to visualize every single process supporting an entire program's curriculum delivery including administrative operations with mechanisms to electronically communicate feedback for improvement to the concerned stakeholders

4. Remote, paper-free, cost effective auditing and reporting mechanisms
5. Relatively easy maintenance of nationwide teaching/learning quality standards based upon real-time alignment of learning outcomes based on 3 learning domains of Bloom’s taxonomy or any other learning domains such as those proposed by the National Qualifications Framework (NQF)
6. Nationwide benchmarking of outcomes assessment results according to specialization, demographics and region with periodic revision of set target goals for monitoring academic improvement in specified time frames
7. Demographics or region-wise comparison of student performance for specific specializations and allocation of budget or other forms of governmental educational assistance to uplift regional illiteracy or poor academic performance
8. Access to course work, learning outcomes, PIs, rubrics and assessment information from programs throughout the nation with vast opportunities for subsequent selection, development of a database of test banks, best outcomes, PIs and assessment information collected from expert contributions of a diverse set of top class faculty
9. Fundamental processes for identification of deficiencies in faculty teaching methods with remediation efforts like specialized feedback/training for improvement or recognition of top class faculty that employ excellent teaching strategies by offering awards, incentives or enlistment in employment retention schemes
10. Relatively easy regulation of examinations standards based upon benchmarked demographic or region-wise performance information by implementation of electronic exams and online scoring systems

11. Relatively easy nationwide implementation of an otherwise difficult process of scientific constructive alignment through well designed assessments mapped to specific learning outcomes with electronic exams and online scoring systems
12. Relatively quick release of student grades following curricular exams
13. Options to provide students with complete electronic access to details of scoring, reasons of failure and feedback for improvement of their performance
14. Access to nationwide student academic records and electronic student academic advising based upon individual student learning outcomes information and
15. Access to nationwide industry and alumni surveys feedback information and consideration of region-wise industry/stakeholders requirements for proper selection and design of student learning outcomes

In summary, sponsorship of Qiyas for a joint venture with Faculty of Engineering, IU for implementation of state of the art digital technology, best practices for outcomes assessment, real time and realistic student learning outcomes data and electronic exams plus online scoring can make a dramatic impact on the improvement of the current state of education systems in the Kingdom of Saudi Arabia and steer towards the vision of migrating from a resource based to an education based economy.

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Tables

Student	abet_PI_5_3	Hw3 (30)	% weighted (wf=5%)	Hw8 (60)	% weighted (wf=7%)	Percent-weighted
student 1	M	20	3.33	40	4.67	66.67
student 2	U	10	1.67	8	0.93	21.67
student 3	E	30	5.00	57	6.65	97.08
student 4	U	26	4.33	10	1.17	45.83
student 5	E	28	4.67	60	7.00	97.22
student 6	E	29	4.83	53	6.18	91.81
student 7	A	29	4.83	40	4.67	79.17
	EAMU	(4,1,1,1)		(2,1,2,2)		(3,1,1,2)
	Average	3.81		2.38		2.86

Table 1: Calculation of aggregated EAMU for a PI

Figures

1. Specification of EAMU performance indicator levels:

This set of EAMU performance criteria apply to key assignments that were selected as objective evidences for meeting course outcomes. The setting here applies to all courses as a basic point of reference. However, individual instructors can alter the indicator levels appropriately applied to their own courses as desired.

Category	General Description	Letter Grade	Nominal Indicator Level
Excellent	Student applies knowledge with virtually no conceptual or procedural errors	E	90.0% - 100%
Adequate	Student applies knowledge with no significant conceptual errors and only minor procedural errors	A	75.0% - 90.0%
Minimal	Student applies knowledge with occasional conceptual errors and only minor procedural errors	M	60.0% - 75.0%
Unsatisfactory	Student makes significant conceptual and/or procedural errors when applying knowledge	U	0.0% - 60.0%

2. Heuristic rules for performance vector tables (PVT):

This set of rules applies to the performance vector tables that are formed by compiling all the key assignments' EAMU results together. The rationalization behind this classification is to streamline the assessment and evaluation processes by focusing on those areas that are out of the ordinary. Based on the color coded flags, the potentail problem areas will be flagged. This set of settign applies to all courses in the program.

Category	General Description	Scale (out of 5)	Maximum Percentage
Red Flag	Any performance vector with an average below the defined scale and a level of unsatisfactory performance that exceeds defined percentage in the U column	below 3.3	and >10%
Yellow Flag	Any performance vector with an average below the defined scale or a level of unsatisfactory performance (U) that exceeds the defined percentage, but not both	below 3.3	or >10%
Green Flag	Any performance vector with an average that is at least greater than the defined scale and no indication of unsatisfactory performance (U)	>= 4.6	
No Flag	Any performance vector that does not fall into one of the above categories		

Figure 1. Performance criteria adopted by the Faculty of Engineering at the Islamic University.

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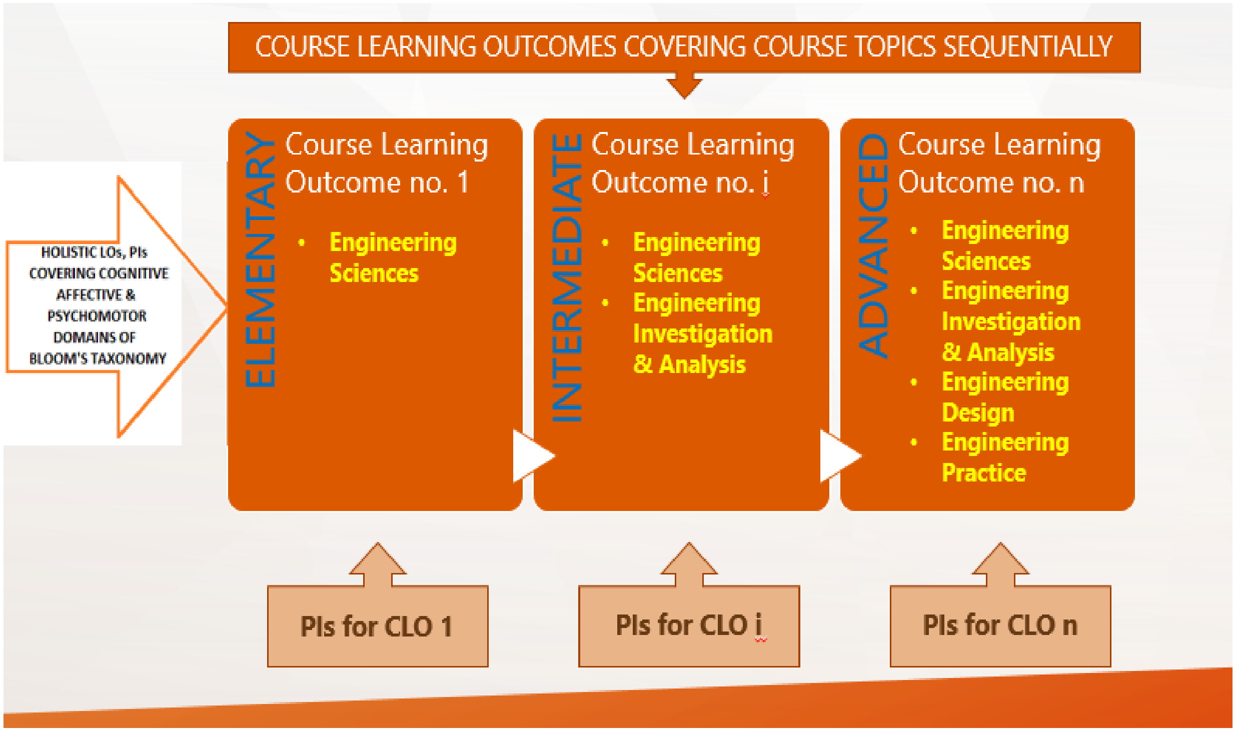


Figure 2. Design flow for creation of comprehensive elementary, intermediate and advanced learning outcomes and their performance indicators sequentially covering all course topics and three domains of Bloom's taxonomy at the course level. Reprinted by permission from the Faculty of Engineering, IU.

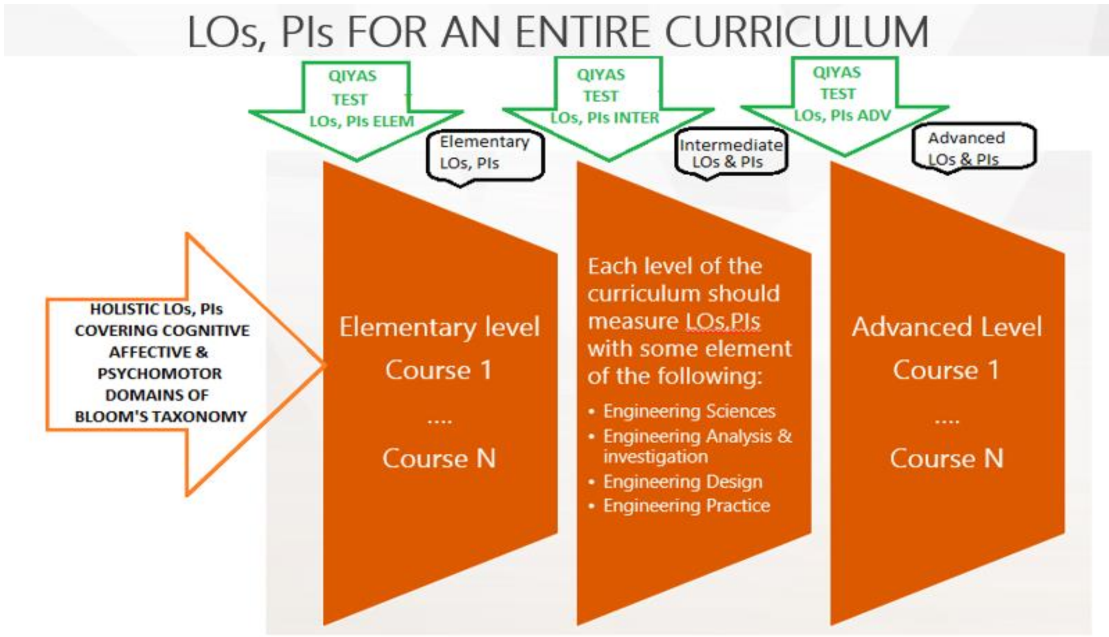


Figure 3. Design flow for creation of advanced, intermediate and elementary learning outcomes and their performance indicators covering three domains of Bloom's taxonomy and spanning courses from different phases of the entire curriculum. Qiyas tests whether online or essay type for measuring these learning outcomes can be embeded into any phase of the curriculum using EvalTools® 6. Reprinted by permission from the Faculty of Engineering, IU.

ME 262–Thermodynamics I

Spring Semester 2014-15 (Term 352)

Quiz 2

Grade

Name, Family Name :________________________________

ID #:__________________ **Signature :** ____________ **Date: 05/03/2015**

1. What is the physical significance of h_{fg}? Can it be obtained from knowledge of h_f and h_g? How? **[3 Marks]**

2. A 1.8-m^3 rigid tank contains steam at 220°C. One third of the volume is in the liquid phase and the rest is in the vapor form. Determine (*a*) the pressure of the steam, (*b*) the quality of the saturated mixture, and (*c*) the density of the mixture. **[7 Marks]**

For instructor use only (Q 2):

SO 5	an ability to identify, formulate, and solve engineering problems
CO 3	**Explain** phase change processes of pure substances and energy interactions. (Ch 3)
PI_5_12	Apply basic concepts of thermodynamics to solve thermodynamic systems, processes and cycles.

Figure 4. Example of design of a unique assessment with high relative coverage for specific performance indicator, course outcomes, ABET student outcomes. Reprinted by permission from the Faculty of Engineering, IU.

Class: ME_200_1585 ENGINEERING MECHANICS
Size: 20

Course Outcomes:

Select	Assignment/ Activities/Events	Standards		
		CO	PI	SO
	QZ-4_Q3	CO 7	abet_PI_5_2	abet_SO_5
	MID-TERM-2_Q4	CO 7	abet_PI_5_2	abet_SO_5
	Final Exam_Q5	CO 5	abet_PI_1_20	abet_SO_1
	Final Exam_Q6	CO 9	abet_PI_5_6	abet_SO_5
	Final Exam_Q7	CO 8	abet_PI_5_10	abet_SO_5
	Final Exam_Q1	CO 3	abet_PI_1_20	abet_SO_1
	Final Exam_Q2	CO 4	abet_PI_5_11	abet_SO_5

Figure 5. Example of splitting existing curricular grade giving assessments to questions, sub questions for high relative coverage of a specific performance indicator, course, ABET student outcomes. Reprinted by permission from the Faculty of Engineering, IU.

DIFFERENT COURSE ASSESSMENTS FORMATS:

1. COURSES WITH NO LABS + NO PROJECT/TERM PAPER

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	40%	8
MID TERM EXAM - 1	25%	5
MID TERM EXAM - 2	25%	5
QUIZ	5%	1
HW	5%	1
TOTAL	100%	-

2. COURSES WITH NO LABS + PROJECT/TERM PAPER

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	30%	6
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
PROJECT/TERM PAPER	30%	6
TOTAL	100%	-

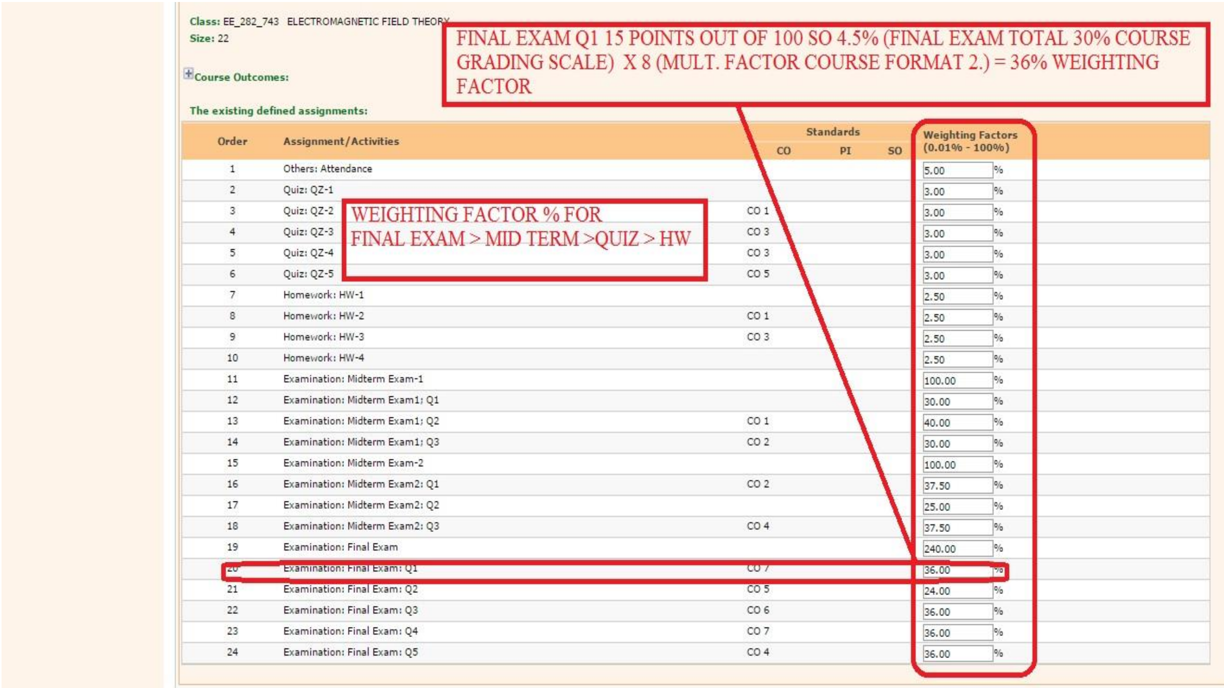
3. COURSES WITH LABS + NO PROJECT/TERM PAPER

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	25%	5
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
LAB EXAMS	30%	6
LAB REPORTS	5%	1
TOTAL	100%	-

4. COURSES WITH LABS + PROJECT/TERM PAPER

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	25%	5
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
LAB EXAMS	15%	3
LAB REPORTS	5%	1
PROJECT/TERM PAPER	15%	3
TOTAL	100%	-

Figure 6. Four course formats developed by the Faculty of Engineering, IU to calculate the multiplication factor for estimating the weights for different assessments. Reprinted by permission from the Faculty of Engineering, IU.



Class: EE_282_743 ELECTROMAGNETIC FIELD THEORY
Size: 22

Course Outcomes:

FINAL EXAM Q1 15 POINTS OUT OF 100 SO 4.5% (FINAL EXAM TOTAL 30% COURSE GRADING SCALE) X 8 (MULT. FACTOR COURSE FORMAT 2.) = 36% WEIGHTING FACTOR

The existing defined assignments:

WEIGHTING FACTOR % FOR FINAL EXAM > MID TERM >QUIZ > HW

Order	Assignment/Activities	Standards CO	PI	SO	Weighting Factors (0.01% - 100%)
1	Others: Attendance				5.00 %
2	Quiz: QZ-1				3.00 %
3	Quiz: QZ-2	CO 1			3.00 %
4	Quiz: QZ-3	CO 3			3.00 %
5	Quiz: QZ-4	CO 3			3.00 %
6	Quiz: QZ-5	CO 5			3.00 %
7	Homework: HW-1				2.50 %
8	Homework: HW-2	CO 1			2.50 %
9	Homework: HW-3	CO 3			2.50 %
10	Homework: HW-4				2.50 %
11	Examination: Midterm Exam-1				100.00 %
12	Examination: Midterm Exam1: Q1				30.00 %
13	Examination: Midterm Exam1: Q2	CO 1			40.00 %
14	Examination: Midterm Exam1: Q3	CO 2			30.00 %
15	Examination: Midterm Exam-2				100.00 %
16	Examination: Midterm Exam2: Q1	CO 2			37.50 %
17	Examination: Midterm Exam2: Q2				25.00 %
18	Examination: Midterm Exam2: Q3	CO 4			37.50 %
19	Examination: Final Exam				240.00 %
20	Examination: Final Exam: Q1	CO 7			36.00 %
21	Examination: Final Exam: Q2	CO 5			24.00 %
22	Examination: Final Exam: Q3	CO 6			36.00 %
23	Examination: Final Exam: Q4	CO 7			36.00 %
24	Examination: Final Exam: Q5	CO 4			36.00 %

Figure 7. Weighting factor calculation example for Final Exam:Q1 by product of course grading scale and multiplication factor applied from course format no.2. Reprinted by permission from the Faculty of Engineering, IU.

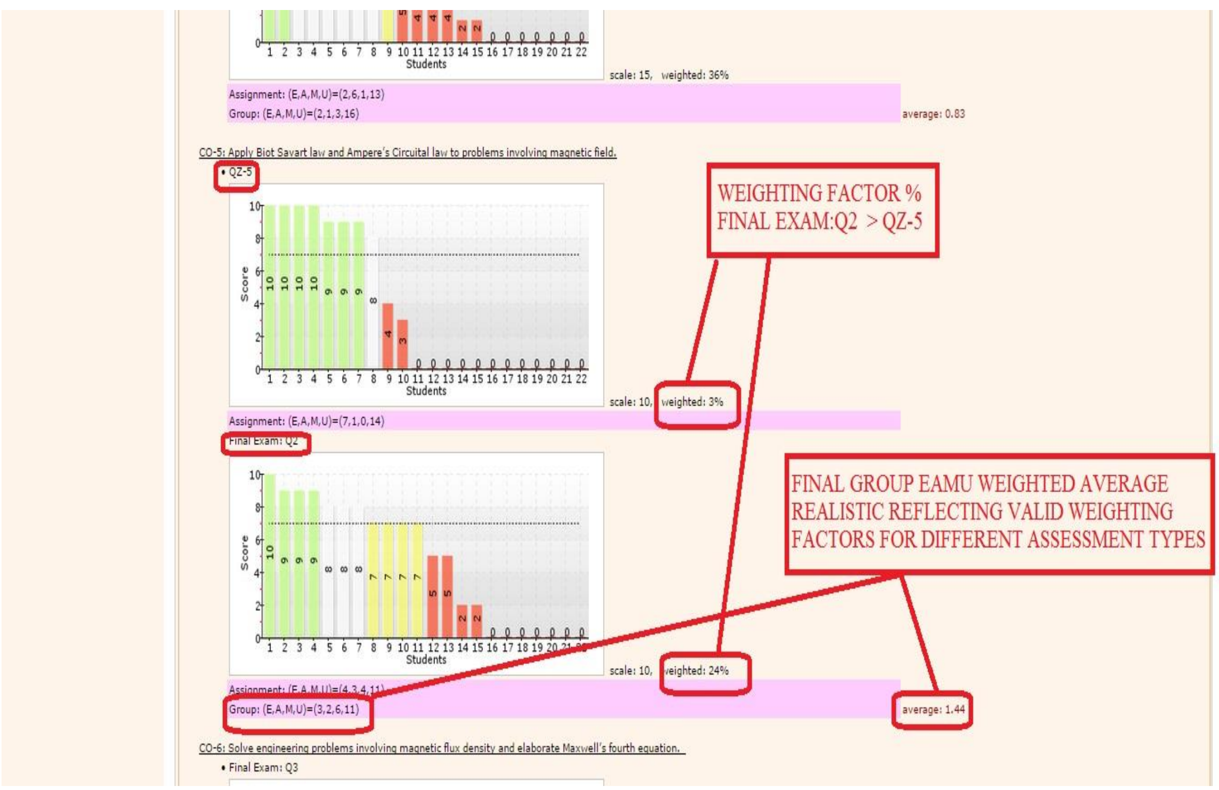


Figure 8. Final group EAMU weighted average is realistic since it is implementing accurate weighting factors % for different assessments. Reprinted by permission from the Faculty of Engineering, IU.

$$EAMU\ average = \frac{3 * E + 2 * A + 1 * M + 0 * U}{E + A + M + U}$$

Figure 9. Equation for EAMU average rating for a 3 point scale. Reprinted by permission from the Faculty of Engineering, IU.

EE_201_1581 CIRCUIT THEORY I

Faculty Name : [redacted]

Department : **EE** Term : **351 2014**

Course Description:

This course introduces the students to the basic circuit theory laws, theorems and methods of AC/DC circuit analysis such as: Circuit elements, Basic laws of electrical circuits: Ohm's law, KVL, KCL, power and energy. Resistive circuits: Resistors in Series & parallel, Voltage and current divider circuits, dependent sources, Delta-to-Wye equivalent circuits. Techniques of circuit analysis: Nodal and Mesh analysis. Network theorems: Thevenin's & Norton's theorems, Source transformation, Superposition and Maximum power transfer theorems. Energy storage elements (L,C,M): definitions and voltage-current relationships, impedance & admittance. Responses of first order RL and RC circuits. Response of second order circuits (Natural and step response of RLC circuits). Sinusoidal steady-state circuit analysis.

Pre-requisites: MATH 241, PHYS 202

Course Outcomes:

CO 1	State the definition of charge, current, voltage, power, energy and circuit elements.
CO 2	State and use Ohm's law, Kirchhoff's current and voltage laws in circuit analysis.
CO 3	Calculate the total resistance connected in series, parallel & combination of series and parallel.
CO 4	Apply voltage and current division rules appropriately to solve simple circuits.
CO 5	Apply the nodal and mesh analysis to solve an electrical circuit.
CO 6	Apply source transformation theorem to solve an electrical circuit.
CO 7	Apply in an electric circuit the Thevenin's and Norton's theorems.
CO 8	Analyze a circuit with superposition and maximum power transfer theorems.
CO 9	Apply first and second order systems with unit step & natural response.
CO 10	Analyze a circuit in the frequency domain by sinusoidal steady state analysis, Kirchhoff's laws, series and parallel transformations, source transformation, Thevenin's and Norton's theorems, nodal and mesh analysis.
CO 11	Apply concept of inductance & mutual inductance in Transformer and an ideal transformer and draw phasor diagrams.
CO 12	Apply knowledge of electrical circuits & systems to verify, identify, formulate, and solve electrical engineering problems by experimentation, simulation and observation.

Figure 10. COs designed to sequentially cover major topics of a course. Reprinted by permission from the Faculty of Engineering, IU.

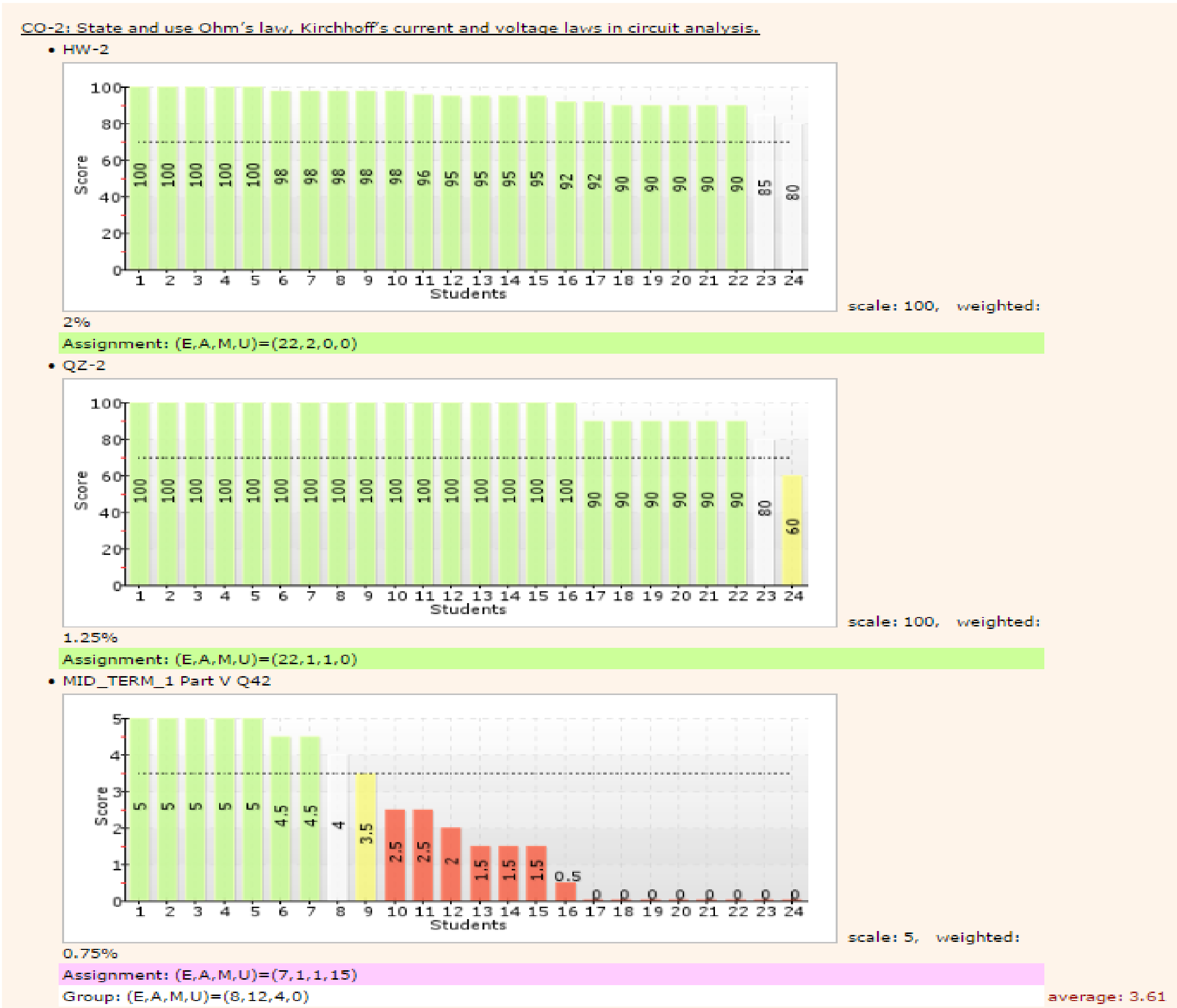


Figure 11. Data for a single course outcome with its multiple assessments. Reprinted by permission from the Faculty of Engineering, IU.

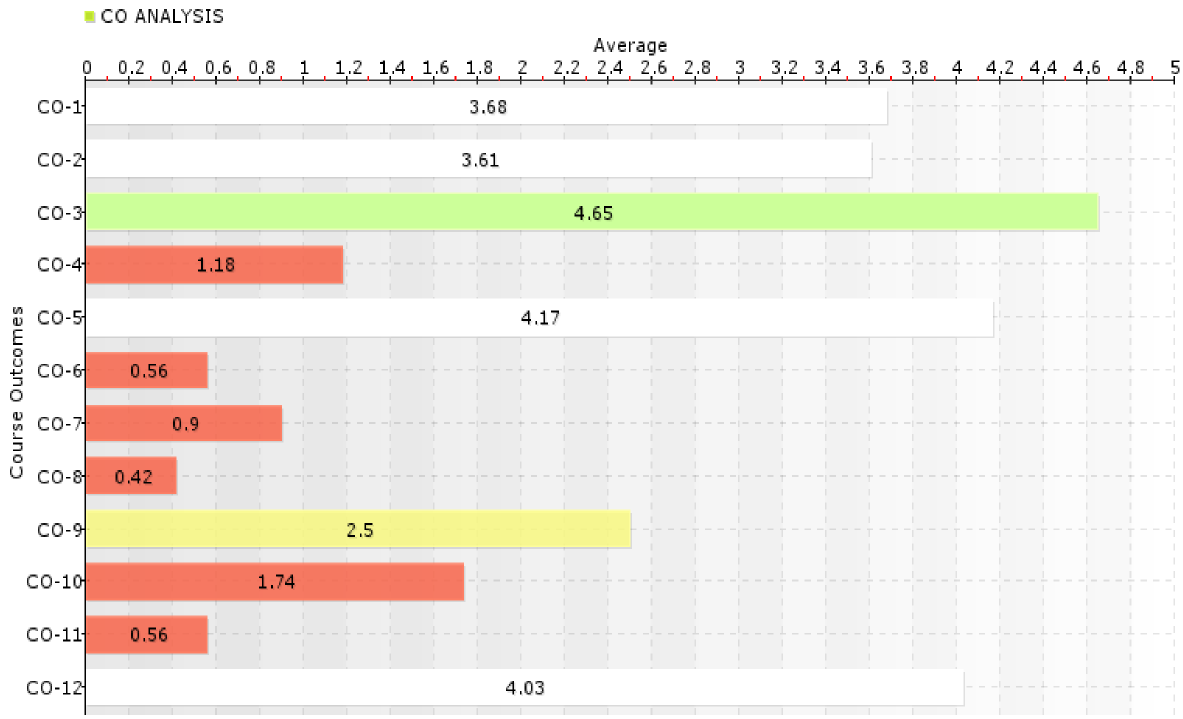


Figure 12. Shows a consolidated histogram plot of all course outcome data. Reprinted by permission from the Faculty of Engineering, IU.

Performance Indicators Assessment:

Item	Performance Indicators	Correlated Student Outcomes	Key Assignments	E	A	M	U	Average
abet_PI_1_27	Apply basic laws and formulas of circuit theory, such as Ohm's and Kirchoff's laws as well as circuit theorems to simplify/analyze circuits (Thevenin and Norton theorems, superposition principle, max power transfer theorem, transformation etc.)	SO_1	MID_TERM_1 Part V Q42	7	1	1	15	1.67
			Final Exam Part IV Q45	2	2	3	17	0.9
			Mid Term-II PART III Q40	1	1	1	21	0.42
			QZ-2	22	1	1	0	4.79
			HW-2	22	2	0	0	4.86
			MID_TERM_1 Part V Q42,Final Exam Part IV Q45,Mid Term-II PART III Q40,QZ-2,HW-2,	1	6	5	12	1.39
abet_PI_1_43	Describe the concept of capacitor and its relationship to electric fields/parallel; the concept of the inductor and its relationship to magnetic fields due to currents in wires and the concept of resistance and its relationship to charge flow under the presence of an electric field.	SO_1	QZ-5	1	14	8	1	2.71
			HW-5	20	2	1	1	4.51
			QZ-5,HW-5,	6	16	1	1	3.54
abet_PI_1_44	Explain basics of electrical engineering parameters such as charge, voltage, current, energy, power, work done, resistance, capacitance, inductance etc.	SO_1	QZ-1	22	1	0	1	4.72
			HW-1	21	3	0	0	4.79
			Lab Exp-1	16	2	3	3	3.82
			Lab HW-2	11	7	2	4	3.4
			Lab QZ-2	6	2	4	12	1.81
			Lab HW-1	12	9	2	1	3.89
			Lab QZ-1	23	0	0	1	4.79
			QZ-1,HW-1,Lab Exp-1,Lab HW-2,Lab QZ-2,Lab HW-1,Lab QZ-1,	9	12	3	0	3.75
abet_PI_2_16	Use basic electrical measurement and experimental tools, such as ammeters, oscilloscopes, power supplies and electrical connections	SO_2	Lab Exp-8	19	4	1	0	4.58
			Lab Exp-9	21	1	2	0	4.65
			Lab Exp-3	18	4	1	1	4.38

Figure 13. List of performance indicators with corresponding assignments mapping to a specific ABET student outcome (PIs listed for ABET SO_1). Reprinted by permission from the Faculty of Engineering, IU.

Student Outcomes Assessment:

Item	Student Outcomes	Correlated Course Outcomes	Key Assignments	E	A	M	U	Average
SO_1	an ability to apply knowledge of mathematics, science, and engineering	CO 1, CO 2, CO 8, CO 7,	HW-1, HW-2, HW-5, QZ-1, QZ-2, QZ-5, Lab HW-1, Lab HW-2, Lab QZ-1, Lab QZ-2, Lab Exp-1, Mid Term-II PART III Q40, MID_TERM_1 Part V Q42, Final Exam Part IV Q45,	0	2	0	1	2.89
SO_2	an ability to design and conduct experiments, as well as to analyze and interpret data	CO 12, CO 12, CO 12,	Lab Exp-2, Lab Exp-3, Lab Exp-4, Lab Exp-5, Lab Exp-7, Lab Exp-8, Lab Exp-9, Midterm Lab Exam, Final Lab Exam, Final Lab Exam - Connections,	1	3	0	0	4.36
SO_5	an ability to identify, formulate, and solve engineering problems	CO 3, CO 5, CO 9, CO 4, CO 6, CO 11,	HW-3, HW-4, HW-6, HW-7, QZ-3, QZ-4, QZ-6, QZ-7, QZ-8,	0	2	2	0	3.14
SO_7	an ability to communicate effectively	CO 11, CO 12,	Lab Exp-6, Final Exam Part IV Q46,	0	0	0	1	0.49
SO_11	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	CO 12, CO 10,	HW-8, Lab Project,	0	0	1	1	2.89

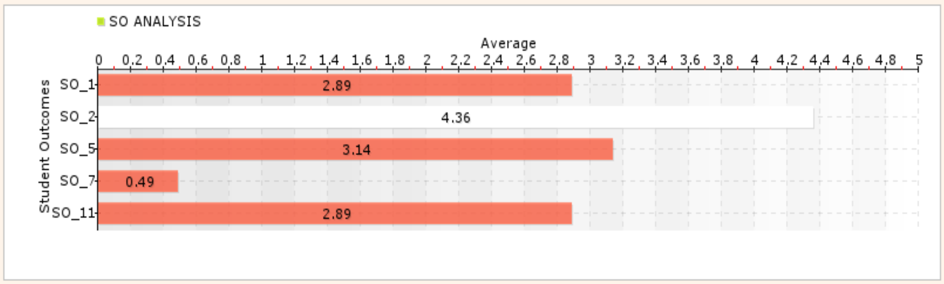


Figure 14. Consolidated list of ABET student outcomes SOs covered by a particular course in a given term. Reprinted by permission from the Faculty of Engineering, IU.

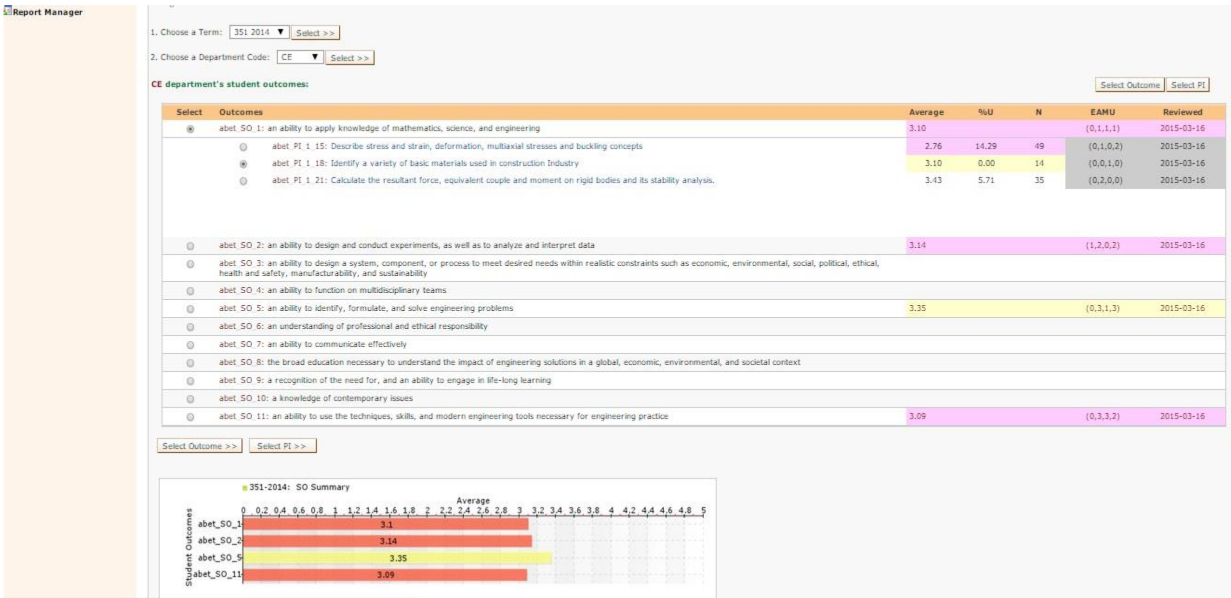


Figure 15. *Performance Indicator Evaluation Module* EvalTools® 6 beginning page showing student outcomes covered by a program in a given term. Reprinted by permission from the Faculty of Engineering, IU.

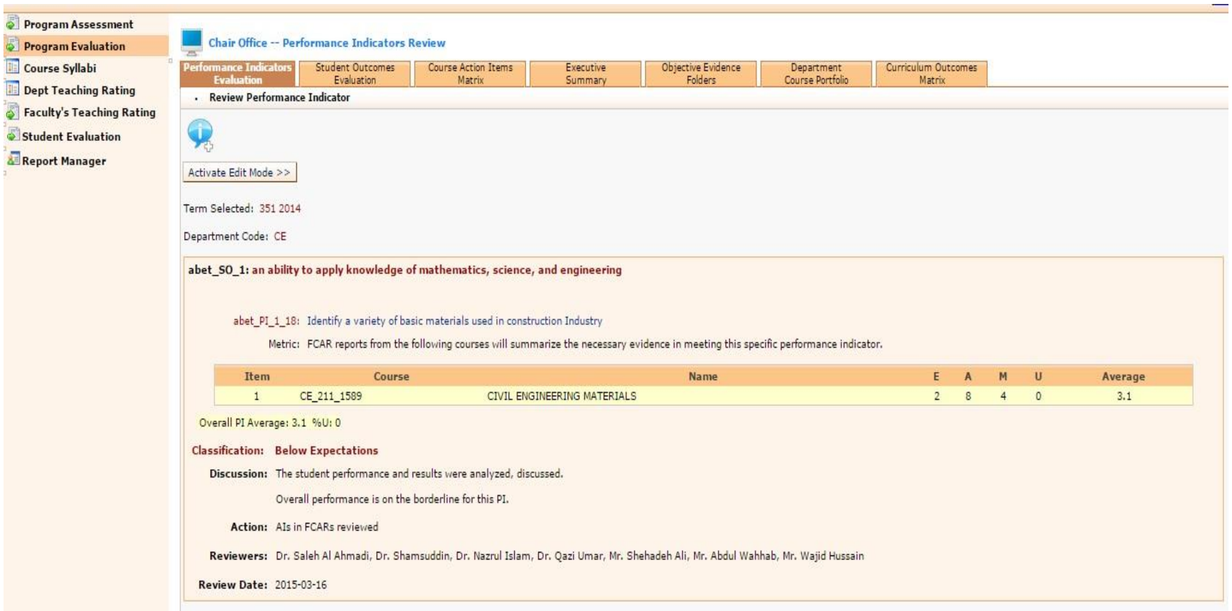
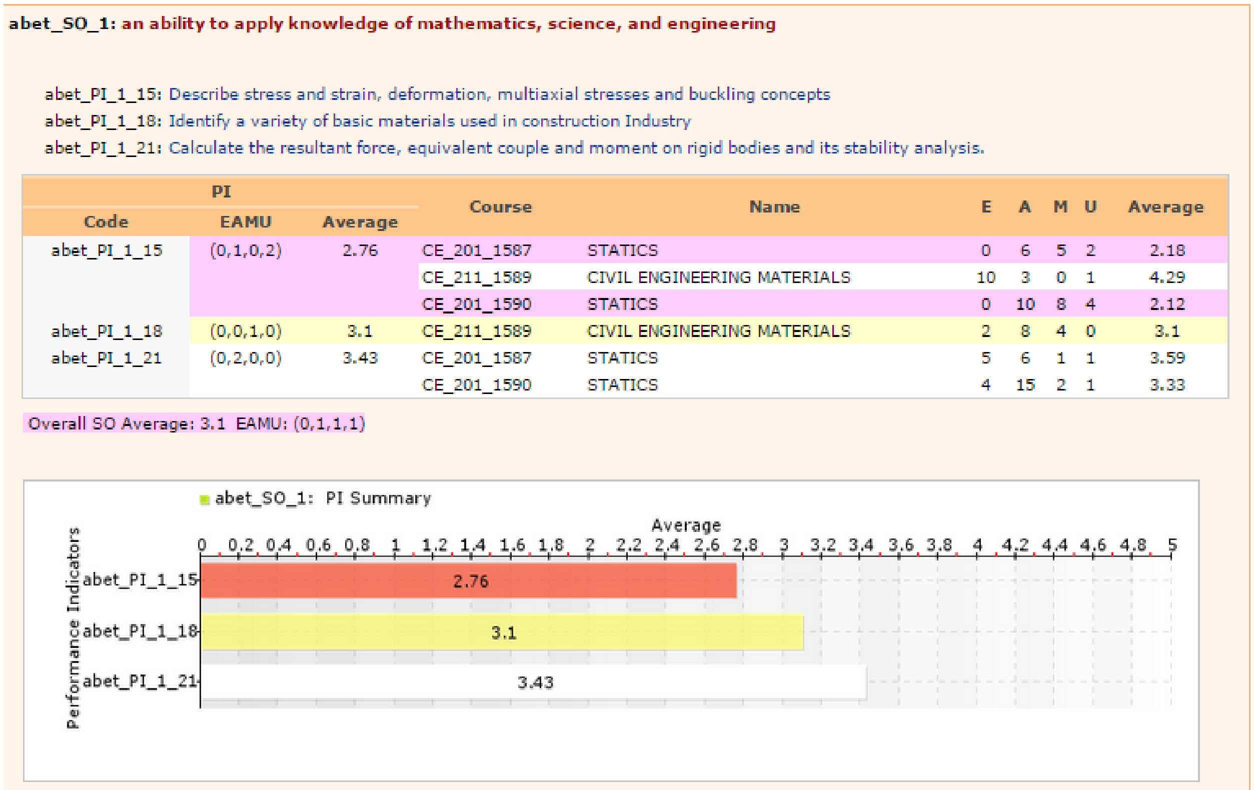


Figure 16. PI evaluation module reviewer comments and action items related to a specific PI and ABET SO. Reprinted by permission from the Faculty of Engineering, IU.



abet_SO_1: an ability to apply knowledge of mathematics, science, and engineering

abet_PI_1_15: Describe stress and strain, deformation, multiaxial stresses and buckling concepts
abet_PI_1_18: Identify a variety of basic materials used in construction Industry
abet_PI_1_21: Calculate the resultant force, equivalent couple and moment on rigid bodies and its stability analysis.

PI			Course	Name	E	A	M	U	Average
Code	EAMU	Average							
abet_PI_1_15	(0,1,0,2)	2.76	CE_201_1587	STATICS	0	6	5	2	2.18
			CE_211_1589	CIVIL ENGINEERING MATERIALS	10	3	0	1	4.29
			CE_201_1590	STATICS	0	10	8	4	2.12
abet_PI_1_18	(0,0,1,0)	3.1	CE_211_1589	CIVIL ENGINEERING MATERIALS	2	8	4	0	3.1
abet_PI_1_21	(0,2,0,0)	3.43	CE_201_1587	STATICS	5	6	1	1	3.59
			CE_201_1590	STATICS	4	15	2	1	3.33

Overall SO Average: 3.1 EAMU: (0,1,1,1)

Figure 17. Detailed performance indicator analysis for a selected ABET student outcome listing the contributing courses and their group EAMU calculations. Reprinted by permission from the Faculty of Engineering, IU.

Department: CE

Detailed SO/PI Executive Summary Report for 351 2014

SO	Detailed Executive Summary	Average	Classification/ Review Date
abet_SO_1	**abet_SO_1 : Overall Summary** Discussion: Students performance was on the border line for some PIs. The preparation of students for quiz was unsatisfactory. The English comprehension, writing skills needs to improve. Reviewers: Dr. Saleh Al Ahmadi, Dr. Shamsuddin, Dr. Nazrul Islam, Dr. Qazi Umar, Mr. Shehadeh Ali, Mr. Abdul Wahhab, Mr. Wajid Hussain	3.10	
	abet_PI_1_15: Discussion: Reminders need to be given through EvalTools LMS before quiz administration. Action: AIs in FCAR reviewed Review Date: 2015-03-16	2.76	Below Expectations
	abet_PI_1_18: Discussion: The student performance and results were analyzed, discussed. Overall performance is on the borderline for this PI. Action: AIs in FCARs reviewed Review Date: 2015-03-16	3.10	Below Expectations
abet_SO_2	**abet_SO_2 : Overall Summary** Discussion: Faculty suggested courses to be introduced into the CE curriculum for better comprehension of the students Reviewers: Dr. Saleh Al Ahmadi, Dr. Shamsuddin, Dr. Nazrul Islam, Dr. Qazi Umar, Mr. Shehadeh Ali, Mr. Abdul Wahhab, Mr. Wajid Hussain	3.14	Below Expectations 2015-03-16

Figure 18. Portion of detailed SO/PI exceutive summary of a sample program term review.

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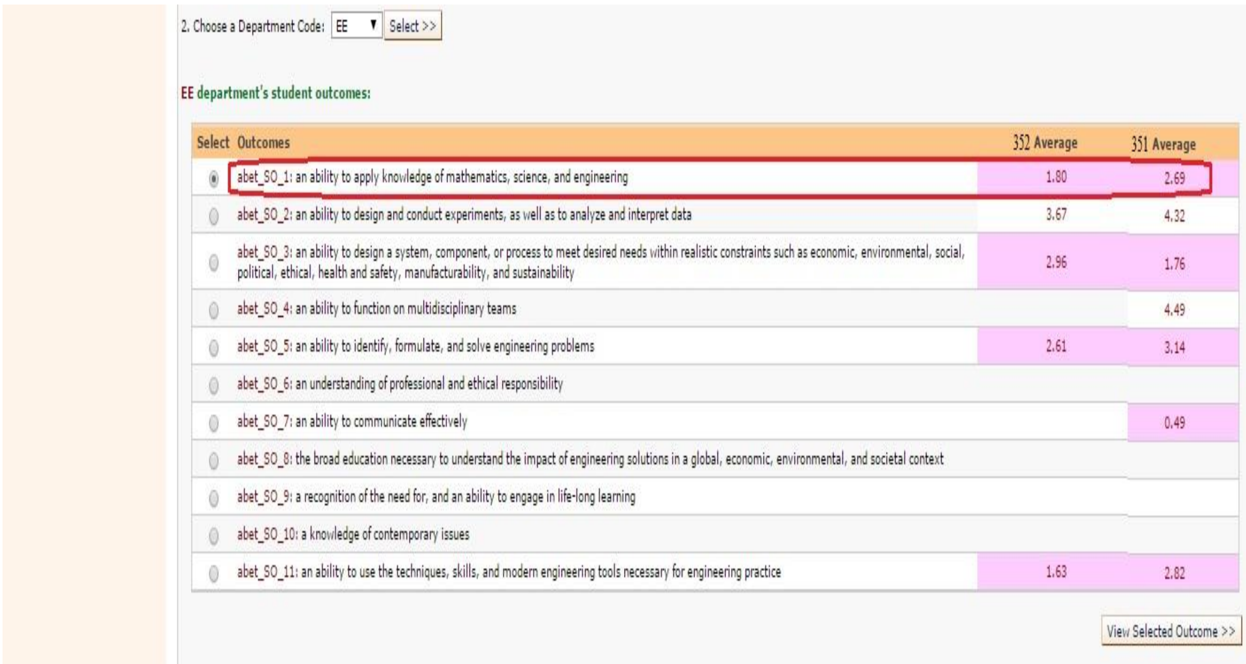


2. Choose a Department Code: EE Select >>

EE department's student outcomes:

Select	Outcomes	352 Average	351 Average
	abet_SO_1: an ability to apply knowledge of mathematics, science, and engineering	1.80	2.69
	abet_SO_2: an ability to design and conduct experiments, as well as to analyze and interpret data	3.67	4.32
	abet_SO_3: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	2.96	1.76
	abet_SO_4: an ability to function on multidisciplinary teams		4.49
	abet_SO_5: an ability to identify, formulate, and solve engineering problems	2.61	3.14
	abet_SO_6: an understanding of professional and ethical responsibility		
	abet_SO_7: an ability to communicate effectively		0.49
	abet_SO_8: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context		
	abet_SO_9: a recognition of the need for, and an ability to engage in life-long learning		
	abet_SO_10: a knowledge of contemporary issues		
	abet_SO_11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	1.63	2.82

View Selected Outcome >>

Figure 19. EE Program ABET SOs data for terms 351, 352 with SO_1 highlighted to show pattern of failure in a certain area of learning reported by multiple raters and from various courses. Reprinted by permission from the Faculty of Engineering, IU.

abet_SO_1: an ability to apply knowledge of mathematics, science, and engineering

TERM 351

abet_PI_1_27: Apply basic laws and formulas of circuit theory, such as Ohm's and Kirchoff's laws as well as circuit theorems to simplify/analyze circuits (Thevenin and Norton theorems, superposition principle, max power transfer theorem, transformation etc.)

abet_PI_1_40: Explain how a number with one radix is converted into a number with another radix

abet_PI_1_41: Convert a given number from one system to an equivalent number in another system

abet_PI_1_42: Perform mathematical operations relating to different number systems

abet_PI_1_43: Describe the concept of capacitor and its relationship to electric fields/parallel; the concept of the inductor and its relationship to magnetic fields due to currents in wires and the concept of resistance and its relationship to charge flow under the presence of an electric field.

abet_PI_1_44: Explain basics of electrical engineering parameters such as charge, voltage, current, energy, power, work done, resistance, capacitance, inductance etc.

	PI		Course	Name	E	A	M	U	Average
Code	EAMU	Average							
abet_PI_1_27	(0,0,0,1)	1.39	EE_201_1581	CIRCUIT THEORY I	1	6	5	12	1.39
abet_PI_1_40	(0,0,0,1)	1.3	EE_261_1584	DIGITAL LOGIC DESIGN	2	6	0	15	1.3
abet_PI_1_41	(0,1,0,0)	4.06	EE_261_1584	DIGITAL LOGIC DESIGN	15	4	3	1	4.06
abet_PI_1_42	(0,0,0,1)	2.1	EE_261_1584	DIGITAL LOGIC DESIGN	6	3	5	9	2.1
abet_PI_1_43	(0,1,0,0)	3.54	EE_201_1581	CIRCUIT THEORY I	6	16	1	1	3.54
abet_PI_1_44	(0,1,0,0)	3.75	EE_201_1581	CIRCUIT THEORY I	9	12	3	0	3.75

Overall SO Average: 2.69 EAMU: (0,3,0,3)

Figure 20. EE Program term 351 ABET SO_1 data with PI_1_27 highlighted to show pattern of failure for specific area of learning. Reprinted by permission from the Faculty of Engineering, IU.

abet_SO_1: an ability to apply knowledge of mathematics, science, and engineering

TERM 352

abet_PI_1_11: Recognize various characteristics of various electronic semiconductor devices, such as diodes, BJT, JFET, MOSFET transistors and their simple applications like inverting and non-inverting amplifiers, metal oxide semiconductor inverters and logic gates, transistor logic circuits, and phase-locked loops

abet_PI_1_12: Employ basic electrical power formulations and quantities, such as complex vectors, delta/star transformation, network flow matrices (network topology and incidence matrices) and symmetrical components

abet_PI_1_23: Explain and apply the concepts of DC and AC (synchronous and induction) machine dynamics and transients as well as the principles of steady state and transient stability of electrical machines

abet_PI_1_26: Demonstrate knowledge of the operating principles of key electronic components and devices, such as PN junctions, diodes and BJT/field-effect transistors (FETs)

abet_PI_1_27: Apply basic laws and formulas of circuit theory, such as Ohm's and Kirchoff's laws as well as circuit theorems to simplify/analyze circuits (Thevenin and Norton theorems, superposition principle, max power transfer theorem, transformation etc.)

abet_PI_1_44: Explain basics of electrical engineering parameters such as charge, voltage, current, energy, power, work done, resistance, capacitance, inductance etc.

abet_PI_1_45: Explain basic semiconductors theory concepts such as applied electric field, junction capacitance, drift/diffusion currents, semiconductor conductivity, doping,electron, hole concentrations, N-type, P-type semiconductors.

abet_PI_1_46: Apply Coulombs law to calculate electric field intensity and electric flux density

abet_PI_1_47: Define Gauss law and Evaluate electric flux and electric flux density in static electric field problems

abet_PI_1_48: Elaborate the four Maxwells equations

abet_PI_1_49: Elaborate time-varying electric and magnetic fields and Explain Faradays law

abet_PI_1_52: Study and analysis of the characteristics of the operational amplifier its applications in negative, positive feedback loops, integration, differentiation, multiplication, addition , instrumentation amplifiers and active filters

PI			Course	Name	E	A	M	U	Average
Code	EAMU	Average							
abet_PI_1_11	(0,0,0,3)	1.88	EE_200_667	FUNDAMENTALS OF ELECTRICAL ENGINEERING	0	5	2	1	2.5
			EE_212_745	ELECTRONICS 1	0	4	11	6	1.51
			EE_200_961	FUNDAMENTALS OF ELECTRICAL ENGINEERING	1	5	10	3	2.02
abet_PI_1_12	(0,0,1,0)	3.51	EE_202_744	CIRCUIT THEORY II	11	3	1	4	3.51
abet_PI_1_23	(0,0,0,2)	1.79	EE_200_667	FUNDAMENTALS OF ELECTRICAL ENGINEERING	2	3	1	2	2.71
			EE_200_961	FUNDAMENTALS OF ELECTRICAL ENGINEERING	2	3	4	10	1.4
abet_PI_1_26	(0,0,0,1)	0.79	EE_212_745	ELECTRONICS 1	0	3	4	14	0.79
abet_PI_1_27	(0,0,0,3)	0.29	EE_200_667	FUNDAMENTALS OF ELECTRICAL ENGINEERING	0	0	1	7	0.21
			EE_202_744	CIRCUIT THEORY II	1	1	1	16	0.53
			EE_200_961	FUNDAMENTALS OF ELECTRICAL ENGINEERING	0	0	1	18	0.09
abet_PI_1_44	(0,0,0,2)	1.73	EE_200_667	FUNDAMENTALS OF ELECTRICAL ENGINEERING	2	2	1	3	2.29
			EE_200_961	FUNDAMENTALS OF ELECTRICAL ENGINEERING	0	4	9	6	1.49
abet_PI_1_45	(0,1,0,0)	3.73	EE_212_745	ELECTRONICS 1	6	14	1	0	3.73
abet_PI_1_46	(0,0,0,1)	2.27	EE_282_743	ELECTROMAGNETIC FIELD THEORY	4	1	1	5	2.27
abet_PI_1_47	(0,0,0,1)	1.21	EE_282_743	ELECTROMAGNETIC FIELD THEORY	1	2	1	7	1.21
abet_PI_1_48	(0,0,0,1)	1.21	EE_282_743	ELECTROMAGNETIC FIELD THEORY	1	2	1	7	1.21
abet_PI_1_49	(0,0,0,1)	0.45	EE_282_743	ELECTROMAGNETIC FIELD THEORY	1	0	0	10	0.45
abet_PI_1_52	(0,1,1,0)	2.78	EE_200_667	FUNDAMENTALS OF ELECTRICAL ENGINEERING	3	3	2	0	3.54
			EE_200_961	FUNDAMENTALS OF ELECTRICAL ENGINEERING	1	8	9	1	2.46

Overall SO Average: 1.8 EAMU: (0,1,2,9)

Figure 21. EE Program term 352 ABET SO_1 data with PI_1_27 highlighted to show pattern of failure for specific area of learning. Reprinted by permission from the Faculty of Engineering, IU.

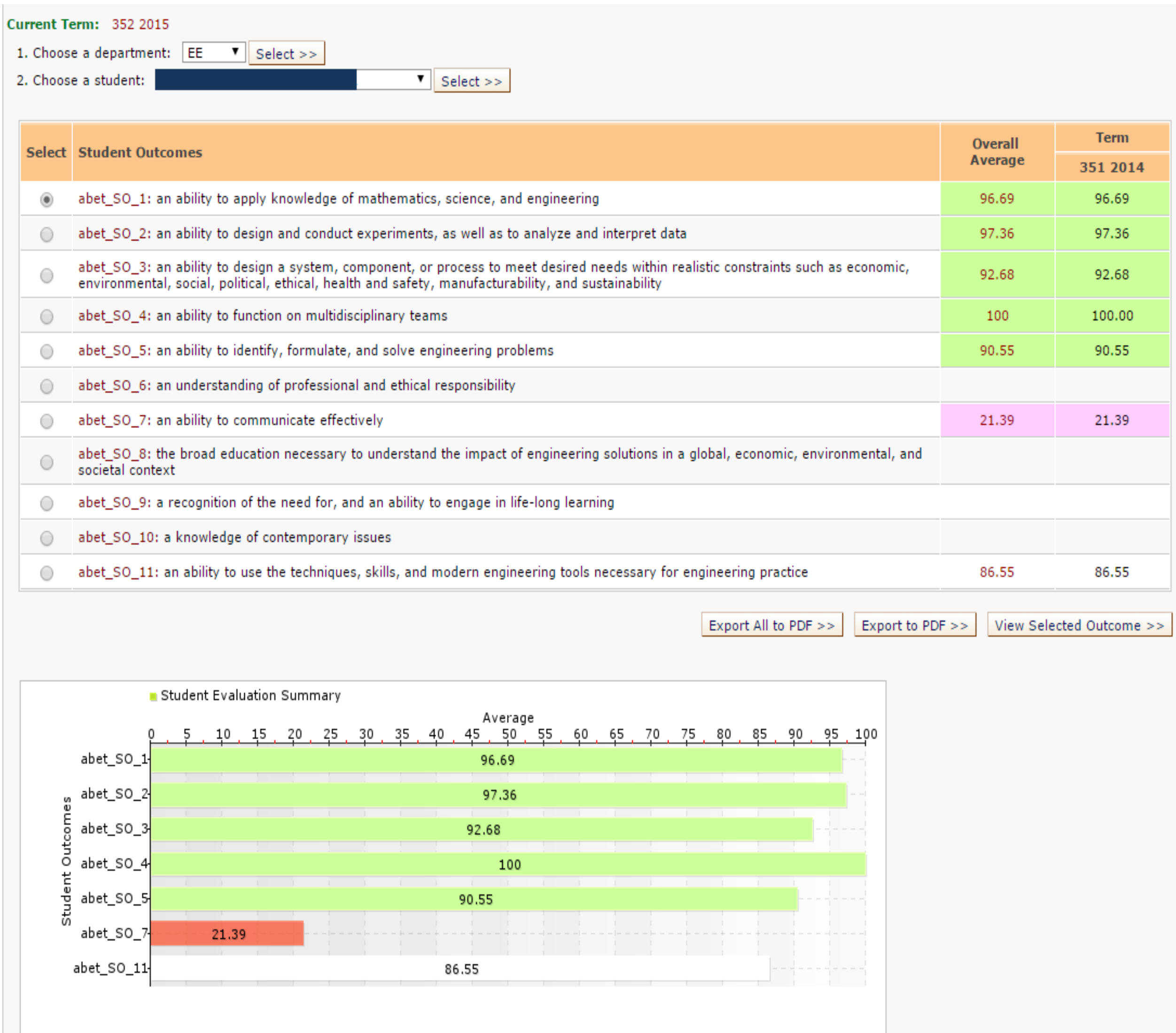


Figure 22. ABET student outcomes listed in a student evaluation. Reprinted by permission from the Faculty of Engineering, IU.

abet_PI_1_12: Employ basic electrical power formulations and quantities, such as complex vectors, delta/star transformation, network flow matrices (network topology and incidence matrices) and symmetrical components

abet_PI_1_26: Demonstrate knowledge of the operating principles of key electronic components and devices, such as PN junctions, diodes and BJT/field-effect transistors (FETs)

abet_PI_1_27: Apply basic laws and formulas of circuit theory, such as Ohm's and Kirchoff's laws as well as circuit theorems to simplify/analyze circuits (Thevenin and Norton theorems, superposition principle, max power transfe theorem, transformation etc.)

abet_PI_1_40: Explain how a number with one radix is converted into a number with another radix

abet_PI_1_41: Convert a given number from one system to an equivalent number in another system

abet_PI_1_42: Perform mathematical operations relating to different number systems

abet_PI_1_43: Describe the concept of capacitor and its relationship to electric fields/parallel; the concept of the inductor and its relationship to magnetic fields due to currents in wires and the concept of resistance and its relationship to charge flow under the presence of an electric field.

abet_PI_1_44: Explain basics of electrical engineering parameters such as charge, voltage, current, energy, power, work done, resistance, capacitance, inductance etc.

abet_PI_1_45: Explain basic semiconductors theory concepts such as applied electric field, junction capacitance, drift/diffusion currents, semiconductor conductivity, doping,electron, hole concentrations, N-type, P-type semiconductors.

abet_PI_1_46: Apply Coulombs law to calculate electric field intensity and electric flux density

abet_PI_1_47: Define Gauss law and Evaluate electric flux and electric flux density in static electric field problems

abet_PI_1_48: Elaborate the four Maxwells equations

abet_PI_1_49: Elaborate time-varying electric and magnetic fields and Explain Faradays law

Performance Indicator	PI Average	Term	Course	EAMU	Average (%)
abet_PI_1_11	61.44	352 2015	EE 212 745 ELECTRONICS 1	(2,2,1,4)	61.44
abet_PI_1_12	100	352 2015	EE 202 744 CIRCUIT THEORY II	(2,0,0,0)	100
abet_PI_1_26	38.17	352 2015	EE 212 745 ELECTRONICS 1	(0,0,1,3)	38.17
abet_PI_1_27	50.75	352 2015	EE 202 744 CIRCUIT THEORY II	(2,0,0,1)	51.49
		351 2014	EE 201 1581 CIRCUIT THEORY I	(1,1,0,3)	50

Assignment	EAMU	WF	Score
HW-2	A	2	85/100
QZ-2	E	1.25	100/100
Mid Term-II PART III Q40	U	0.9	0/6
MID_TERM_1 Part V Q42	U	0.75	0/5
Final Exam Part IV Q45	U	1	0/3

Performance Indicator	PI Average	Term	Course	EAMU	Average (%)
abet_PI_1_40	15	351 2014	EE 261 1584 DIGITAL LOGIC DESIGN	(0,1,0,1)	15
abet_PI_1_41	90	351 2014	EE 261 1584 DIGITAL LOGIC DESIGN	(1,0,0,0)	90
abet_PI_1_42	40	351 2014	EE 261 1584 DIGITAL LOGIC DESIGN	(0,0,0,1)	40
abet_PI_1_43	87.69	351 2014	EE 201 1581 CIRCUIT THEORY I	(1,1,0,0)	87.69
abet_PI_1_44	88.86	351 2014	EE 201 1581 CIRCUIT THEORY I	(4,2,1,0)	88.86
abet_PI_1_45	90.69	352 2015	EE 212 745 ELECTRONICS 1	(2,0,1,0)	90.69
abet_PI_1_46	8.79	352 2015	EE 282 743 ELECTROMAGNETIC FIELD THEORY	(1,0,0,2)	8.79
abet_PI_1_47	13.33	352 2015	EE 282 743 ELECTROMAGNETIC FIELD THEORY	(0,0,0,2)	13.33
abet_PI_1_48	0	352 2015	EE 282 743 ELECTROMAGNETIC FIELD THEORY	(0,0,0,1)	0
abet_PI_1_49	0	352 2015	EE 282 743 ELECTROMAGNETIC FIELD THEORY	(0,0,0,1)	0

Figure 23. Patterns of comparatively better learning in specific related skills observed from a two term student evaluation report for a typical underperforming EE student. Reprinted by permission from the Faculty of Engineering, IU.

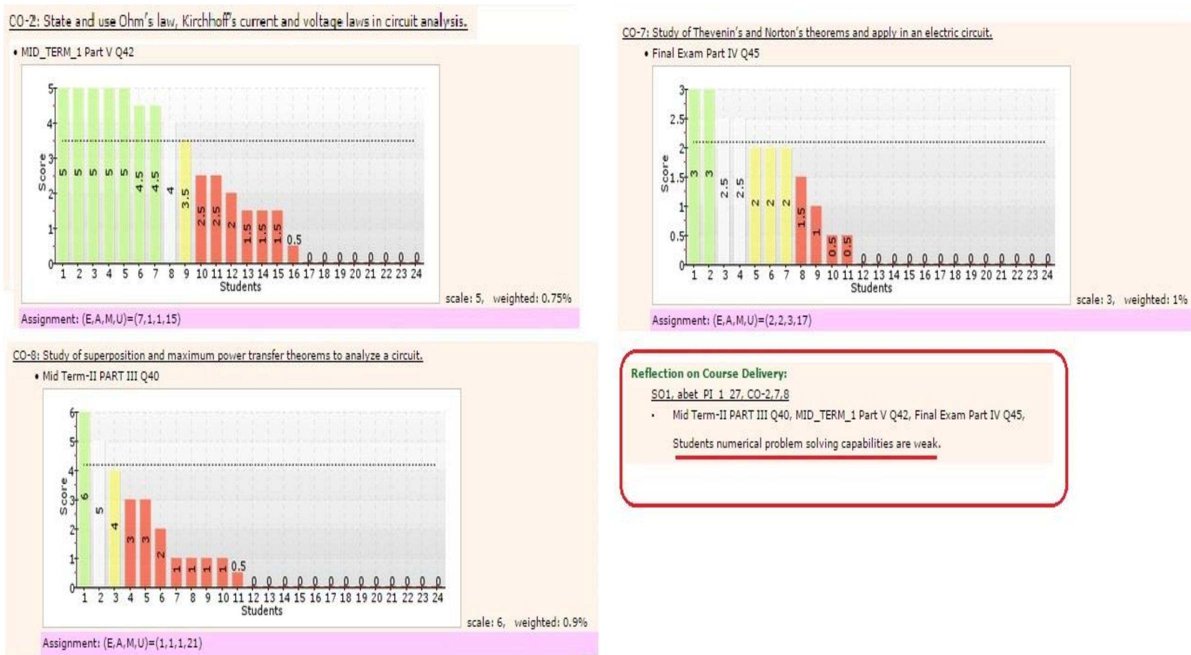
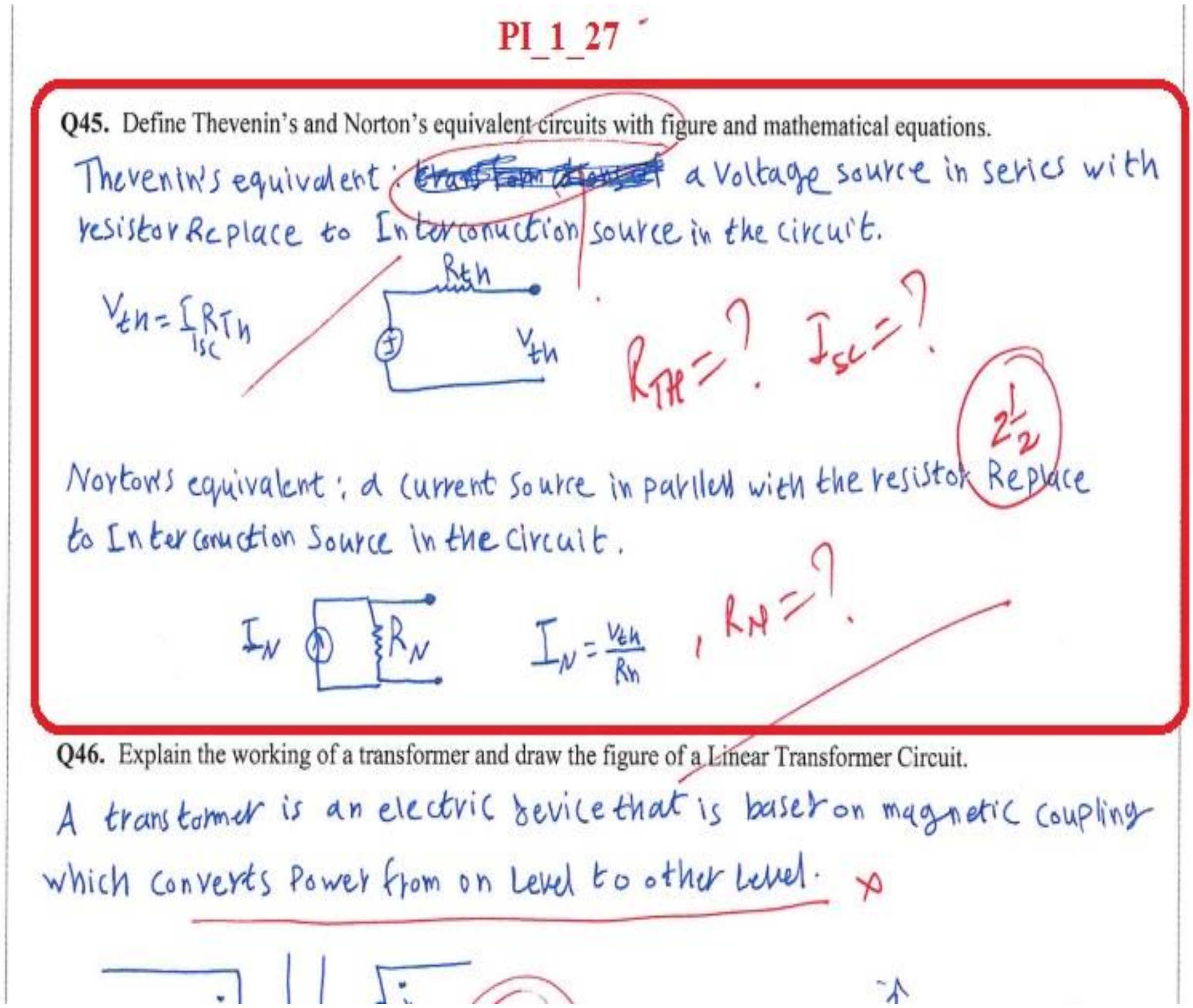


Figure 24. Patterns of failure indicated for PI_1_27 in various assessments. Reprinted by permission from the Faculty of Engineering, IU.



PI_1_27

Q45. Define Thevenin's and Norton's equivalent circuits with figure and mathematical equations.

Thevenin's equivalent: ~~transform~~ a Voltage source in series with resistor Replace to Interconuction source in the circuit.

$V_{th} = I_{sc} R_{Th}$

R_{th}

V_{th}

$R_{TH} = ?$. $I_{sc} = ?$

$2\frac{1}{2}$

Nortons equivalent: a current Source in parllel with the resistor Replace to Interconuction Source in the circuit.

I_N R_N $I_N = \frac{V_{th}}{R_N}$, $R_N = ?$

Q46. Explain the working of a transformer and draw the figure of a Linear Transformer Circuit.

A transformer is an electric device that is baser on magnetic coupling which converts Power from on Level to other Level.

Figure 25. Objective evidence Final Exam Part-III Q45 indicating weakness in fundamental math skills. Reprinted by permission from the Faculty of Engineering, IU.

Reflection on Course Delivery:

SO1, abet PI 1 27, CO-2,7,8

- Mid Term-II PART III Q40, MID_TERM_1 Part V Q42, Final Exam Part IV Q45,

  Students numerical problem solving capabilities are weak.

SO5, abet PI 5 7, CO6

- HW6,7: Majority submitted incomplete solutions of HWs

SO5, abet PI 5 19, CO4,6

- QZ3,4: Numerical problem solving ability of the students is weak.

SO7, abet PI 7 2, CO11

- Final Exam Part IV Q46 was optional question. so more than 50 % students did not attempt to answer this question while some of the students did not perform well.

SO11, abet PI 11 26, CO10

- HW8: Majority submitted incomplete solutions of HWs

LAB & THEORY

- Theory and Lab sessions were combined and therefore the theory was not assigned sufficient number of lectures, further there should be some tutorial lectures in the theory.

ENGLISH COMPREHENSION & MATHEMATICAL ABILITY

- The students English comprehension , writing and mathematical problem solving abilities are very weak.

CLASS TIMING

- The class timings were in the afternoon and not appropriate.

New Action Items:

Action Items	Owner	Closing Date
SO1, abet_PI_1_27, CO-2,7,8: emphasis was laid more on numerical examples in class as well through assignments. This weakness should be referred to the preparatory year program for improvement of the mathematics fundamentals	Ansari, Mohammad	352, May 2015
SO5, abet_PI_5_7, CO6: Need to reduce the number of assignments		
SO7, abet_PI_7_2, CO11: N/A		
SO11, abet_PI_11_26, CO10: Need to reduce the number of assignments		
LAB & THEORY: Lab and theory need to be separated		
ENGLISH COMPREHENSION & MATHEMATICAL ABILITY: Need to refer weaknesses in English to the preparatory year program		
CLASS TIMING: Need to allocate morning class timings.		

Figure 26. Circuit Theory-I course FCAR reflections and action items. Reprinted by permission from the Faculty of Engineering, IU.

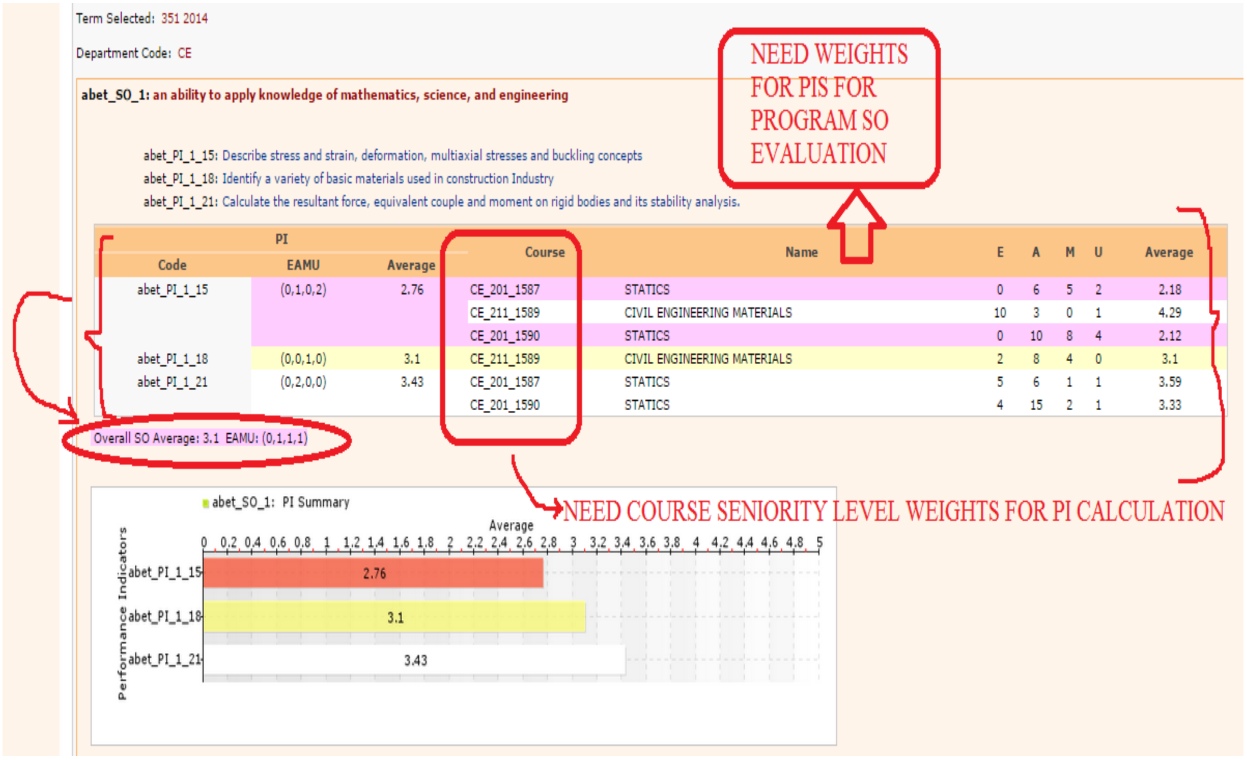


Figure 27. PIs weighted average based upon revised Bloom's taxonomy to be applied for ABET SO value computations. Reprinted by permission from the Faculty of Engineering, IU.

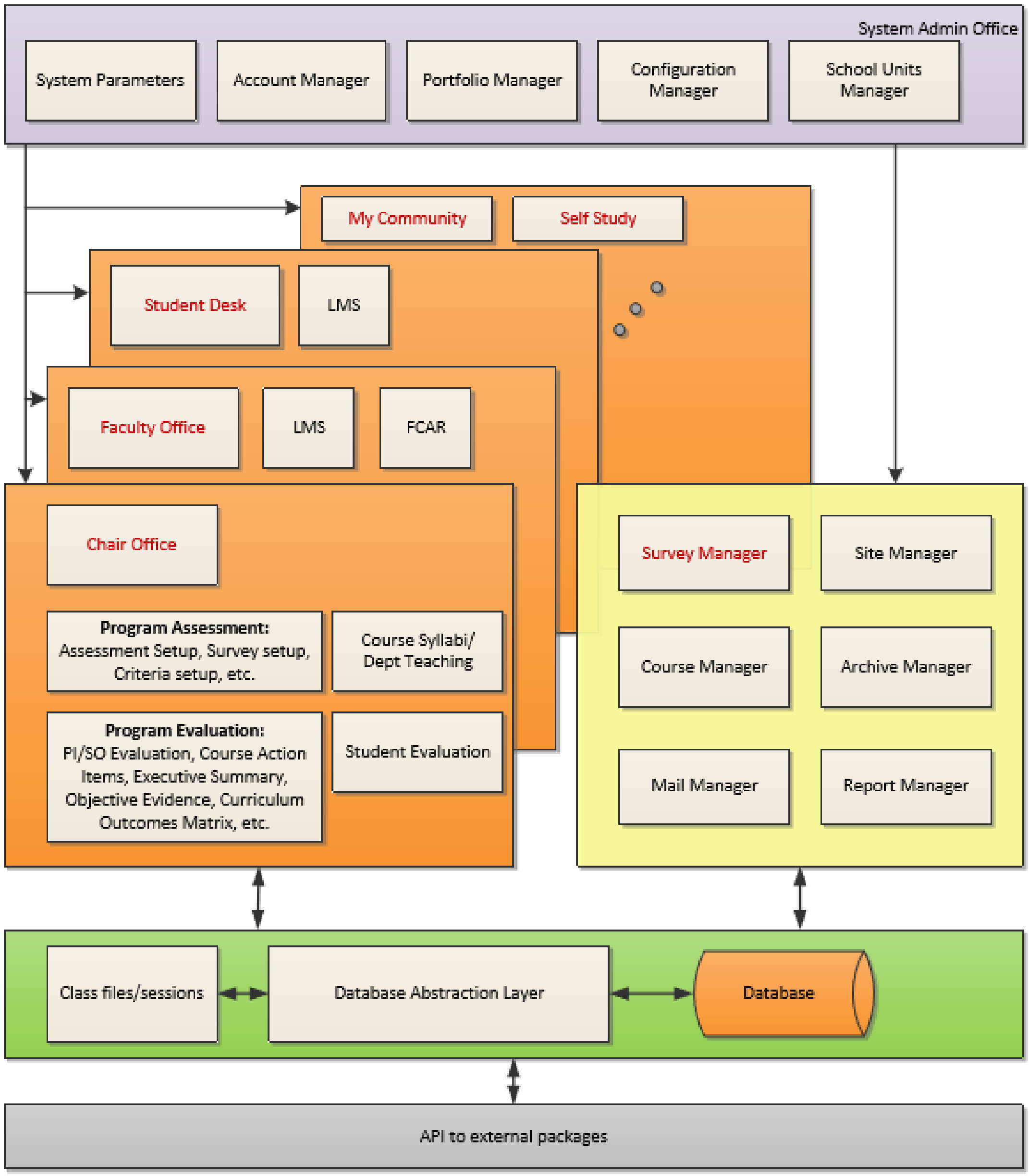


Figure 28. EvalTools® 6 System Architecture. Proprietary information and property of MAKTEAM Software. © Copyright 2015. http://www.makteam.com. Reprinted with permission from MAKTEAM Software.

Class: ENGR_101_1562 CREATIVITY IN ENGINEERING DESIGN I
Size: 13

Course Outcomes:

Select	Assignment/ Activities/Events	Standards CO	Standards PI	Standards SO	No. of Submissions	Faculty Assigned Task
◉	HW-1	CO 1	abet_PI_10_9	abet_SO_10	student: 0; faculty: 10	fac 6481 ENGR 101 1562 HW-1.docx fac 6481 ENGR 101 1562 HW-1-Formatting-Rules.docx fac 6481 ENGR 101 1562 HW-1-Grading-Table.docx
○	HW-2	CO 3	abet_PI_5_1	abet_SO_5	student: 0; faculty: 14	fac 6481 ENGR 101 1562 HW-2.docx fac 6481 ENGR 101 1562 HW-2-Formatting-Rules.docx fac 6481 ENGR 101 1562 HW-2-Grading-Table.docx
○	HW-3	CO 5	abet_PI_4_10	abet_SO_4	student: 0; faculty: 14	fac 6481 ENGR 101 1562 HW-3.docx fac 6481 ENGR 101 1562 HW-3-Formatting-Rules.docx fac 6481 ENGR 101 1562 HW-3-Grading-Table.docx
○	HW-4	CO 7	abet_PI_5_8	abet_SO_5	student: 0; faculty: 14	fac 6481 ENGR 101 1562 HW-4.docx fac 6481 ENGR 101 1562 HW-4-Formatting-Rules.docx fac 6481 ENGR 101 1562 HW-4-Grading-Table.doc
○	HW-5	CO 8	abet_PI_9_11	abet_SO_9	student: 0; faculty: 13	fac 6481 ENGR 101 1562 HW-5.docx fac 6481 ENGR 101 1562 HW-5-Formatting-Rules.docx fac 6481 ENGR 101 1562 HW-5-Grading-Table.doc
○	HW-6	CO 6	abet_PI_7_11	abet_SO_7	student: 0; faculty: 14	fac 6481 ENGR 101 1562 HW-6.docx fac 6481 ENGR 101 1562 HW-6-Formatting-Rules.docx fac 6481 ENGR 101 1562 HW-6-Grading-Table.docx
○	HW-7	CO 11	abet_PI_7_6	abet_SO_7	student: 0; faculty: 14	fac 6481 ENGR 101 1562 HW-7.docx fac 6481 ENGR 101 1562 HW-7-Formatting-Rules.docx fac 6481 ENGR 101 1562 HW-7-Grading-Table.docx
○	QZ-1	CO 1	abet_PI_9_12	abet_SO_9	student: 0; faculty: 11	fac 6481 ENGR 101 1562 QZ-1-Questions.pdf fac 6481 ENGR 101 1562 QZ-1-Solutions.pdf
○	QZ-2	CO 2	abet_PI_3_16	abet_SO_3	student: 0; faculty: 12	fac 6481 ENGR 101 1562 QZ-2-Questions.pdf fac 6481 ENGR 101 1562 QZ-2-Solutions.pdf
○	QZ-3	CO 4	abet_PI_4_5	abet_SO_4	student: 0; faculty: 13	fac 6481 ENGR 101 1562 QZ-3-Questions.pdf fac 6481 ENGR 101 1562 QZ-3-Solutions.pdf
○	QZ-4	CO 7	abet_PI_5_8	abet_SO_5	student: 0; faculty: 13	fac 6481 ENGR 101 1562 QZ-4-Questions.pdf fac 6481 ENGR 101 1562 QZ-4-Solutions.pdf
○	QZ-5	CO 9	abet_PI_8_14	abet_SO_8	student: 0; faculty: 13	fac 6481 ENGR 101 1562 QZ-5-Questions.pdf fac 6481 ENGR 101 1562 QZ-5-Solutions.pdf
○	QZ-6	CO 12	abet_PI_9_13	abet_SO_9	student: 0; faculty: 10	fac 6481 ENGR 101 1562 QZ-6-Questions.pdf fac 6481 ENGR 101 1562 QZ-6-Solutions.pdf
○	Project Prsnt.	CO 3	abet_PI_3_12	abet_SO_3	student: 0; faculty: 14	fac 6481 ENGR 101 1562 Project Prsnt-Grading-Table.docx
○	Midterm Exam-1				student: 0; faculty: 14	fac 6481 ENGR 101 1562 Midterm-Exam-1-Questions.pdf fac 6481 ENGR 101 1562 Midterm-Exam-1-Solutions.pdf
○	Midterm Exam-2				student: 0; faculty: 14	fac 6481 ENGR 101 1562 Midterm-Exam-2-Questions.pdf fac 6481 ENGR 101 1562 Midterm-Exam-2-Solutions.pdf
○	Final Exam				student: 0; faculty: 13	fac 6481 ENGR 101 1562 Final-Exam-Questions.pdf fac 6481 ENGR 101 1562 Final-Exam-Solutions.pdf

Figure 29. All faculty submitted assignments to students for a specific course are available in a digital database for instant access. Reprinted by permission from the Faculty of Engineering, IU.

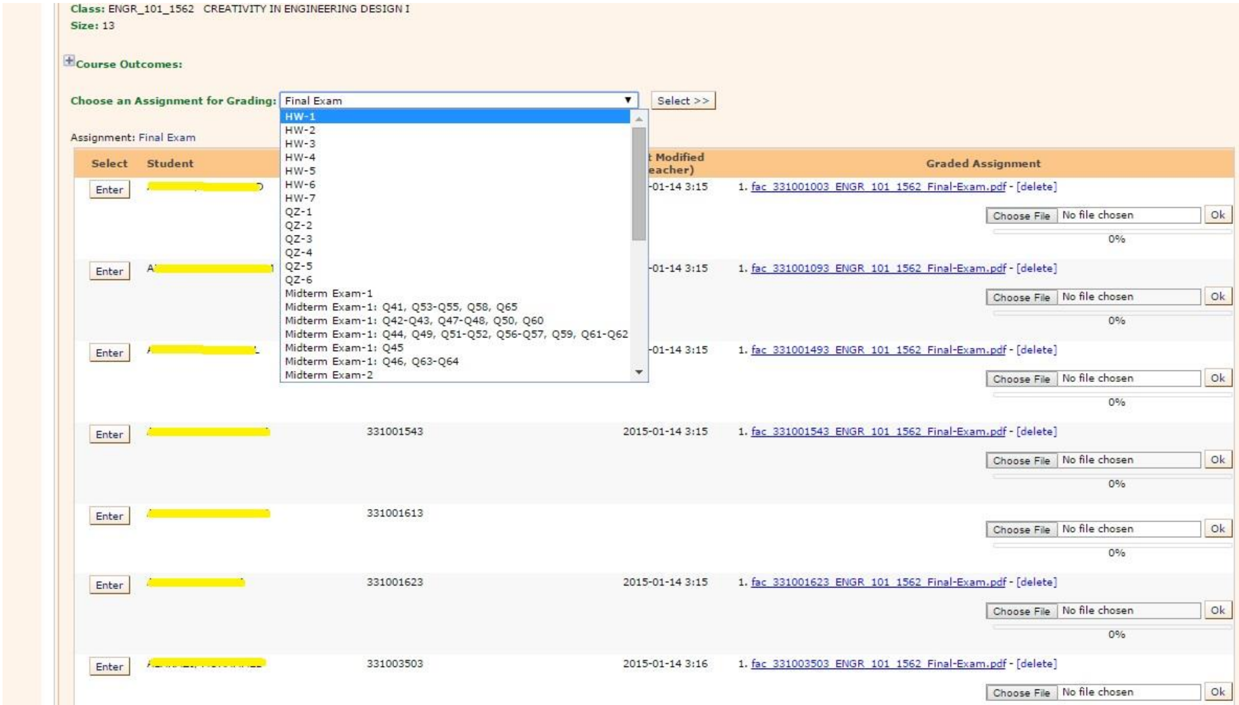


Figure 30. All student submitted graded assignments for a specific course are available in a digital database for instant access. Reprinted by permission from the Faculty of Engineering, IU.

FCAR:

CE_224_674 STRENGTH OF MATERIALS

Faculty :

Department : **CE**

Response Rate : **10/12**

Term : **352 2015**

Pre-requisites: Static (CE 201) and MATH 202

Co-requisites: nil

Course Description:

This is a core subject. Students will be able to understand the basic theory of the fundamental principles of mechanics of materials. Students will be able to incorporate these basic fundamentals into application of the basic design of simple structures. It will assure them of the concepts of stress and strain, plane-stress transformation, shear force and bending moment, stresses in beams, deflections of beams, columns, and torsion. At the end of the course, the students should be able to solve numerous problems that depict realistic situations encountered in engineering practice. The students will also be able to develop and master the skills of reducing any such problem from its physical description to a model or symbolic representation to which the principles may be applied.

Outcomes Section

	Course Outcomes	Self Evaluation	Student Response
1	Define normal and shear stresses, plane-stress transformation, transverse shear and bending stresses of beam.	5.0	3.0
2	Analyse for deflection of beam and trusses by different methods.	4.0	2.9
3	Calculate Deformation and thermal stresses in axially loaded members.	3.0	2.9
4	Analyse the allowable axial force to prevent instability.	4.0	2.8
5	Analyse the allowable axial force and torsional forces in the members.	5.0	2.8
6	Apply the basic principles of mechanics of materials to calculate moment of resistance and allowable deformations.	4.0	2.9
7	Calculate shear force and Bending moment at various section of beams and draw SFD (Shear Force Diagram) and BMD (Bending Moment Diagram) for the beams under various loading and support conditions.	5.0	2.9
8	Define Buckling of Column and calculate the critical load for Struts under different edge conditions using Euler Formula.	4.0	2.7
9	Explain and Draw Shear Stress distribution for various cross sections of Beams.	5.0	2.9
10	Calculate and Draw Bending Stress distribution for various cross sections of Beams	4.0	2.9
11	Determine Torsional Deformation and shear stress for Circular Shafts.	4.0	3.1

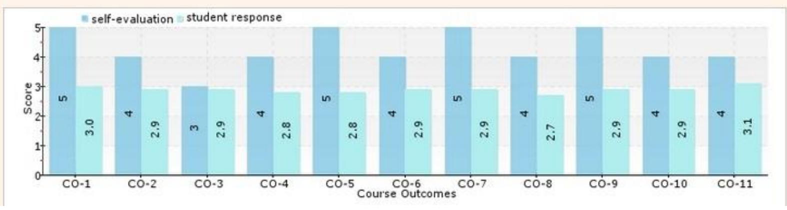


Figure 31. Histogram plot depicting the student course exit survey & faculty self evaluation results in the basic FCAR for a typical engineering course. Reprinted by permission from the Faculty of Engineering, IU.

CE_224_674 STRENGTH OF MATERIALS

Faculty : [redacted]

Department : CE

Response Rate : 10/12

Term : 352 2015

Main Survey Body

Outcomes Section

	Outcomes	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N.A.	$\bar{x}(5)$	sd
1	Define normal and shear stresses, plane-stress transformation, transverse shear and bending stresses of beam.	20.0	10.0	20.0	30.0	10.0	10.0	3.0	0.61
2	Analyse for deflection of beam and trusses by different methods.	20.0	0.0	30.0	30.0	10.0	10.0	2.9	0.59
3	Calculate Deformation and thermal stresses in axially loaded members.	20.0	0.0	30.0	30.0	10.0	10.0	2.9	0.59
4	Analyse the allowable axial force to prevent instability.	20.0	0.0	20.0	40.0	10.0	10.0	2.8	0.64
5	Analyse the allowable axial force and torsional forces in the members.	20.0	0.0	20.0	40.0	10.0	10.0	2.8	0.64
6	Apply the basic principles of mechanics of materials to calculate moment of resistance and allowable deformations.	20.0	10.0	20.0	20.0	20.0	10.0	2.9	0.67
7	Calculate shear force and Bending moment at various section of beams and draw SFD (Shear Force Diagram) and BMD (Bending Moment Diagram) for the beams under various loading and support conditions.	20.0	10.0	20.0	20.0	20.0	10.0	2.9	0.67
8	Define Buckling of Column and calculate the critical load for Struts under different edge conditions using Euler Formula.	20.0	0.0	30.0	10.0	30.0	10.0	2.7	0.77
9	Explain and Draw Shear Stress distribution for various cross sections of Beams.	20.0	0.0	20.0	30.0	10.0	20.0	2.9	0.67
10	Calculate and Draw Bending Stress distribution for various cross sections of Beams	20.0	0.0	30.0	30.0	10.0	10.0	2.9	0.59
11	Determine Torsional Deformation and shear stress for Circular Shafts.	20.0	10.0	30.0	20.0	10.0	10.0	3.1	0.55
	Total Class Response:	**20.0**	**3.6**	**24.5**	**27.3**	**13.6**	**10.9**	**2.9**	**0.64**

Course Items

	Questions	Very	Good	Neutral	Minimal	Not at all	N.A.	$\bar{x}(5)$	sd
1	How would you rate your level of interest in this course?	20.0	0.0	20.0	40.0	10.0	10.0	2.8	0.64
2	Compared to other courses, the amount of work required in this course was:	20.0	0.0	30.0	40.0	0.0	10.0	3.0	0.63
3	How effective has this course been in achieving its instructional objectives and/or student learning outcomes?	20.0	0.0	20.0	30.0	20.0	10.0	2.7	0.68
	Total Class Response:	**20.0**	**0.0**	**23.3**	**36.7**	**10.0**	**10.0**	**2.8**	**0.65**

1 Comments related to course work and objectives:

Course Syllabus

	Questions	Yes	No	N.A.	$\bar{x}(2)$	sd
1	Was the course syllabus distributed that included course outcomes and/or student learning outcomes?	30.0	30.0	40.0	1.5	0.35
	Total Class Response:	**30.0**	**30.0**	**40.0**	**1.5**	**0.35**

Course Instruction

Figure 32. Portion of a student course exit survey report displaying statistical information.

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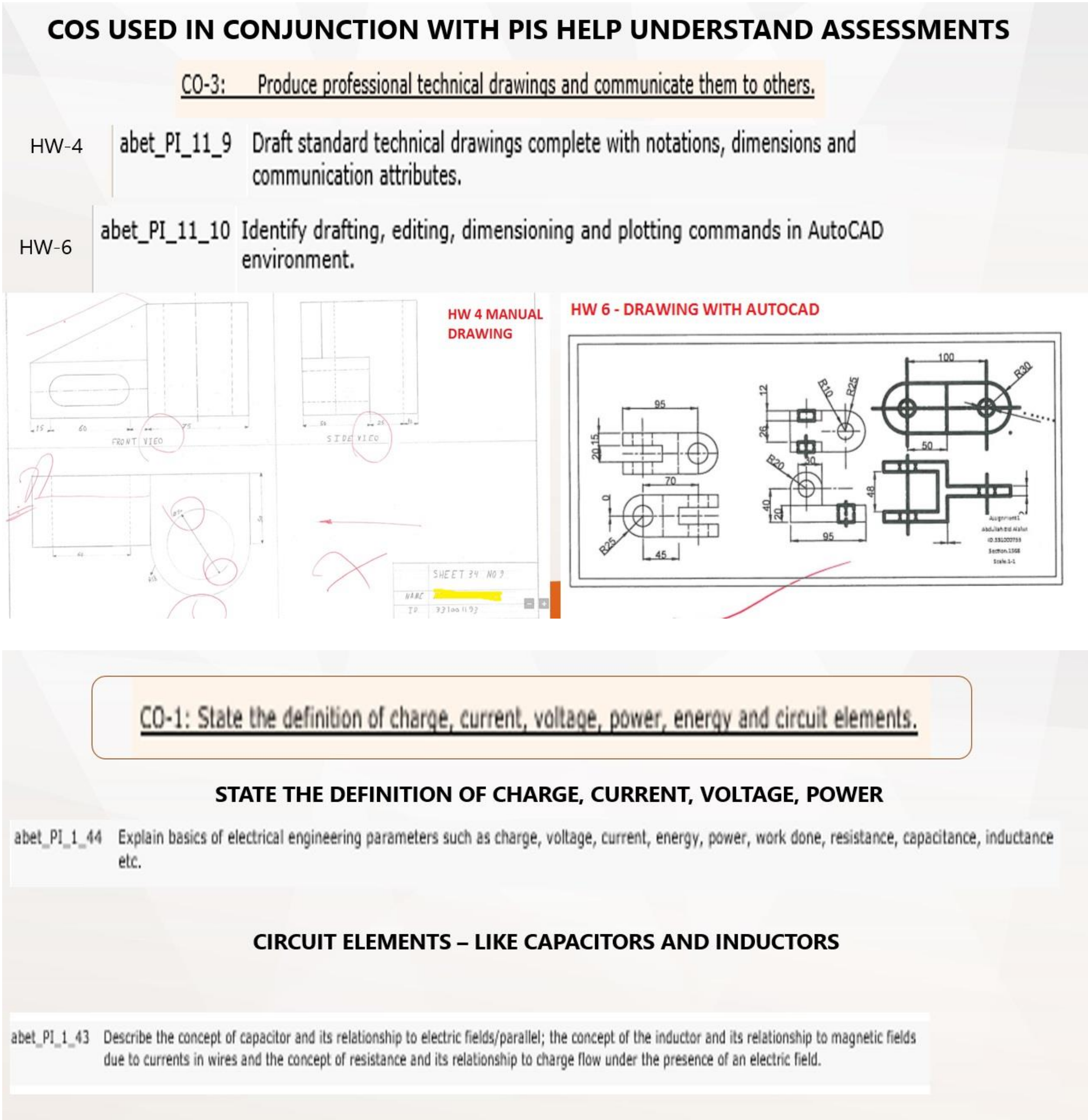

Figure 33. Civil engineering drawing & electrical engineering electric circuits course examples where specific performance criteria help identify certain skills related to course learning outcomes. Reprinted by permission from the Faculty of Engineering, IU.

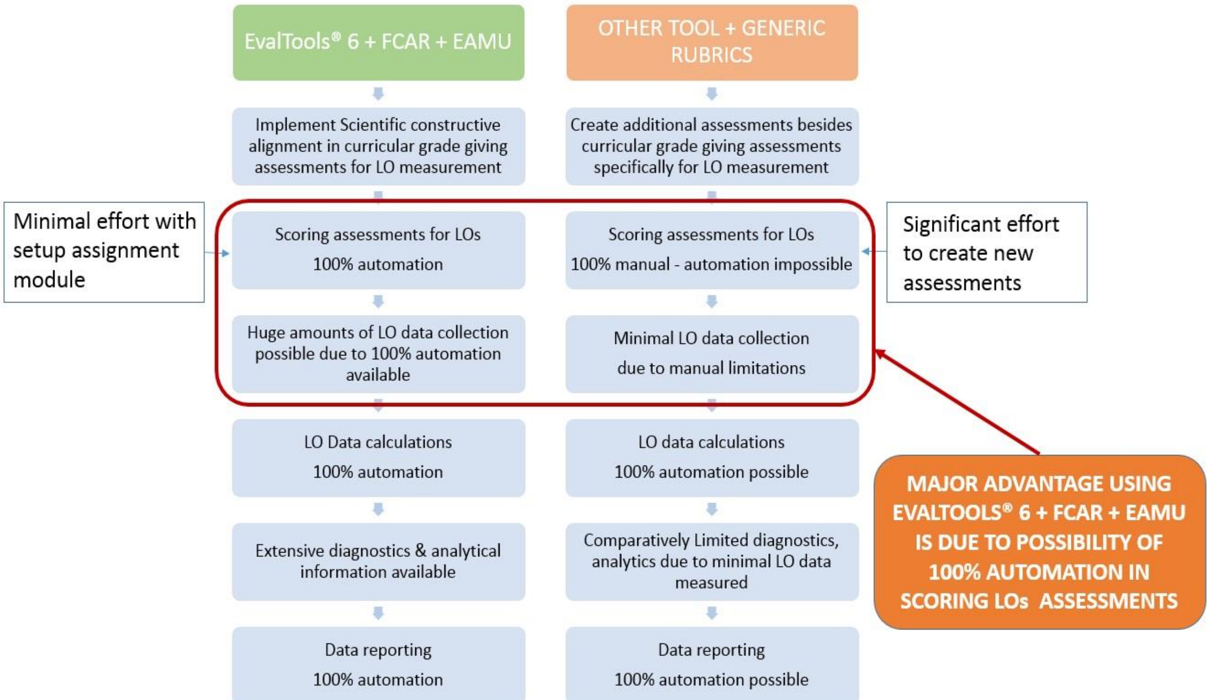

Figure 34. Comparative study of the advantages of automation achieved with EvalTools® 6 + FCAR + EAMU versus other tools with generic rubrics used for learning outcomes (LOs) measurements. Reprinted by permission from the Faculty of Engineering, IU.

Publication (b): Hussain, W. and Addas, M. F. (2016, April), "*Digitally Automated Assessment of Outcomes Classified per Bloom's Three Domains and Based on Frequency and Types of Assessments*". National Institute for Learning Outcomes Assessment (NILOA), Lumina, Teague Foundation, University of Illinois, Urbana Champaign.

Assessment in Practice

Digitally Automated Assessment of Outcomes Classified Per Bloom's Three Domains and Based on Frequency and Type of Assessments

Wajid Hussain & Mohammad F. Addas
Islamic University in Madinah

April 2016

One of the primary reasons outcomes information is not utilized for Continuous Quality Improvement (CQI) is that the information collected is insufficient to make improvement decisions due to impractical manual processes that are either too exhaustive to complete for timely measurement and reporting, or too minimal for basic fulfillment of accreditation requirements. Massive amounts of outcomes data collected from various stages of curriculum delivery is a critical requirement for informing improvement decisions. Therefore, manual assessment, documentation and reporting systems are major factors that exacerbate the implementation of streamlining activities which are necessary to integrate improvement efforts of several stakeholders in an academic CQI process. In an age of technological advancement, use of digital technology allows for the collection of various evidence sources. The Faculty of Engineering at the Islamic University outlined five crucial elements of their outcomes assessment methodology which fully supports automation and digital technology based assessment/documentation/reporting systems to collect, analyze and utilize outcomes data to establish meaningful CQI and not just fulfill accreditation requirements.

1. MEASUREMENT OF OUTCOMES IN ALL COURSE LEVELS OF A PROGRAM CURRICULUM (refer Figure 1).

Generally institutions classify courses of a program curriculum into three levels: introductory, reinforced and mastery with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for an effective program evaluation. This approach presents a

Assessment in Practice

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Generally institutions classify courses of a program curriculum into three levels: introductory, reinforced and mastery with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for an effective program evaluation. This approach presents a major deficiency for CQI in a student centered outcomes-based education model since performance information of a graduating batch of students collected at just the mastery level to measure program Student Outcomes (SOs) is at a final phase of a typical quality cycle and too late for implementation of remedial efforts for performance failures of the students in consideration. A holistic approach for a CQI model would require a systematic measurement of performance indicators in all three of Bloom's domains of learning and their corresponding categories of learning levels for all course levels of a program's curriculum.

abet_SO_1: an ability to apply knowledge of mathematics, science, and engineering

abet_PI_1_1: Psychomotor: Mechanism Describe the fundamentals of engineering drawing, surveying and spatial measurements

abet_PI_1_21: Cognitive: Analyzing Calculate the resultant force, equivalent couple and moment on rigid bodies and its stability analysis.

abet_PI_1_23: Psychomotor: Complex overt response Calculate the shear force and bending moment at various sections of the beam and draw the bending moment (BMD) and shear force (SFD) diagrams.

abet_PI_1_25: Cognitive: Applying Describe structural components with various types of loadings like dead load, live load, wind load, earthquake load.

abet_PI_1_26: Cognitive: Understanding State the significance of Structural Analysis for statically indeterminate structures in the Civil Engineering context.

abet_PI_1_28: Cognitive: Understanding Explain scalar and vector definitions of moment of a force about an axis/point or resultant.

abet_PI_1_29: Cognitive: Analyzing Analyze the equilibrium of rigid bodies subjected to frictional forces

abet_PI_1_30: Cognitive: Understanding Memorize and Employ Newton's Second Law to derive other important theories in Fluid Mechanics

abet_PI_1_31: Cognitive: Understanding Derive Bernoulli Equation from Newton's Second Law

abet_PI_1_35: Cognitive: Applying Calculate quantities in fluid mechanics using their basic definition including velocity, acceleration, momentum, pressure

abet_PI_1_36: Cognitive: Understanding Differentiate between mass and weight

abet_PI_1_37: Cognitive: Understanding Differentiate between pressure and force

abet_PI_1_38: Cognitive: Understanding Derive linear momentum equation

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_1_1	(0,0,0,1)	2.5	CE_202_2534	CIVIL ENGINEERING DRAWING	Introductory	2	4	4	2	2.5
abet_PI_1_21	(0,0,0,2)	2.96	CE_201_380	STATICS	Introductory	3	1	4	1	2.78
			CE_201_397	STATICS	Introductory	4	0	3	1	3.13
abet_PI_1_23	(0,1,2,0)	3.04	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	0	3	7	0	2.17
			CE_201_380	STATICS	Introductory	5	2	2	0	3.89
			CE_201_397	STATICS	Introductory	7	0	0	1	4.38
abet_PI_1_25	(0,1,0,0)	3.67	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	5	2	3	0	3.67
abet_PI_1_26	(0,1,0,0)	4.17	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	6	3	1	0	4.17
abet_PI_1_28	(0,0,1,1)	3.22	CE_201_380	STATICS	Introductory	4	3	1	1	3.52
			CE_201_397	STATICS	Introductory	2	4	0	2	2.92
abet_PI_1_29	(0,1,1,0)	3.91	CE_201_380	STATICS	Introductory	5	3	1	0	4.07
			CE_201_397	STATICS	Introductory	5	1	1	1	3.75
abet_PI_1_30	(0,0,1,0)	4.17	CE_351_379	FLUID MECHANICS	Reinforced	10	0	0	2	4.17
abet_PI_1_31	(1,0,0,0)	5	CE_351_379	FLUID MECHANICS	Reinforced	12	0	0	0	5
abet_PI_1_35	(0,1,0,0)	4.58	CE_351_379	FLUID MECHANICS	Reinforced	11	0	0	1	4.58
abet_PI_1_36	(0,0,1,0)	3.61	CE_351_379	FLUID MECHANICS	Reinforced	8	1	0	3	3.61
abet_PI_1_37	(0,0,0,1)	2.36	CE_351_379	FLUID MECHANICS	Reinforced	5	1	0	6	2.36
abet_PI_1_38	(0,1,0,0)	3.61	CE_351_379	FLUID MECHANICS	Reinforced	3	8	1	0	3.61

*Figure 1: Multiple course levels and PIs classified per Bloom's 3 domains learning levels utilized for outcomes measurement***

2. FACULTY COURSE ASSESSMENT REPORT (FCAR) UTILIZING THE EAMU PERFORMANCE VECTOR METHODOLOGY

EvalTools® 6 is chosen as the platform for outcomes assessment since it employs the unique Faculty Course Assessment Report (FCAR) and EAMU performance vector methodology (J. Estell, J. Yoder, B. Morrison, F. Mak, 2012) which facilitate the use of existing curricular grade giving assessments for outcomes measurement and help in achieving a high level of automation of the data collection process (Figure 2.), feature-rich pick-and-choose assessment/ reporting tools, and the flexibility to provide customized features (www.makteam.com, 2015).

The EvalTools® 6 FCAR module provides summative/formative options and consists of the following components: course description, COs indirect assessment, grade distribution, COs direct assessment, assignment list, course reflections, old action items, new action items, student outcomes assessment and performance indicators assessment.

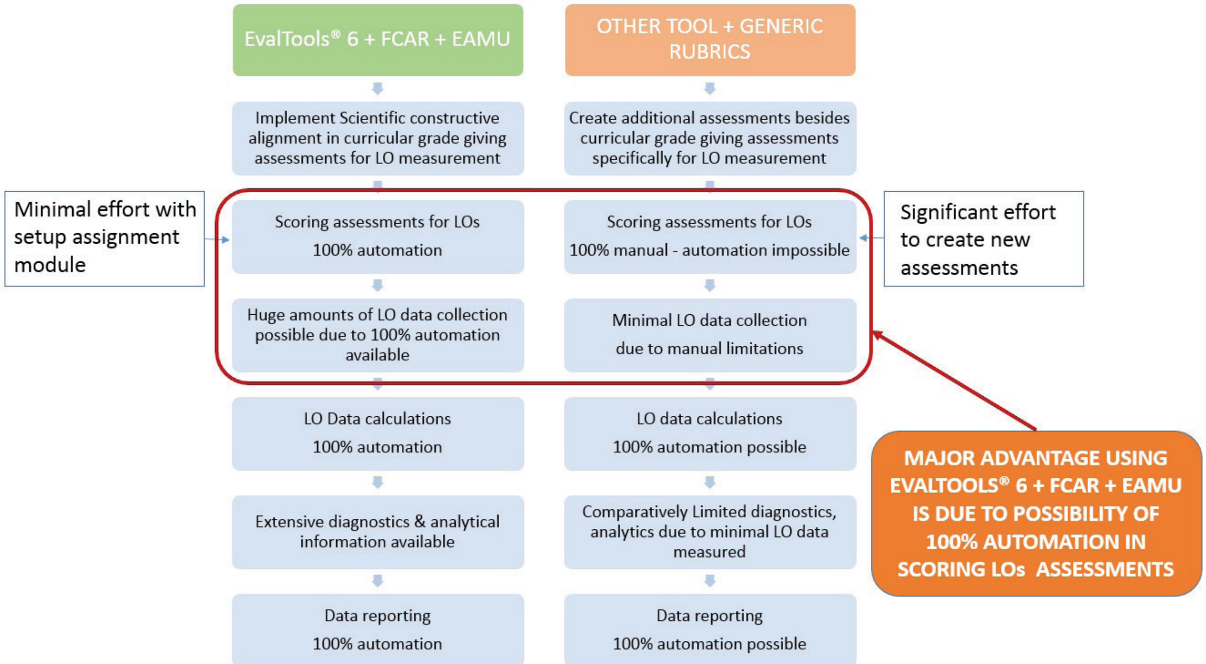


Figure 2: Comparative study of the advantages of automation in outcomes assessment achieved with EvalTools® 6 + FCAR + EAMU versus other tools © 2015 Wajid Hussain

1. Specification of EAMU performance indicator levels:

This set of EAMU performance criteria apply to key assignments that were selected as objective evidences for meeting course outcomes. The setting here applies to all courses as a basic point of reference. However, individual instructors can alter the indicator levels appropriately applied to their own courses as desired.

Category	General Description	Letter Grade	Nominal Indicator Level
Excellent	Student applies knowledge with virtually no conceptual or procedural errors	E	90.0% 100%
Adequate	Student applies knowledge with no significant conceptual errors and only minor procedural errors	A	75.0% - 90.0%
Minimal	Student applies knowledge with occasional conceptual errors and only minor procedural errors	M	60.0% - 75.0%
Unsatisfactory	Student makes significant conceptual and/or procedural errors when applying knowledge	U	0.0% 60.0%

2. Heuristic rules for performance vector tables (PVT):

This set of rules applies to the performance vector tables that are formed by compiling all the key assignments' EAMU results together. The rationalization behind this classification is to streamline the assessment and evaluation processes by focusing on those areas that are out of the ordinary. Based on the color coded flags, the potentail problem areas will be flagged. This set of settign applies to all courses in the program.

Category	General Description	Scale (out of 5)	Maximum Percentage
Red Flag	Any performance vector with an average below the defined scale and a level of unsatisfactory performance that exceeds defined percentage in the U column	below 3.3	and >10%
Yellow Flag	Any performance vector with an average below the defined scale or a level of unsatisfactory performance (U) that exceeds the defined percentage, but not both	below 3.3	or >10%
Green Flag	Any performance vector with an average that is at least greater than the defined scale and no indication of unsatisfactory performance (U)	>= 4.6	
No Flag	Any performance vector that does not fall into one of the above categories		

Figure 3: Performance criteria: EAMU PI levels and heuristic rules for Performance Vector Tables (PVT) adopted by the Faculty of Engineering at the Islamic University of Madinah

The FCAR uses the performance vector, conceptually based on a performance assessment scoring rubric developed by Miller and Olds (R. L. Miller, B. M. Olds, 1999) to categorize aggregate student performance.

The EAMU performance vector (Figure 3) counts the number of students that passed the course whose proficiency for that outcome was rated **E**xcellent, **A**dequate, **M**inimal, or **U**nsatisfactory. Program faculty report failing course outcomes (COs), ABET student outcomes (SOs), performance indicators (PIs), comments on student indirect assessments and other general issues of concern in the respective course reflections section of the FCAR. Based upon these course reflections, new action items are generated by the faculty. Old action items status details are carried over into the current FCAR from the information generated during the previous offering for this specific course. Modifications and proposals to a course are made with consideration of the status of the old action items (W. Hussain, M.F. Addas, 2015).

3. DIGITAL DATABASE OF SPECIFIC PERFORMANCE INDICATORS (PIs) CLASSIFIED PER BLOOM'S REVISED 3 DOMAINS OF LEARNING AND THEIR ASSOCIATED LEVELS (according to the 3-Level Skills Grouping Methodology) (W. Hussain, M. F. Addas and Mak F., ASEE 2016)

An important observation made by the Faculty of Engineering is that Bloom's 3 learning domains present an easier classification of specific PIs for realistic outcomes assessment versus other models that categorize learning domains as knowledge, cognitive, interpersonal, communication/ IT/numerical and/or psychomotor skills. In addition, categories of learning domains which seem very relevant for the engineering industry and career-related requirements may not be practically easy to implement when it comes to classification, measurement of PIs, and realistic final results for CQI measurement.

A hypothetical *Learning Domains Wheel* as shown in Figure 4 was developed by the Faculty of Engineering to analyze the popular learning domains models available, including Bloom's, with a perspective of realistic measurement of outcomes based on valid PIs classification that does not result in a vague indicator mechanism for CQI in engineering education. *Learning domains* categories mentioned in this paper specifically refer to broad categories with well-defined learning levels selected for the classification of specific PIs. The *Learning Domains Wheel* was implemented with Venn diagrams to represent details of the relationship of popular *learning domains categories*, interpersonal skills, and the types of knowledge.

The cognitive domain involves acquiring factual, conceptual knowledge dealing with remembering facts and understanding core concepts. Procedural and metacognitive knowledge deal essentially with problem solving, which includes problem identification, critical thinking and metacognitive reflection. Remembering facts, understanding concepts and problem solving are essential, core and universal cognitive skills that would apply to all learning domains. Problem identification, definition, critical thinking and metacognitive reflection are some of the main elements of problem solving skills. These main elements of problem solving skills apply to all levels of learning for the three domains. Activities related to any learning domain require operational levels of four kinds of knowledge: factual, conceptual, procedural and metacognitive that are proportional to the expected degree of proficiency of skills for proper completion of tasks. For example, successfully completing psychomotor tasks for solving problems involves acquiring very specialized proportions of factual, conceptual, procedural and metacognitive knowledge of various physical processes with accepted levels of their activities skills proficiency. Similarly, an affective learning domain activity, such as implementing a code of professional ethics, involves acquiring factual, conceptual, procedural and metacognitive knowledge related to industry standards, process of application, level of personal responsibility and impact on stakeholders. Hence, the psychomotor and affective domains skills overlap with the cognitive domain for the necessary factual, conceptual, procedural and metacognitive areas of knowledge.

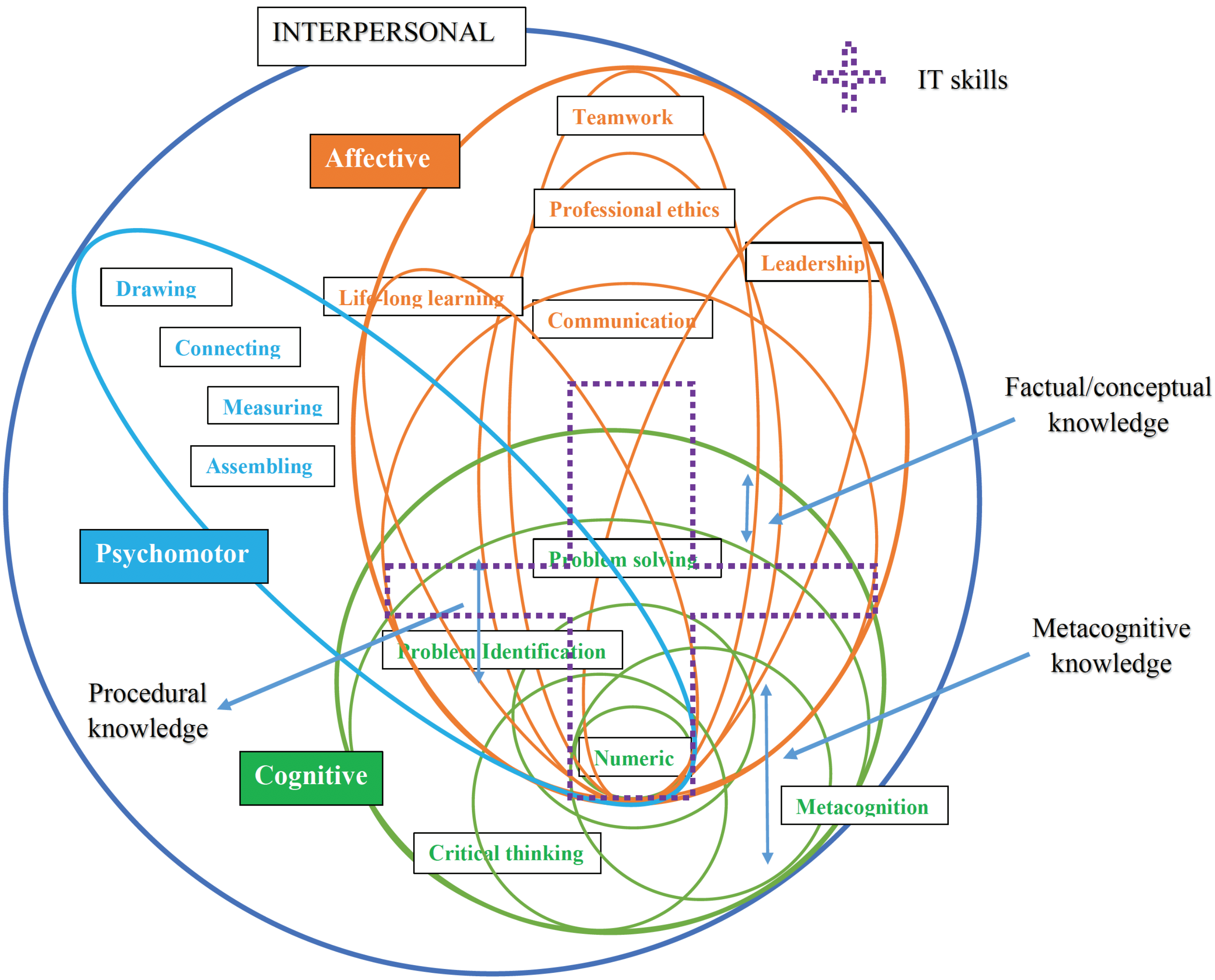


Figure 4: The Learning Domains Wheel for snapshot analysis and selection of learning domains categories to achieve realistic outcomes measurement with easier PIs classification process © 2015 Wajid Hussain

The *learning domains categories* such as interpersonal, IT, knowledge, cognitive, communication, numerical skills etc., exhibit significant areas of overlap as shown in the *Learning Domains Wheel* in Figure 4. This large overlap of skills within multiple *learning domains* presents a serious dilemma to engineering programs in the PIs classification and measurement process. A difficult choice must be made whether to select the most appropriate *learning domain category* and discard the others or repeat mapping similar PIs to multiple learning domain categories for each classification. Defining the learning levels for the overlapping categories to precisely classify PIs would also be challenging. Finally, *learning domain categories* with significant areas of overlap would result in the repeated measurement of common PIs in multiple domains and the accumulation of too many types of PIs in any single *learning domain category*, thus obscuring specific measured information. Therefore, for practical reasons the categories of learning domains have to be meticulously selected with a primary goal of implementing a viable PIs classification process to achieve realistic outcomes measurement for program evaluation.

Crucial guidelines were logically derived from the *Learning Domains Wheel* for the selection of the *learning domains categories* as follows:

1. Very broad learning domains categories consist of many skills sets that will present difficulty in the classification of PIs when grouped with other categories and will result in the redundancy of outcomes data; for example, interpersonal skills grouped with IT, communication or psychomotor, etc.
2. Avoid selection of any two skills sets as learning domains categories when one is an absolute subset of another. Just select either the most relevant one or the one which is a whole set. For example, select cognitive or numeric skills, but not both; if both are required, select cognitive as a category since it is a whole set. Numeric skills, its subset, can be classified as a cognitive skill.
3. If selecting a certain skills set that is a whole set as a learning domains category, then it should not contain any other skills sets which are required to be used as learning domains categories; e.g., do not select affective as a learning domains category since it is a whole set if you also plan on selecting teamwork skills as a category.
4. A learning domain category could contain skills sets which will not be utilized for PIs classification; e.g., affective learning domain category containing leadership, teamwork and professional ethics skills sets; leadership, teamwork and professional ethics will NOT be a learning domain category but will be classified as affective domain skill sets.

Bloom's 3 domains, cognitive, affective and psychomotor, are not absolute subsets of one another. They contain skills sets as prescribed by the 11 EAC ABET SOs which are not *learning domains categorie*s. Therefore Bloom's 3 learning domains satisfy selection guidelines derived from the *Learning Domains Wheel* and facilitate a relatively easier classification process for specific PIs. Calculation of term-wide weighted average values for ABET SOs using this classification of specific PIs resulted in realistic outcomes data since most of the PIs were uniquely mapped to each of the 3 domains with minimal overlap and redundancy.

Figure 5 shows the design flow for the creation of holistic learning outcomes and their performance indicators for all courses corresponding to introductory, reinforced and mastery levels spanning the curriculum. The Faculty of Engineering studied past research, which grouped Bloom's learning levels in each domain based on their relation to the various teaching and learning strategies. With some adjustments, a new *3-Level Skills Grouping Methodology* was developed for each learning domain with a focus on grouping activities which are closely associated to a similar degree of skills complexity. Figure 6 exhibits this new grouping.

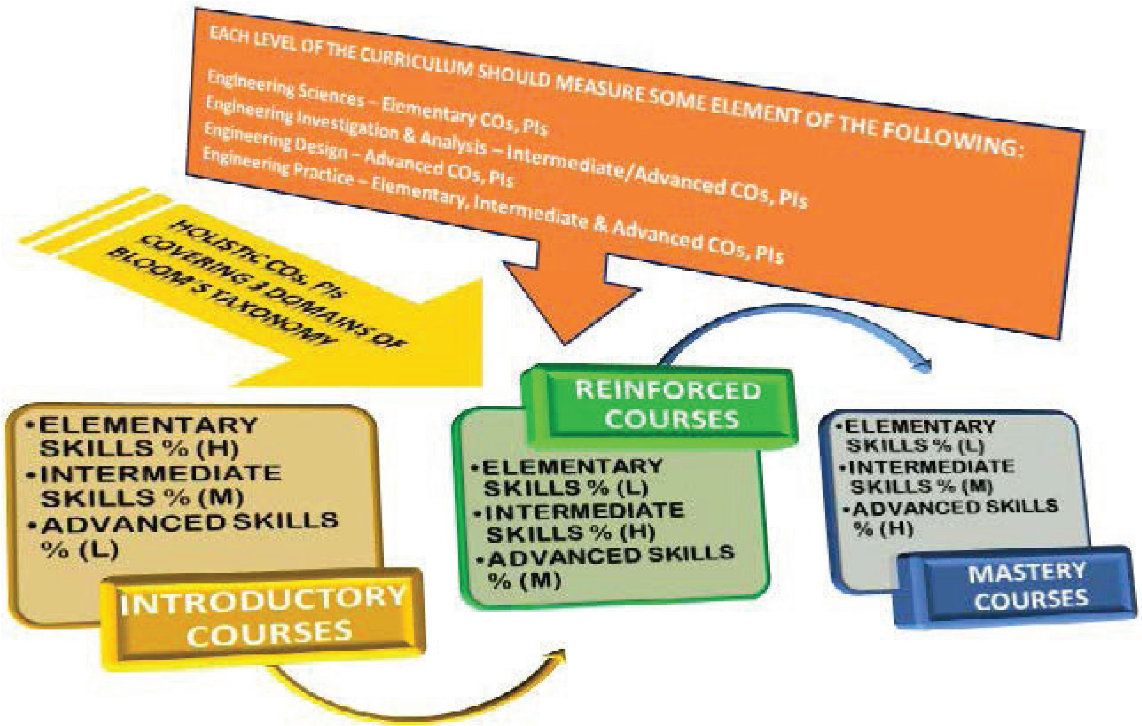


Figure 5: Design flow for the creation of advanced, intermediate and elementary COs, PIs covering three domains of Bloom's taxonomy and spanning courses in different phases of the curriculum © 2015 Wajid Hussain

SKILLS LEVEL	COGNITIVE DOMAIN (Bloom, 1956; Anderson & Krathwohl 2001)	AFFECTIVE DOMAIN (Krathwohl, Bloom, & Masia, 1973)	PSYCHOMOTOR DOMAIN (Simpson, 1972)
ELEMENTARY	1. Knowledge 2. Comprehension	1. Receiving phenomena 2. Responding to phenomena	1. Perception 2. Set 3. Guided response
INTERMEDIATE	3. Application 4. Analysis	3. Valuing	4. Mechanism 5. Complex overt response
ADVANCED	4. Evaluation 5. Creation	4. Organizing values into priorities 5. Internalizing	6. Adaptation 7. Origination

Figure 6: 3-Level Skills Grouping Methodology of Bloom's revised taxonomy © 2015 Wajid Hussain

Performance indicators should be specific to collect precise learning outcomes information related to various course topics and phases of a curriculum, while addressing various levels of proficiency of a measured skill. Design of COs and their PIs was meticulously completed by using appropriate action verbs and subject content, thus rendering the COs, their associated PIs, and assessments at a specific skill level—elementary, intermediate or advanced. Figure 7 shows an example from a civil engineering course. In this example, CO_2: *Describe the composition of soil and solve volume-mass relationship equations for soils*; and its associated specific PI_5_34: *Determine the physical properties of soil using given parameters*; measured by assessment Mid Term Q9 are of similar complexity and at the same level of learning. The corresponding category of learning is *intermediate-cognitive-applying*. Therefore COs would be measured by PIs and assessments strictly following the *3-Level Skills Grouping Methodology*.

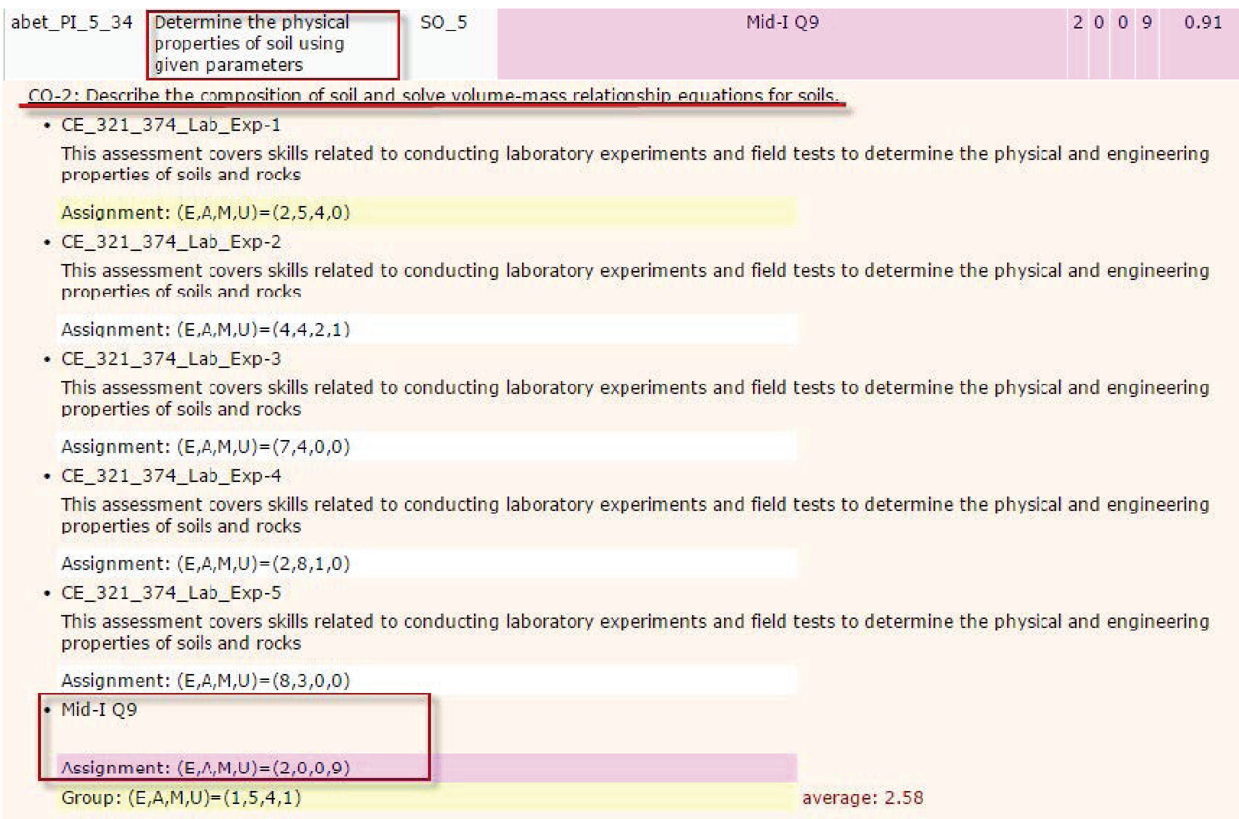


*Figure 7: Example of a civil engineering course showing CO_2, PI_5_34 and assessment Mid Term Q9 assigned to intermediate-cognitive-applying skill level based on the 3-Level Skills Grouping Methodology***

Ideally, all courses should measure the elementary, intermediate and advanced level skills with their COs, specific PIs and associated assessments. However, introductory level courses should measure a greater proportion of the elementary level skills with their COs, PIs and assessments. On the other hand, mastery level courses should measure more of the advanced, but fewer intermediate and elementary level skills. Figure 8 indicates an ideal learning level distribution of COs and PIs for the introductory, intermediate and mastery level courses.

The measurement of outcomes and PIs designed following such an ideal distribution will result in a comprehensive database of learning outcome information, which will facilitate a thorough analysis of each phase of the learning process and a comparatively easier mechanism for early detection of the root cause of student performance failures at any stage of a student's education.

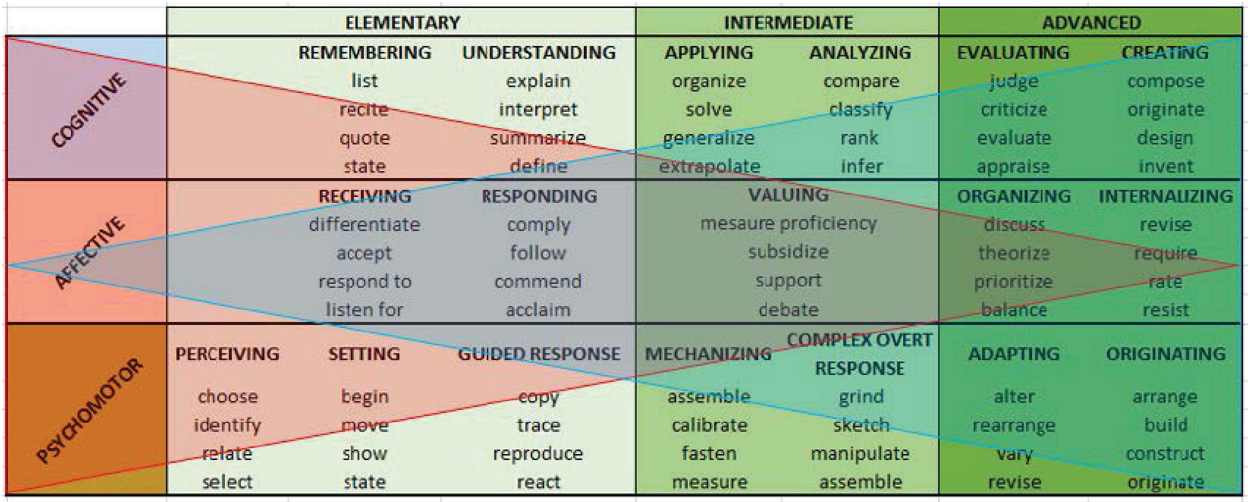


Figure 8: An ideal learning level distribution scenario for COs, PIs and associated assessments for introductory (indicated by shaded red triangle looking L to R) to mastery (indicated by a shaded blue triangle looking R to L) level courses © 2015 Wajid Hussain

The measurement of outcomes and PIs designed following such an ideal distribution will result in a comprehensive database of learning outcome information, which will facilitate a thorough analysis of each phase of the learning process and a comparatively easier mechanism for early detection of the root cause of student performance failures at any stage of a student's education.

4. SCIENTIFIC CONSTRUCTIVE ALIGNMENT AND UNIQUE ASSESSMENTS TO OBTAIN REALISTIC OUTCOMES DATA (one specific PI per assessment)

Designing any assessment related to specific course content would require considering measurement of the most appropriate performance criteria. For scientific constructive alignment, as opposed to conventional constructive alignment, the contribution of various performance criteria to the total score of an assessment would be defined during assessment design. The performance criteria of interest to be measured by a specific assessment would be given a nearly 70% or more share in the total score distribution and the effect of grading results of the other performance criteria on the total score would be thus rendered negligible. Figure 9 shows an example where a sample unique assessment (quiz 2) with high relative coverage (Q2 7 points) is designed with maximum coverage (70%) of a specific PI_5_12 mapping to a CO3, ABET SO5.

Such assessments or set of questions are said to be unique since they are just used once for measurement of a certain PI. This methodology of implementing unique assessments with high relative coverage of PIs mapping to COs and ABET SOs would ensure realistic measurement of outcomes assessment data for comprehensive continuous improvement.

ME 262–Thermodynamics I

Spring Semester 2014-15 (Term 352)

Quiz 2

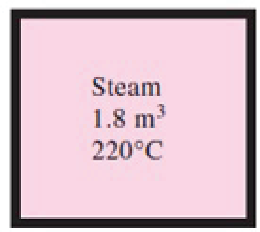
Grade

Name, Family Name : ______________________________________

ID #: ______________________ **Signature :** _______________ **Date: 05/03/2015**

1. What is the physical significance of h_{fg}? Can it be obtained from knowledge of h_f and h_g? How? **[3 Marks]**

2. A 1.8-m^3 rigid tank contains steam at 220°C. One third of the volume is in the liquid phase and the rest is in the vapor form. Determine (*a*) the pressure of the steam, (*b*) the quality of the saturated mixture, and (*c*) the density of the mixture. **[7 Marks]**



For instructor use only (Q 2):

SO 5	an ability to identify, formulate, and solve engineering problems
CO 3	**Explain** phase change processes of pure substances and energy interactions. (Ch 3)
PI_5_12	Apply basic concepts of thermodynamics to solve thermodynamic systems, processes and cycles.

*Figure 9: Scientific constructive alignnment****

5. PROGRAM AND COURSE EVALUATIONS BASED UPON WEIGHTS ASSIGNED TO TYPE AND COUNTS OF ASSESSMENTS ASSOCIATED TO PIs AND COURSE LEVELS

Relevant assignments termed as “key assignments” are used as assessments for measuring specific PIs related to SOs in each course. Most assessments in courses were formative in application (utilizing the formative option in EvalTools® 6) resulting in an adjustment of teaching and learning strategies by faculty. Since assessments are equivalent to learning in the OBE model it was decided to consider the type of assessments, their frequency of implementation and the learning level of measured specific PIs in Bloom’s 3 domains for course and overall program evaluations. At the course level the types of assessments are classified using the course formats chart to calculate their weighting factors (W. Hussain, M.F. Addas, 2015) which are then applied using the setup course portfolio module of EvalTools® 6 . The results are available for view in the FCAR and are used for course evaluations.

The program level SO evaluations employ a weighting scheme which considers the frequency of assessments implemented in various courses for a given term to measure PIs associated with specific learning levels of Bloom's domains (W. Hussain et al., ASEE 2016). Figure 10 shows the EE program term 361 composite (cognitive, affective and psychomotor) learning domains evaluation data for 11 ABET SOs. For each SO the counts and aggregate average values of assessments implemented in various courses for measuring PIs associated with the specific learning levels are shown. (Mastery level courses were not offered in term 361).

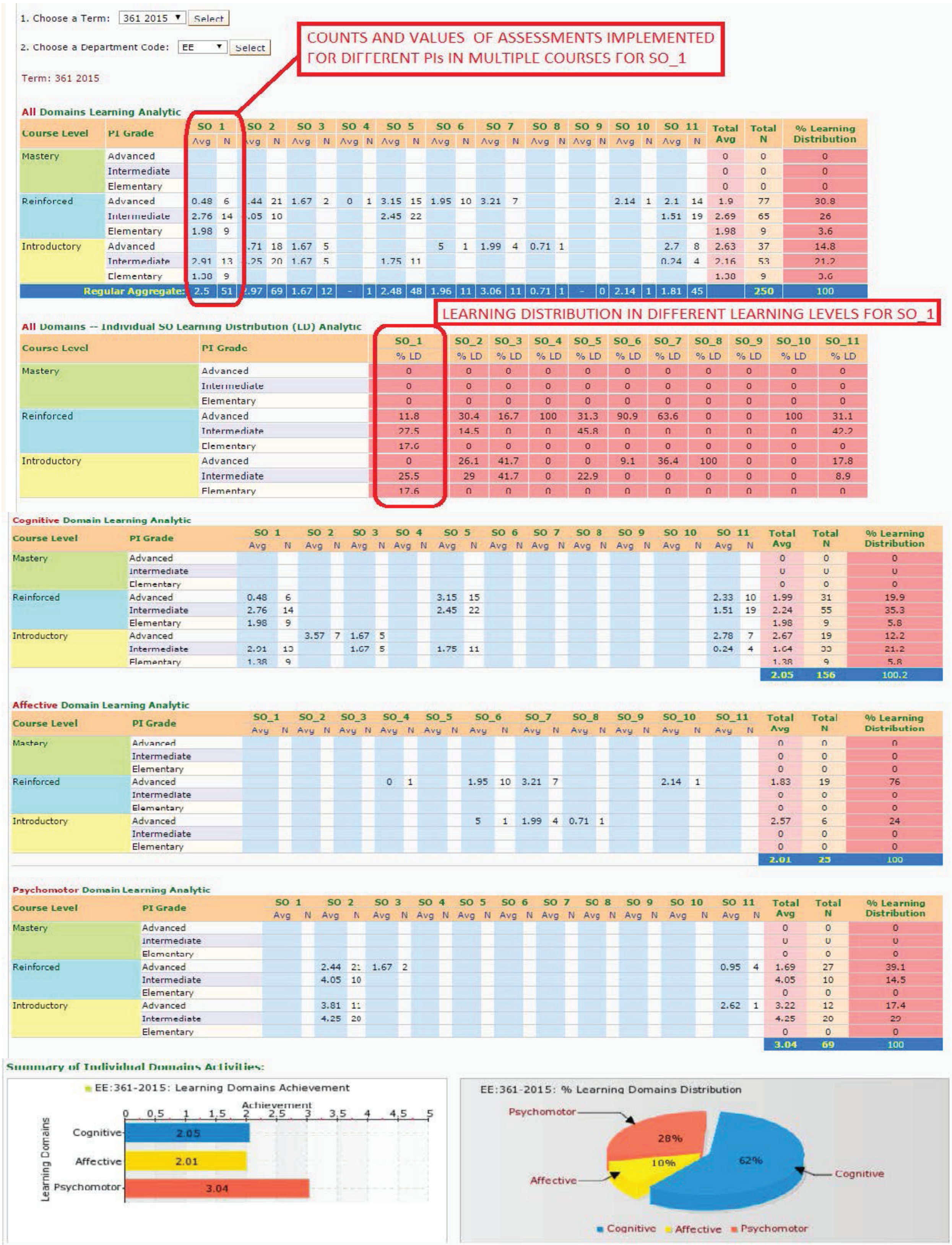


*Figure 10: EE program term 361† Learning domains evaluations***

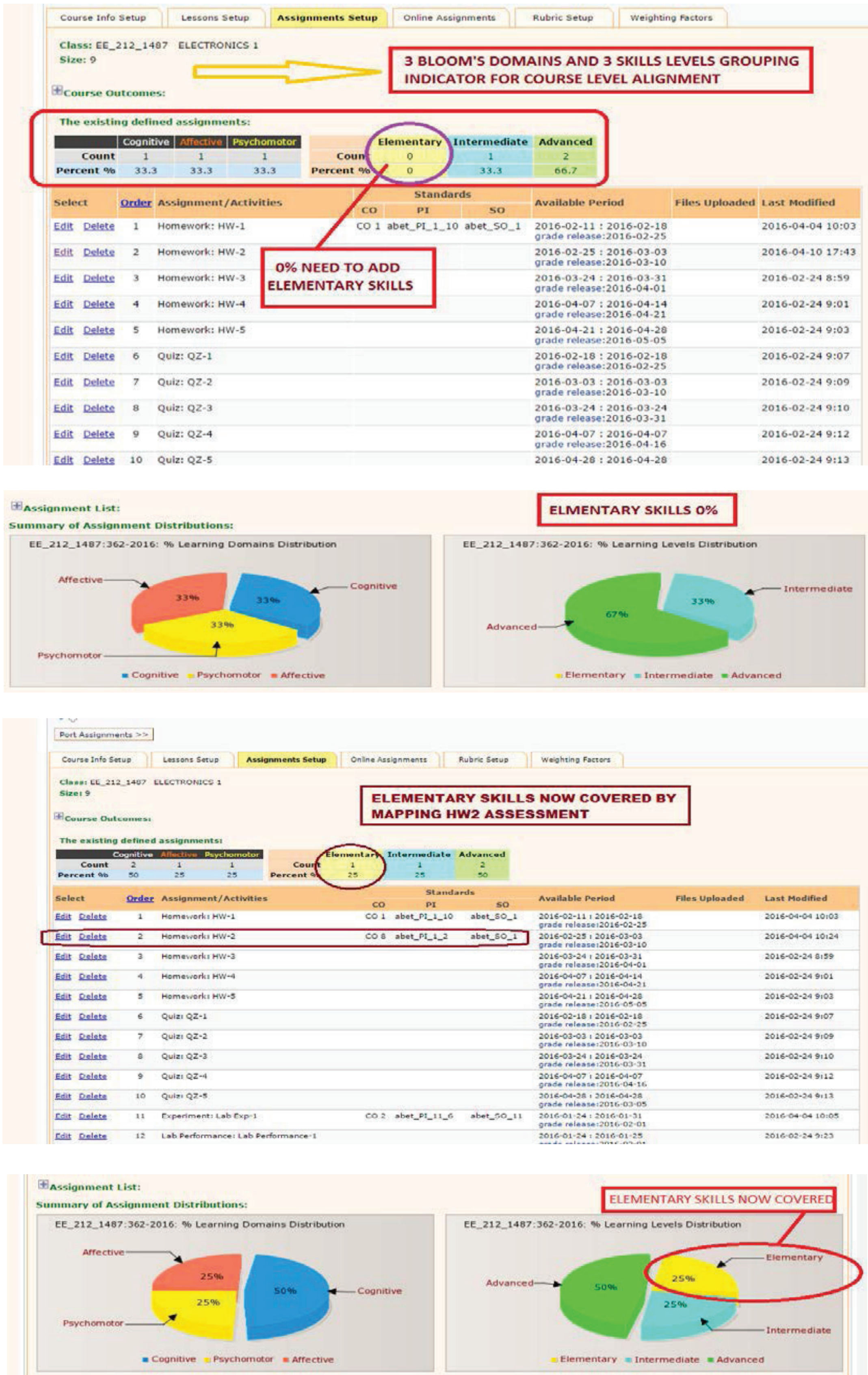


*Figure 11: Course level CQI with alignment of assessments, teaching & learning strategies according to Bloom's 3 domains and 3-Skills Levels Methodology***

Figure 11 shows the course level alignment of assessments, teaching & learning strategies to cover the deficiency in measurement of elementary skills thereby rendering the assessments formative. (W. Hussain, M.F. Addas, Mak F., FIE 2016). Figure 12 shows program term reviews (SO/PI evaluations) report sample exhibiting CQI efforts, action items, discussions etc. (W. Hussain et al., FIE 2016).

Department: EE

Detailed SO/PI Executive Summary Report for 361 2015

SO	Detailed Executive Summary	Average	Classification/ Review Date
abet_SO_1	**abet SO 1 : Overall Summary** Discussion: Math skills, additional examples and lectures, preparation for quizzes were discussed Reviewers: Dr. Saleh Al Ahmadi, Dr. Kemal Fidanboylu, Dr. Imdad Khan, Dr. Laiq Khan, DR. Mazhar, Dr. H Abdul Wajid, Dr. Azzedine Draou, Dr. Hassan Chattha, Mr. Mohiuddin, Mr. Arshad K V, Mr. Shujaur Rahman, Mr. Wajid Hussain	2.50	Below Expectations 2016-03-03
	abet_PI_1_12. Discussion: Students' preparation for quizzes was discussed Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2016-03-01	2.86	Below Expectations
	abet_PI_1_25: Discussion: Math skills especially performance with linear equations were discussed. Action: FCAR AIs were reviewed and necessary elevations to concerned committees were processed Review Date: 2016 03 01	0.00	Below Expectations
	abet_PI_1_27: Discussion: ME_1_Q4, LAB QZ-6, LAB QZ-7 : The topics of Thevenin and Norton theorems are not properly understood by the students in this phase of the course Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2016 03 01	1.43	Below Expectations
	abet_PI_1_44: Discussion: LAB QZ1, FE Q1_1: These were the first assignments in the course and he students were inadequate in their preparation and seriousness for the assignments Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2016-03-01	0.74	Below Expectations

*Figure 12: Program term reviews (SO/PI evaluations) report sample exhibiting CQI efforts, action items, discussions etc***

6. ELECTRONIC INTEGRATION OF ADMINISTRATIVE ASSISTANT SYSTEM (AAS), LEARNING MANAGEMENT SYSTEM (LMS) WITH OUTCOMES ASSESSMENT SYSTEM (OAS) AND CONTINUOUS IMPROVEMENT MANAGEMENT SYSTEM (CIMS) FACILITATING FACULTY INVOLVEMENT FOR REALISTIC CQI

7. ELECTRONIC INTEGRATION OF ACTION ITEMS (AIs) GENERATED FROM PROGRAM OUTCOMES TERM REVIEWS WITH STANDING COMMITTEES MEETINGS, TASKS LISTS AND OVERALL CQI PROCESSES (CIMS FEATURE) (W. Hussain et al., ASEE 2016)

A minority of faculty members were initially reluctant to implement digital technology incorporating FCAR methodology and PIs classification per Bloom's 3 domains. One of the reasons for this resistance was the lack of comprehension of ABET accreditation, latest outcomes assessment processes, and experience regarding their management. Detailed training sessions followed up with extensive technical and intellectual support from the Office of Quality and Accreditation for the Faculty of Engineering significantly alleviated their reservations. Various program level sessions held for the development and classification of specific PIs actually galvanized the interest levels of faculty members by providing them with a first-hand learning experience to develop measurable learning outcomes, their PIs and assessments as per Bloom's 3 domains, and their learning levels. The most difficult aspect of continuous improvement and accreditation efforts for faculty members was to create action items for improvement based upon deficient outcomes assessment data, assign them to the concerned parties or individuals, and follow up for closing the loop. Implementing physical systems to maintain huge amounts of paper-based documentation and manual processes to access specific, on-time information for CQI activity related to closing the loop were specifically the biggest challenges faced by the faculty members.

The Continuous Improvement Management System (CIMS) provided our faculty with efficient streamlining mechanisms for quality improvement efforts by employing very high levels of automation and paper-free digital documentation. Instant electronic access to digital records of single or multi-term outcomes assessment information from program reviews and detailed meeting minutes, action items status of 17 standing committees, essential for CQI efforts, were compelling reasons for an eventual, almost 100% faculty buy-in of the implemented digital systems and outcomes assessment methodologies.

With a majority of positive aspects, one limitation of our system, the allocation of resources to scan paper documents, is currently performed by either the lecturers or teaching assistants. Work is currently in progress to develop state-of-the-art digital systems that automate outcomes assessment development and scoring processes. This technology would integrate with existing digital systems to significantly reduce the overhead related to overall time spent by faculty in the outcomes assessment process and scanning work done by lecturers. In conclusion, we have achieved our goal to evaluate engineering programs based on the automated measurement of PIs classified into the cognitive, affective and psychomotor learning domains of the revised Bloom's taxonomy.

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† Islamic University of Madinah semester naming system, where first two digits '36' refer to the local year code and the last digit refers to the semester, 1: fall, 2: spring and 3: summer.

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Hussain, W., Addas, M. F., and Mak, F. (2016). *Quality improvement with automated engineering program evaluations using performance indicators classified based upon Bloom's 3 domains*. Submitted to FIE 2016 conference, Erie, PA.

SOURCES OF FURTHER INFORMATION

Further Information on outcomes assessment methodology, 3-level skills grouping methodology & the learning domains wheel available at http://engineering.iu.edu.sa/index.php/assessment-methodology/

Information on EvalTools® available at http://www.makteam.com

W. Hussain: Digital Technology for Outcomes Assessment in Higher Education, https://www.youtube.com/watch?v=JaQ0trgk6YE

W. Hussain: Automated Engineering Program Outcomes, Bloom's Learning Domains Evaluations https://www.youtube.com/watch?v=HAGaoRUrJlE

Please Cite As:

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About NILOA

- The National Institute for Learning Outcomes Assessment (NILOA) was established in December 2008, and is co-located at the University of Illinois and Indiana University.
- The NILOA website contains free assessment resources and can be found at http://www.learningoutcomesassessment.org.
- The NILOA research team has scanned institutional websites, surveyed chief academic officers, and commissioned a series of occasional papers.

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Paper ID #14792

Engineering Program Evaluations Based on Automated Measurement of Performance Indicators Data Classified into Cognitive, Affective, and Psychomotor Learning Domains of the Revised Bloom's Taxonomy

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Engineering Program Evaluations Based on Automated Measurement of Performance Indicators Data Classified into Cognitive, Affective and Psychomotor Learning Domains of the Revised Bloom's Taxonomy

***Abstract*:** This research references past work which indicates that the major driving force of outcomes assessment initiatives in engineering institutions has been regional and specialized accreditation standards. Continuous quality improvement and accreditation-based activity at various engineering institutions remain as relatively isolated processes, with realistic continuous quality improvement efforts maintaining minimal reference to learning outcomes assessment data measured for accreditation. The lack of utilization of digital technology and appropriate methodologies supporting the automation of outcomes assessment further exacerbate this situation. Furthermore, learning outcomes data measured by most institutions is rarely classified into all three domains of the revised Bloom's taxonomy and their corresponding categories of the levels of learning. Generally institutions classify courses of a program curriculum into three levels: introductory, reinforced and mastery. The outcomes assessment data is measured for mastery level courses in order to streamline the documentation and effort needed for an effective program evaluation. A major disadvantage of this approach is that it does not facilitate early remediation of performance failures because necessary outcomes information related to deficient teaching and learning mechanisms is measured only for mastery level courses. A holistic approach for continuous quality improvement in academic learning would require a systematic measurement of performance indicators in all three domains and their corresponding categories of learning levels for all course levels in a given program's curriculum.

In this research, we present an innovative methodology for engineering program evaluation utilizing significant customization implemented in a web-based software, EvalTools® 6. Unique curricular assessments implementing scientific constructive alignment are utilized for the measurement of specific performance indicators related to ABET student outcomes. Performance indicators are classified according to the three domains of the revised Bloom's taxonomy and their corresponding categories of learning levels. Final values of ABET student outcomes used as a performance index in program term reviews are obtained based on calculations applying an intelligent weighted averaging algorithm to associated performance indicators. The weights are related to the numerical counts of performance indicators measured for the different levels of learning for each of the three domains in multiple course levels. Analytical information related to the performance indicators measured for multiple course levels, their distribution in each of the learning domains, and corresponding categories of learning levels provide valuable information that helps identify specific areas for improvement in the education process.

I. Introduction

Assessment is an essential element of the educational process and is the basis of Continuous Quality Improvement (CQI). Educational assessment refers to all activities which provide information to be used as feedback to revise and improve instruction and learning strategies [1,14]. Recently, a new trend in educational assessment has been observed with more academic institutions moving away from traditional curriculum-based assessment models towards outcomes-based ones [4,5]. According to some recent studies, students enrolled in respected academic institutions often fail to exhibit fundamental understanding of basic concepts and fairly easy physical systems [7]. This is mainly because curriculum-based education models do not usually make clear measurable statements as to what students are expected to achieve upon completing a program of study. Having a carefully designed curriculum and a highly qualified faculty do not necessarily mean that students comprehend the offered material. Therefore, to improve the efficiency of learning processes, academic institutions are increasingly adopting Outcomes-Based Education (OBE) models for curriculum design and delivery [2]. A list of current signatories of the Washington Accord presents strong evidence of a global migration towards OBE [3]. The Accreditation Board of Engineering and Technology (ABET) is a founding member of the Washington Accord since 1989 [49]. Recently, the Canadian Engineering Accreditation Board (CEAB) has updated its accreditation criteria to adopt the OBE model [4]. Just a few years ago, the National Commission of Academic Accreditation and Assessment (NCAAA) in Saudi Arabia was established, following the OBE model [48]. This shift makes institutions focus more on assessing the expected outcomes of the educational experience rather than the quality of the offered curriculum.

Additionally, the learning outcomes data measured by most engineering institutions are rarely classified into all three learning domains of the revised Bloom's taxonomy [38] and their corresponding categories of the levels of learning. Generally, institutions classify courses of a program curriculum into three levels: introductory, reinforced, and mastery, with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for an effective program evaluation. This approach presents a major deficiency for CQI in a student-centered OBE model because performance information collected at just the mastery level is at the final phase of a typical quality cycle and is too late for implementation of remedial efforts. Instead, student outcomes and performance criteria progressing from the elementary to advanced levels should be measured at the course level for all courses spanning the entire curriculum [42,43]. A holistic approach for a CQI model would require a systematic measurement of performance indicators in all three of Bloom's domains of learning and their corresponding categories of learning levels for all course levels of a program's curriculum.

It is clearly stated in multiple research papers published by the National Institute of Learning Outcomes Assessment (NILOA) [15,16] and others [5,17,18] that in many higher education institutions, actual CQI and accreditation efforts are minimally integrated and that ideally CQI instead of accreditation standards should be the prime driver for outcomes assessment. Unfortunately, accreditation was the prime driver for outcomes assessment and the topic of more than 1,300 journal articles between 2002 and 2004 [5]. The indispensable necessity of digital technology to automate and streamline outcomes assessment for accreditation is explained in many research papers [19,20,21,36,37,40]. State-of-the-art digital technology-based outcomes assessment systems would definitely help fulfill accreditation standards and achieve excellent CQI results as well.

Faculty compliance for outcomes assessment has been quoted by many [6,9,10,20,26,30,36,37,40] as a major issue in achieving realistic CQI. A majority of faculty members are not keen to get involved in the assessment process, mostly because they are not familiar with the assessment process and/or the methods used. Hence, there exists a dire need to explore avenues by which faculty can become actively engaged in the assessment process at the course and program levels. Myriad complexities related to improper tools that do not integrate multiple processes for direct/indirect outcomes assessment for the identification of failures, remedial actions and CQI are identified as the root cause for the lack of faculty involvement. A paper-free web-based digital system with a user-friendly interface encouraging faculty participation while integrating multiple outcomes assessment processes for CQI is therefore highly desired [30].

The above-mentioned recent global trends highlighting a shift towards OBE coupled with established arguments in favor of automation presented in research literature summarize the fact that automation of outcomes assessment using state of the art digital technology is essential for CQI in education.

II. Methodology for Assessment

The Faculty of Engineering at the Islamic University of Madinah has studied various options for developing its assessment methodology and systems [5,6,7,8,9] to establish actual CQI and not just to fulfill accreditation requirements of ABET [49] or NCAAA [48]. The following points summarize the essential elements chosen by the faculty to implement state-of-the-art assessment systems for achieving realistic CQI in engineering education:

1. OBE assessment model
2. ABET, Engineering and Accreditation Commission (EAC) outcomes assessment model employing Program Educational Objectives (PEOs), 11 EAC Student Outcomes (SOs) and Performance Indicators (PIs) to measure Course Outcomes (COs)
3. Measurement of outcomes information in all course levels of a program curriculum: introductory, reinforced and mastery.
4. The Faculty Course Assessment Report (FCAR) utilizing the EAMU (Excellent, Adequate, Minimal, Unsatisfactory) performance vector methodology [33,34,35,36]
5. Well-defined performance criteria for course and program levels
6. A digital database of specific PIs [25] classified as per Bloom's revised 3 domains of learning and their associated levels (according to the *3-Level Skills Grouping Methodology*)
7. Unique Assessments mapping to one specific PI [37]
8. Scientific Constructive Alignment for designing assessments to obtain realistic outcomes data representing information for one specific PI per assessment[13,27,28,29,37]
9. Integration of direct, indirect, formative and summative outcomes assessments for course and program evaluations
10. Calculation of program and course level ABET SOs, COs data based upon weights assigned to type of assessments, PIs and course levels
11. Course, program and student level measurement and analysis of ABET SOs [37]
12. A student academic advising module related to measured outcomes data
13. Electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS), Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI [32,37]
14. Electronic integration of Action Items (AIs) generated from program outcomes term reviews with the Faculty of Engineering standing committees' meetings, tasks lists and overall CQI processes (CIMS feature)
15. Customized web-based software EvalTools® 6 facilitating all of the above [32]

In the following sections, we will elaborate on the program evaluation mechanism using computed performance indices for ABET SOs as indicators while specifically focusing on points 6 and 11.

III. Outcomes Assessment Model and ABET SOs for Program Accreditation

The OBE model is chosen due to the many benefits discussed earlier and for the fulfillment of regional and ABET accreditation standards. ABET criteria for program accreditation have been implemented in the assessment model, which requires that programs make decisions using assessment data collected from students and other program constituencies, thus ensuring a quality program improvement process. This requires development of quantitative/qualitative measures to make sure that students have satisfied the COs which are measured using a set of specific PIs/assessments and consequently the program level ABET SOs [49]. Figure 1 shows the outcomes assessment model adopted by the Faculty of Engineering at the Islamic University of Madinah. The assessment model involves activities like comprehensive review of the PEOs, ABET SOs, PIs/assessments and COs leading to further improvement in the program. All activities in the various phases of the CQI process actively involve faculty members.

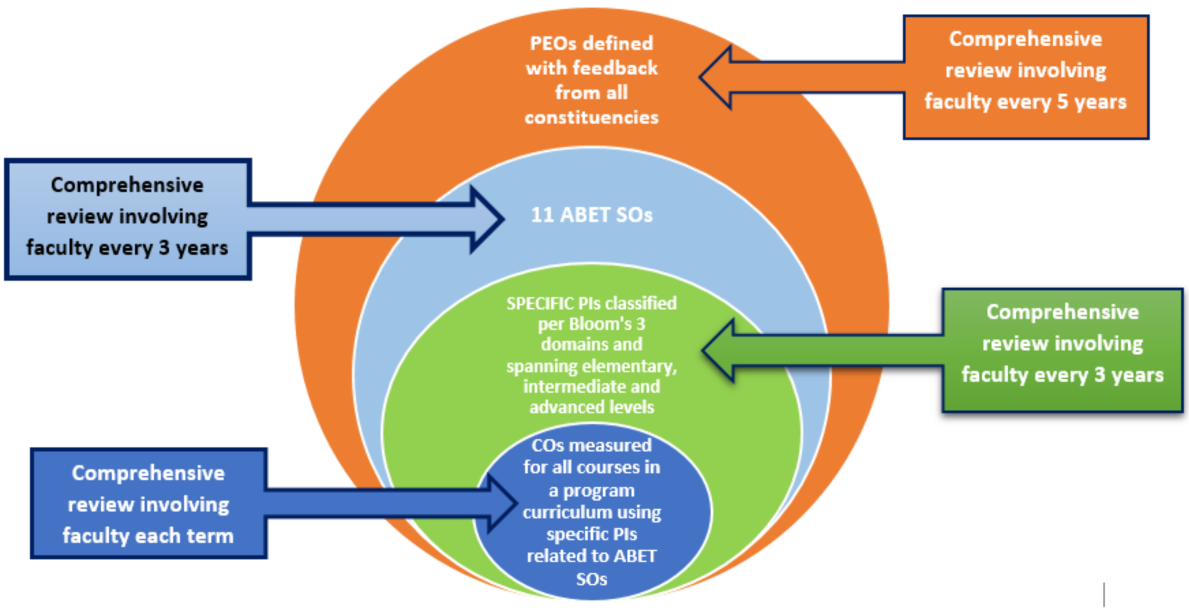


Figure 1: Faculty of Engineering's comprehensive outcomes assessment model

IV. COs, Specific PIs and Associated Assessments Classification Based upon the Revised Bloom's Taxonomy, 3 Domains and Their Learning Levels

Figure 2 shows the design flow for the creation of holistic learning outcomes and their performance indicators for all courses corresponding to introductory, reinforced and mastery levels spanning the curriculum. The Faculty of Engineering studied past research [44], which grouped Bloom's learning levels in each domain based on their relation to the various teaching and learning strategies. With some adjustments, a new *3-Level Skills Grouping Methodology* was developed for each learning domain with a focus on grouping activities which are closely associated to a similar degree of skills complexity. Figure 3 exhibits this new grouping.

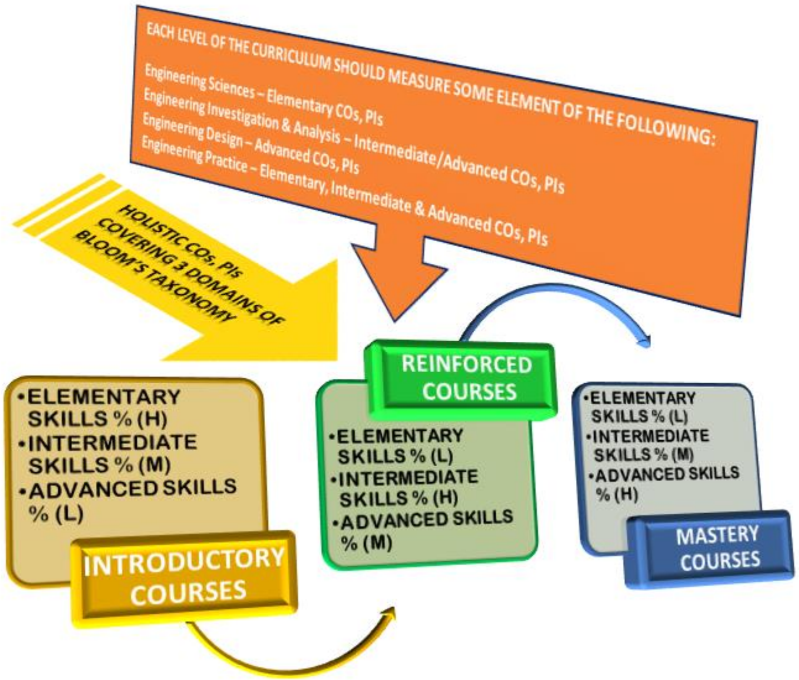


Figure 2: Design flow for the creation of advanced, intermediate and elementary COs, PIs covering three domains of Bloom's taxonomy and spanning courses in different phases of the curriculum

Skills Level	Cognitive Domain (Bloom, 1856; Anderson & Krathwohl, 2001)	Affective Domain (Krathwohl, Bloom & Masia, 1973	Psychomotor Domain (Simpson, 1972)
Elementary	1. Knowledge 2. Comprehension	1. Receiving phenomena 2. Responding to phenomena	1. Perception 2. Set 3. Guided response
Intermediate	3. Application 4. Analysis	3. Valuing	4. Mechanism 5. Complex overt response
Advanced	5. Evaluation 6. Creation	4. Organizing values into problems 5. Internalizing	6. Adaptation 7. Origination

Figure 3: 3-Level skills grouping methodology of Bloom's revised taxonomy

Performance indicators should be specific to collect precise learning outcomes information related to various course topics and phases of a curriculum, while addressing various levels of proficiency of a measured skill [11,25,26,29,37,42,43]. Design of COs and their PIs was meticulously completed by using appropriate action verbs and subject content, thus rendering the COs, their associated PIs, and assessments at a specific skill level—elementary, intermediate or advanced. Figure 4 shows an example from a civil engineering course. In this example, CO_2: *Describe the composition of soil and solve volume-mass relationship equations for soils*; and its associated specific PI_5_34: *Determine the physical properties of soil using given parameters*; measured by assessment Mid Term Q9 are of similar complexity and at the same level of learning. The corresponding category of learning is *intermediate-cognitive-applying*. Therefore COs would be measured by PIs and assessments strictly following the *3-Level Skills Grouping Methodology*.

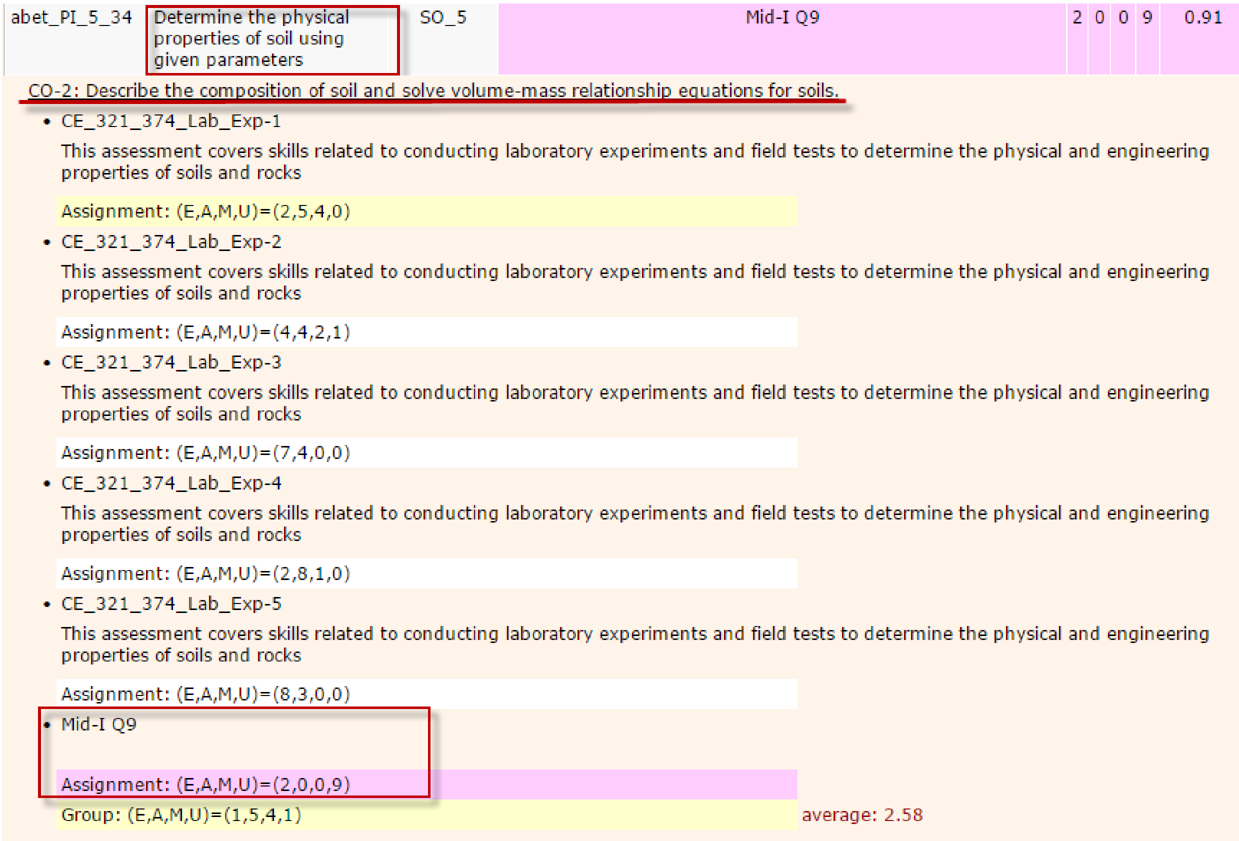


Figure 4: Example of a civil engineering course showing CO_2, PI_5_34 and assessment Mid Term Q9 assigned to *intermediate-cognitive-applying* skill level based on the *3-Level Skills Grouping Methodology*

Ideally, all courses should measure the elementary, intermediate and advanced level skills with their COs, specific PIs and associated assessments. However, introductory level courses should measure a greater proportion of the elementary level skills with their COs, PIs and assessments. On the other hand, mastery level courses should measure more of the advanced, but fewer intermediate and elementary level skills. Figure 5 indicates an ideal learning level distribution of COs and PIs for the introductory, intermediate and mastery level courses.

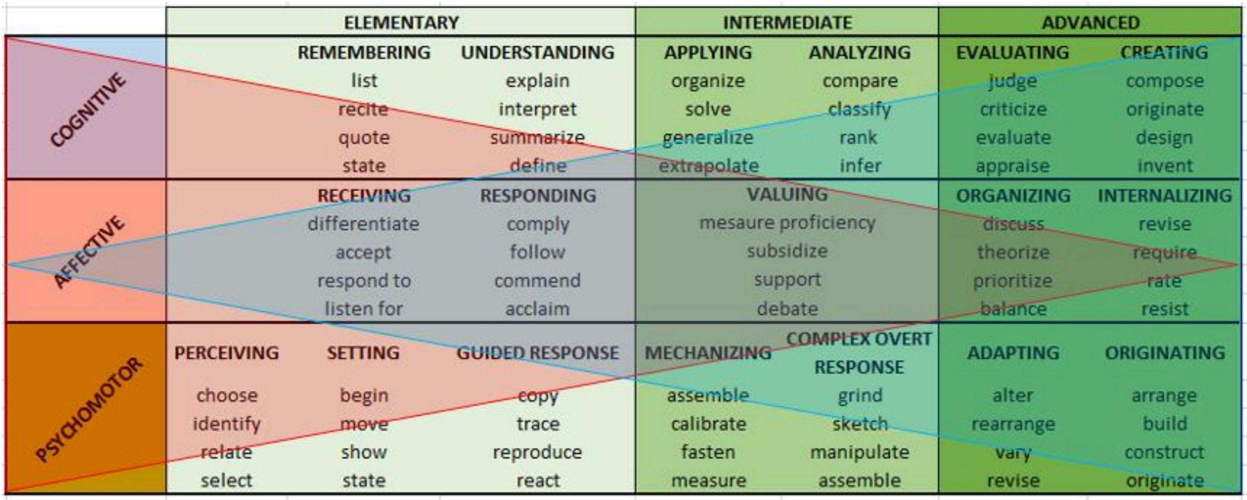


Figure 5: An ideal learning level distribution scenario for COs, PIs and associated assessments for introductory (indicated by shaded red triangle looking L to R) to mastery (indicated by a shaded blue triangle looking R to L) level courses

The measurement of outcomes and PIs designed following such an ideal distribution will result in a comprehensive database of learning outcome information, which will facilitate a thorough analysis of each phase of the learning process and a comparatively easier mechanism for early detection of the root cause of student performance failures at any stage of a student's education [37].

V. ABET SOs Coverage of Bloom's 3 Domains by Measurement of Associated COs and PIs

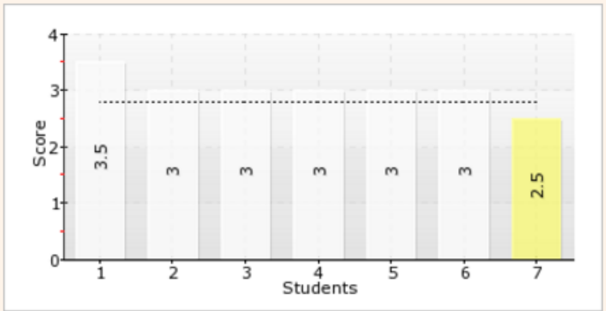
Any CO can map to multiple ABET SOs using different assessments and the unique assessments rule [37]. In an example shown in Figure 6, we consider an electrical engineering course, Electric Circuits, where CO_2: *Apply voltage and current division rules appropriately to solve simple circuits*; its associated PI_5_19: *Apply circuit theorems (source transformation, parallel/series element combinations, voltage, current divider rules, delta/wye transformations) to simplify the analysis of circuits and construct basic circuits and measure currents and voltages within those circuits*; and assessment Mid Term Exam-1Q3 are at *Intermediate-Cognitive level* (since applying and analyzing correspond to the intermediate skills level refer Figure 3.) relating to ABET SO 'e' (SO_5): *An ability to identify, formulate and solve engineering problems.*

The same CO_2 has another associated PI_2_18: *Analyze and interpret electrical engineering experimental data and output information from electrical tests and experiments;* and assessment Lab Report-3 at *Intermediate-Cognitive* level (analysis) relating to ABET SO 'b' (SO_2): *An ability to design and conduct experiments, as well as to analyze and interpret data.*

Therefore, a specific CO can be used to map to multiple ABET SOs using several specific PIs, different assessments, and cover multiple domains of the revised Bloom's taxonomy [37].

CO-4: Apply voltage and current division rules appropriately to solve simple circuits.

- Midterm Exam-1Q3

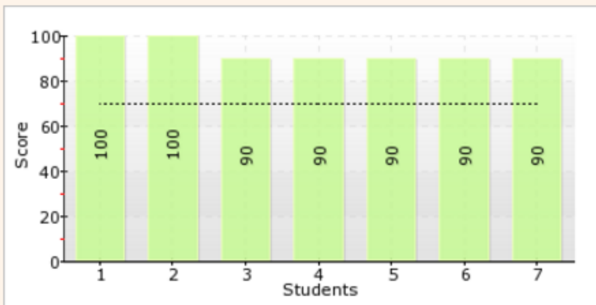


scale: 4,

weighted: 12%

Assignment: (E,A,M,U)=(0,6,1,0)

- Lab Report 3



scale: 100, weighted: 0.66%

Assignment: (E,A,M,U)=(7,0,0,0)

Group: (E,A,M,U)=(0,6,1,0) average: 3.1

abet_PI_2_18	Analyze and interpret electrical engineering experimental data and output information from electrical tests and experiments	SO_2	Lab Performance 9	5	2	0	0	4.52
			Lab Report 3	7	0	0	0	5
			Lab Performance 3	6	1	0	0	4.76
			Lab Performance 9,Lab Report 3,Lab Performance 3,	5	2	0	0	4.52
abet_PI_5_19	Apply circuit theorems (source transformation, parallel/series element combinations, voltage, current divider rules, delta/wye transformations) to simplify the analysis of circuits and construct basic circuits and measure currents and voltages within those circuits	SO_5	Midterm Exam-1Q3	0	6	1	0	3.1
			Midterm Exam-2Q2	4	3	0	0	4.29
			Final Exam-Q1-2	2	5	0	0	3.81
			Lab Quiz 3	6	0	1	0	4.52
			Lab Quiz 5	6	0	0	1	4.29
			Midterm Exam-1Q3,Midterm Exam-2Q2,Final Exam-Q1-2,Lab Quiz 3,Lab Quiz 5,	1	6	0	0	3.57

Figure 6: An example of an electrical engineering course, Electric Circuits, showing how one CO can map to multiple ABET SOs using various specific PIs

In an OBE model, assessments related to specific PIs measure the level of teaching and learning achievement and help outline future actions related to course delivery, syllabus, teaching and learning strategies for CQI [10,11,12,14,25,31,41,45]. By performing an exhaustive design and classification exercise of several hundred specific PIs related to COs and ABET SOs for the Electrical Engineering (EE), Mechanical Engineering (ME) and Civil Engineering (CE) programs, the Faculty of Engineering has observed that ABET SOs exhibit relevance and coverage of the revised Bloom's learning domains as shown in Table 1. In Table 1, 'H' High; 'M': Medium; or 'L": Low; refers to the degree of relevance and coverage of an ABET SO for a learning domain, which is estimated by the type, number of activities and assessments processed in different courses of a program in a given term for the measurement of PIs related to this learning domain. Hence it is important to note that Table 1 is hypothetically generated without actual outcomes measurement by using assessments and their counts information from various courses, but rather based purely upon theoretical grounds as a result of a *semantic analysis* of the 11 ABET SOs and their classified PIs. A later section of this paper will compare the results of actual measured ABET SOs data in 3 domains with this hypothetical information.

Table 1: Hypothetical relevance and coverage of ABET SOs to Bloom's 3 learning domains

SO_NO.	ABET SOs	DOMAINS RELEVANCE & COVERAGE		
		COGNITIVE	AFFECTIVE	PSYCHOMOTOR
SO_1	a. an ability to apply knowledge of mathematics, science and engineering	H	L	L
SO_2	b. an ability to design and conduct experiments, as well as to analyze and interpret data	H	M	H
SO_3	c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	H	H	H
SO_4	d. an ability to function on multidisciplinary teams	M	H	L
SO_5	e. an ability to identify, formulate, and solve engineering problems	H	L	L
SO_6	f. an understanding of professional and ethical responsibility	M	H	L
SO_7	g. an ability to communicate effectively	M	H	M
SO_8	h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	M	H	L
SO_9	i. a recognition of the need for, and an ability to engage in life-long learning	M	H	L
SO_10	j. a knowledge of contemporary issues	M	H	L
SO_11	k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	H	L	H

VI. Appropriateness of Using Bloom's Three Learning Domains for the Classification of Specific PIs for Realistic Measurement of ABET SOs

An important observation made by the Faculty of Engineering is that Bloom's 3 learning domains present an easier classification of specific PIs for realistic outcomes assessment versus other models that categorize learning domains as knowledge, cognitive, interpersonal, communication/ IT/numerical and/or psychomotor skills [48]. In addition, categories of learning domains which seem very relevant for the engineering industry and career-related requirements may not be practically easy to implement when it comes to classification, measurement of PIs, and realistic final results for CQI measurement.

A hypothetical *Learning Domains Wheel* as shown in Figure 7 was developed by the Faculty of Engineering to analyze the popular learning domains models available, including Bloom's, with a perspective of realistic measurement of outcomes based on valid PIs classification that does not result in a vague indicator mechanism for CQI in engineering education. *Learning domains categories* mentioned in this paper specifically refer to broad categories with well-defined learning levels selected for the classification of specific PIs. *The Learning Domains Wheel* was implemented with Venn diagrams to represent details of the relationship of popular *learning domains categories*, interpersonal skills, and the types of knowledge.

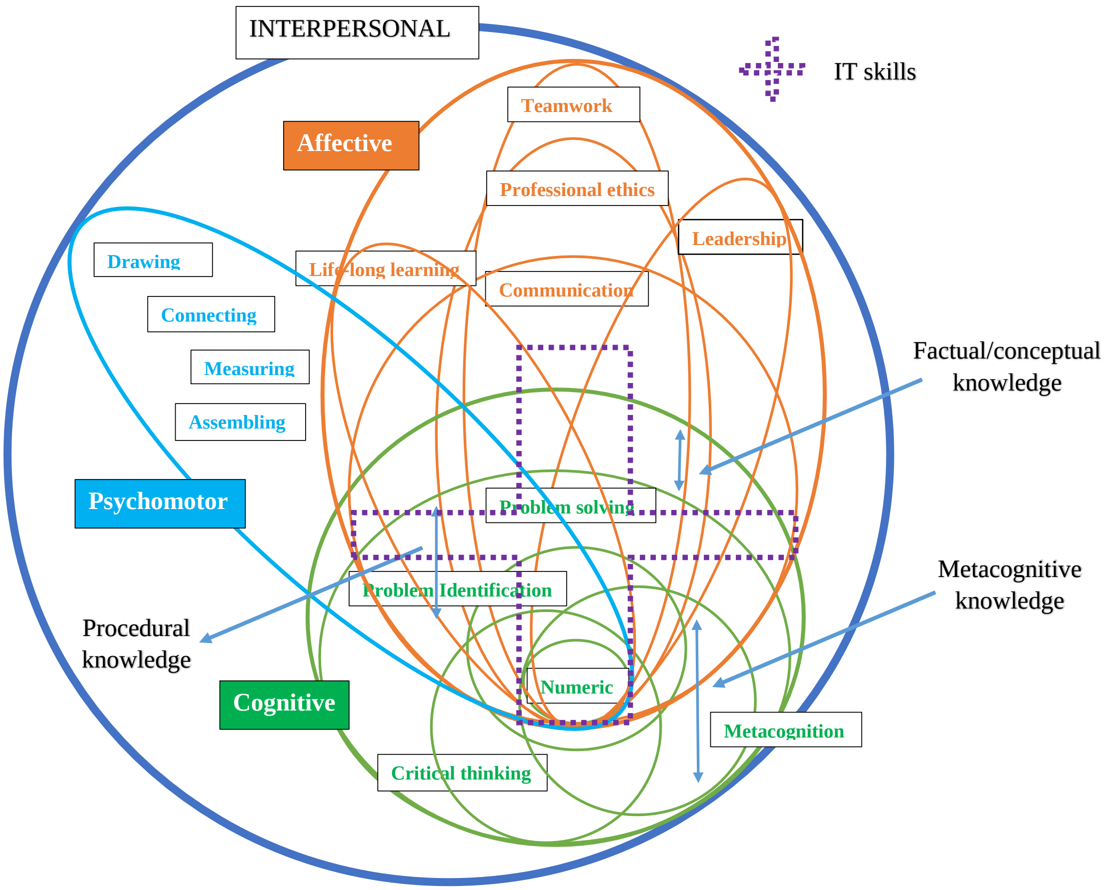


Figure 7: The *Learning Domains Wheel* for snapshot analysis and selection of *learning domains categories* to achieve realistic outcomes measurement with easier PIs classification process

The cognitive domain involves acquiring factual, conceptual knowledge dealing with remembering facts and understanding core concepts. Procedural and metacognitive knowledge deal essentially with problem solving, which includes problem identification, critical thinking and metacognitive reflection. Remembering facts, understanding concepts and problem solving are essential, core and universal cognitive skills that would apply to all learning domains [44, 46]. Problem identification, definition, critical thinking and metacognitive reflection are some of the main elements of problem solving skills. These main elements of problem solving skills apply to all levels of learning for the three domains. Activities related to any learning domain require operational levels of four kinds of knowledge: factual, conceptual, procedural and metacognitive [44] that are proportional to the expected degree of proficiency of skills for proper completion of tasks. For example, successfully completing psychomotor tasks for solving problems involves acquiring very specialized proportions of factual, conceptual, procedural and metacognitive knowledge of various physical processes with accepted levels of their activities skills proficiency. Similarly, an affective learning domain activity, such as implementing a code of professional ethics, involves acquiring factual, conceptual, procedural and metacognitive knowledge related to industry standards, process of application, level of personal responsibility and impact on stakeholders. Hence, the psychomotor and affective domains skills overlap with the cognitive domain for the necessary factual, conceptual, procedural and metacognitive areas of knowledge.

The *learning domains categories* such as interpersonal, IT, knowledge, cognitive, communication, numerical skills etc., exhibit significant areas of overlap as shown in the *Learning Domains Wheel* in Figure 7. A top-level grasp of the relationship of these categories demonstrates the process of the selection of learning domain categories. For example, interpersonal skills, as shown in Figure 7, is too broad a category, thereby presenting serious problems in PIs classification and realistic outcomes measurement when grouped with other skills sets such as *learning domains categories*. Numerical skills are used for decision making activities in the affective domain and also for the proper execution of psychomotor actions in physical processes. Numerical skills are an absolute subset of cognitive skills for any engineering discipline. IT skills cover some areas of psychomotor (connection, assembly, measurement, etc.), affective (safety, security, etc.) and cognitive (knowledge of regional standards, procedural formats, etc.) domains. Leadership and management skills require effective communication and teamwork. This large overlap of skills within multiple learning domains presents a serious dilemma to engineering programs in the PIs classification and measurement process. A difficult choice must be made whether to select the most appropriate *learning domain category* and discard the others or repeat mapping similar PIs to multiple *learning domain categories* for each classification. Defining the learning levels for the overlapping categories to precisely classify PIs would also be challenging. Finally, *learning domain categories* with significant areas of overlap would result in the repeated measurement of common PIs in multiple domains and the accumulation of too many types of PIs in any single *learning domain category*, thus obscuring specific measured information. Therefore, for practical reasons the categories of learning domains have to be meticulously selected with a primary goal of implementing a viable PIs classification process to achieve realistic outcomes measurement for program evaluation.

Crucial guidelines were logically derived from the *Learning Domains Wheel* for the selection of the *learning domains categories* as follows:

1. Very broad *learning domains categories* consist of many skills sets that will present difficulty in the classification of PIs when grouped with other categories and will result in the redundancy of outcomes data; for example, interpersonal skills grouped with IT, communication or psychomotor, etc.
2. Avoid selection of any two skills sets as *learning domains categories* when one is an absolute subset of another. Just select either the most relevant one or the one which is a whole set. For example, select cognitive or numeric skills, but not both; if both are required, select cognitive as a category since it is a whole set. Numeric skills, its subset, can be classified as a cognitive skill.
3. If selecting a certain skills set that is a whole set as a *learning domains category*, then it should not contain any other skills sets which are required to be used as *learning domains categories*; e.g., do not select affective as a *learning domains category* since it is a whole set if you also plan on selecting teamwork skills as a category.
4. A *learning domain category* could contain skills sets which will not be utilized for PIs classification; e.g., affective *learning domain category* containing leadership, teamwork and professional ethics skills sets; leadership, teamwork and professional ethics will NOT be a learning domain category but will be classified as affective domain skill sets.

Bloom's 3 domains, cognitive, affective and psychomotor, are not absolute subsets of one another. They contain skills sets as prescribed by the 11 EAC ABET SOs which are not *learning domains categories.* Therefore Bloom's 3 learning domains satisfy selection guidelines derived from the

Learning Domains Wheel and facilitate a relatively easier classification process for specific PIs. Calculation of term-wide weighted average values for ABET SOs using this classification of specific PIs resulted in realistic outcomes data since most of the PIs were uniquely mapped to each of the 3 domains with minimal overlap and redundancy.

VII. Weighting Factors for Assessments

Realistic learning outcomes measurements are achieved by assigning weights [11,34] to different assessments according to a combination of their course grading policy and type [12,37]. The first rationale in order of priority is the type of assessments so that higher weight is assigned to laboratory/design related assessments compared to purely theoretical assessments, because laboratory/design work covers all three domains of Bloom's taxonomy [38,39]. Similarly, final exams are higher than quizzes since the final exam is more comprehensive and well-designed. Students are generally more prepared for a final exam as many of their skills reach a higher level of maturity and proficiency by that time [37]. The second rationale in priority is to account for the percentage contribution of the given assessment which is derived from the course grading scale. Figure 8 shows the 4 course formats developed by the Faculty of Engineering at the Islamic University of Madinah to calculate the weighting factors for the different types of assessments [37].

DIFFERENT COURSE ASSESSMENTS FORMATS:

1. **COURSES WITH NO LABS + NO PROJECT/TERM PAPER**

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	40%	8
MID TERM EXAM - 1	25%	5
MID TERM EXAM - 2	25%	5
QUIZ	5%	1
HW	5%	1
TOTAL	100%	-

3. **COURSES WITH LABS + NO PROJECT/TERM PAPER**

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	25%	5
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
LAB EXAMS	30%	6
LAB REPORTS	5%	1
TOTAL	100%	-

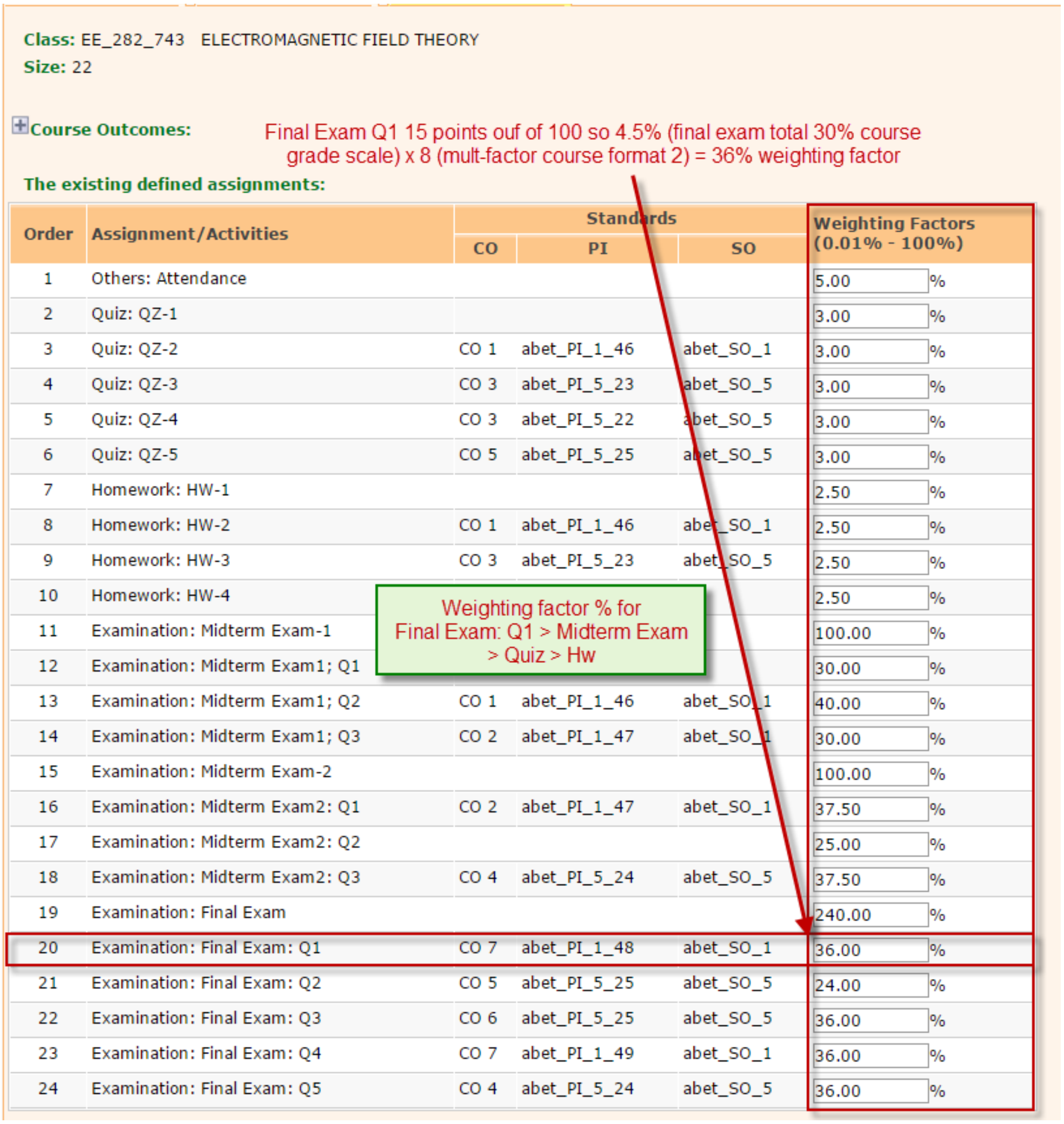
2. **COURSES WITH NO LABS + PROJECT/TERM PAPER**

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	30%	6
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
PROJECT/TERM PAPER	30%	6
TOTAL	100%	-

4. **COURSES WITH LABS + PROJECT/TERM PAPER**

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	25%	5
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
LAB EXAMS	15%	3
LAB REPORTS	5%	1
PROJECT/TERM PAPER	15%	3
TOTAL	100%	-

Figure 8: Four course formats developed by the Faculty of Engineering, Islamic University of Madinah, to calculate the multiplication factor for estimating the weights for different assessments.



Class: EE_282_743 ELECTROMAGNETIC FIELD THEORY
Size: 22

Course Outcomes:

The existing defined assignments:

Order	Assignment/Activities	Standards CO	Standards PI	Standards SO	Weighting Factors (0.01% - 100%)
1	Others: Attendance				5.00 %
2	Quiz: QZ-1				3.00 %
3	Quiz: QZ-2	CO 1	abet_PI_1_46	abet_SO_1	3.00 %
4	Quiz: QZ-3	CO 3	abet_PI_5_23	abet_SO_5	3.00 %
5	Quiz: QZ-4	CO 3	abet_PI_5_22	abet_SO_5	3.00 %
6	Quiz: QZ-5	CO 5	abet_PI_5_25	abet_SO_5	3.00 %
7	Homework: HW-1				2.50 %
8	Homework: HW-2	CO 1	abet_PI_1_46	abet_SO_1	2.50 %
9	Homework: HW-3	CO 3	abet_PI_5_23	abet_SO_5	2.50 %
10	Homework: HW-4				2.50 %
11	Examination: Midterm Exam-1				100.00 %
12	Examination: Midterm Exam1; Q1				30.00 %
13	Examination: Midterm Exam1; Q2	CO 1	abet_PI_1_46	abet_SO_1	40.00 %
14	Examination: Midterm Exam1; Q3	CO 2	abet_PI_1_47	abet_SO_1	30.00 %
15	Examination: Midterm Exam-2				100.00 %
16	Examination: Midterm Exam2: Q1	CO 2	abet_PI_1_47	abet_SO_1	37.50 %
17	Examination: Midterm Exam2: Q2				25.00 %
18	Examination: Midterm Exam2: Q3	CO 4	abet_PI_5_24	abet_SO_5	37.50 %
19	Examination: Final Exam				240.00 %
20	Examination: Final Exam: Q1	CO 7	abet_PI_1_48	abet_SO_1	36.00 %
21	Examination: Final Exam: Q2	CO 5	abet_PI_5_25	abet_SO_5	24.00 %
22	Examination: Final Exam: Q3	CO 6	abet_PI_5_25	abet_SO_5	36.00 %
23	Examination: Final Exam: Q4	CO 7	abet_PI_1_49	abet_SO_1	36.00 %
24	Examination: Final Exam: Q5	CO 4	abet_PI_5_24	abet_SO_5	36.00 %

Figure 9: Weighting factor calculation example for Final Exam: Q1 by product of course grading scale and multiplication factor applied using course format no.2

Figure 10 shows how EAMU is computed by taking the appropriate weighting factors into account. In this example, Final Exam Q2 (24%) is weighted more than Qz-5 (2%). The final group EAMU reflects the priority of the Final Exam Q2 over Qz-5.

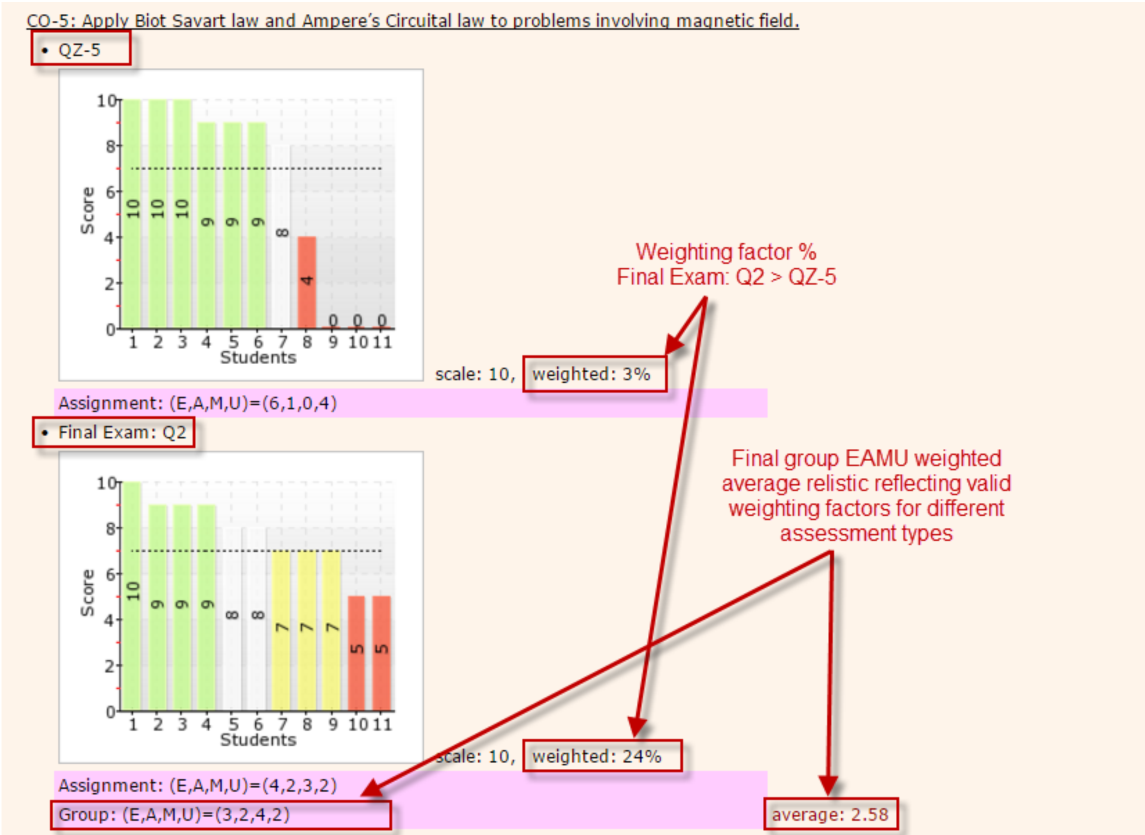


Figure 10: Realistic final group EAMU weighted average due to application of accurate weighting factors % applied to different assessments

VIII. FCAR, EAMU Performance Vector Methodology and Web-based Software EvalTools® 6

EvalTools® 6 [32] is chosen as the platform for outcomes assessment instead of Blackboard® [22] since it is the only tool that employs the Faculty Course Assessment Report (FCAR) and *EAMU performance vector methodology* [33,34,35,36]. This methodology facilitates the use of existing curricular scores, giving assessments for outcomes measurement and assists in achieving a high level of automation of the data collection process as shown in Figure 11 [37].

The EvalTools® 6 FCAR module provides summative/formative options and consists of the following components: course description, COs indirect assessment, grade distribution, COs direct assessment, assignment list, course reflections, old action items, new action items, student outcomes assessment and performance indicators assessment [37].

The FCAR uses the performance vector, conceptually based on a performance assessment scoring rubric developed by Miller and Olds [47], to categorize aggregate student performance. Figure 12 shows the performance vector called EAMU [34].

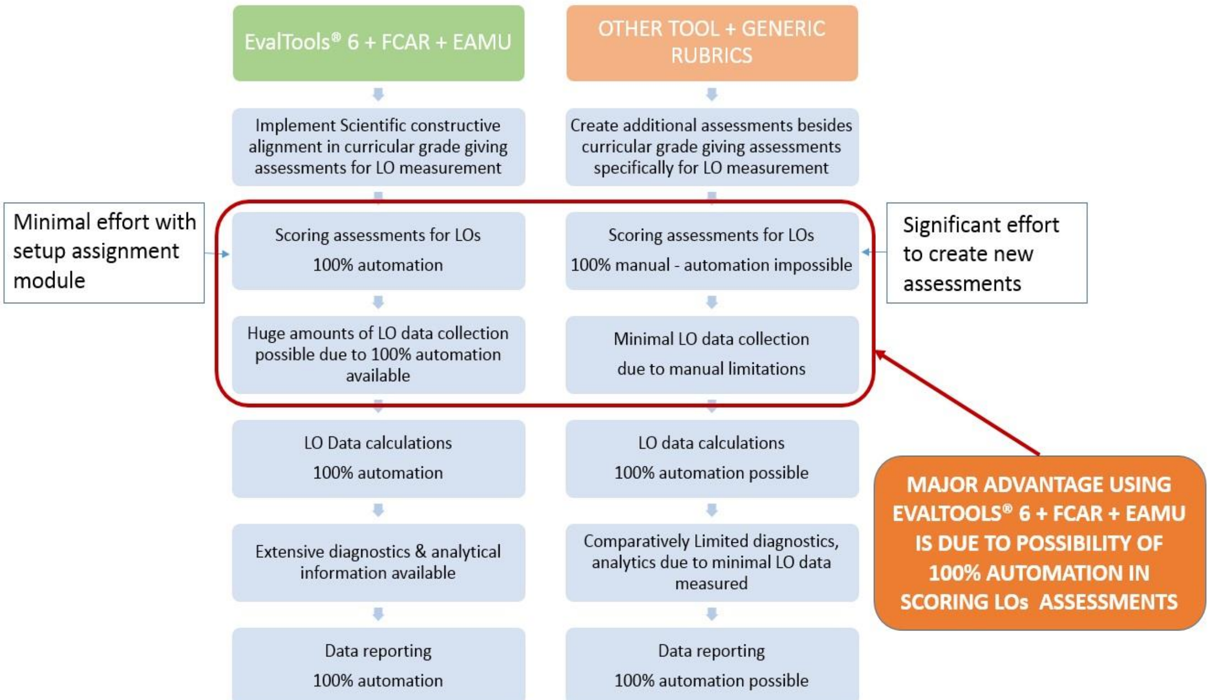


Figure 11: Comparative study of the advantages of automation achieved with EvalTools® 6 versus other tools with generic rubrics used for learning outcomes (LOs) measurements

1. Specification of EAMU performance indicator levels:

This set of EAMU performance criteria apply to key assignments that were selected as objective evidences for meeting course outcomes. The setting here applies to all courses as a basic point of reference. However, individual instructors can alter the indicator levels appropriately applied to their own courses as desired.

Category	General Description	Letter Grade	Nominal Indicator Level
Excellent	Student applies knowledge with virtually no conceptual or procedural errors	E	90.0% - 100%
Adequate	Student applies knowledge with no significant conceptual errors and only minor procedural errors	A	75.0% - 90.0%
Minimal	Student applies knowledge with occasional conceptual errors and only minor procedural errors	M	60.0% - 75.0%
Unsatisfactory	Student makes significant conceptual and/or procedural errors when applying knowledge	U	0.0% - 60.0%

2. Heuristic rules for performance vector tables (PVT):

This set of rules applies to the performance vector tables that are formed by compiling all the key assignments' EAMU results together. The rationalization behind this classification is to streamline the assessment and evaluation processes by focusing on those areas that are out of the ordinary. Based on the color coded flags, the potentail problem areas will be flagged. This set of settign applies to all courses in the program.

Category	General Description	Scale (out of 5)	Maximum Percentage
Red Flag	Any performance vector with an average below the defined scale and a level of unsatisfactory performance that exceeds defined percentage in the U column	below 3.3	and >10%
Yellow Flag	Any performance vector with an average below the defined scale or a level of unsatisfactory performance (U) that exceeds the defined percentage, but not both	below 3.3	or >10%
Green Flag	Any performance vector with an average that is at least greater than the defined scale and no indication of unsatisfactory performance (U)	>= 4.6	
No Flag	Any performance vector that does not fall into one of the above categories		

Figure 12: Performance criteria: EAMU PI levels and heuristic rules for Performance Vector Tables (PVT) adopted by the Faculty of Engineering at the Islamic University of Madinah

EAMU performance vector methodology

Steps Employed By EvalTools® 6 to Calculate the EAMU Vectors [34,37]

1. Faculty use EvalTools® 6 *Assignment Setup Module* to identify an assignment with a set of specific questions, or split an assignment to use a specific question or sub question for outcomes assessment with relative high coverage of a certain PI mapping to CO, ABET SO (for EAMU calculation).
2. EvalTools® 6 removes students who received DN, F, W or I in a course from EAMU vector calculations, and enters student scores on the selected assignments and questions for remaining students.
3. For each student, EvalTools® 6 calculates the weighted average percentage on the assessments, a set of questions selected by faculty. Weights for assessments are set according to the product of their percentage in the course grading scale and multiplication factor based on the course format (refer to Figure 8) and entered in the weighting factor section of the *Assignment Setup Module*.
4. EvalTools® 6 uses the average percentage to determine how many students fall into the EAMU categories using the pre-selected EAMU assessment criteria (refer Figure 12).
5. EvalTools® 6 calculates the EAMU average rating by rescaling to 5 for a weighted average based on a 3 point scale as shown in Equation (1).

$$EAMU\ average = \frac{3*E+2*A+1*M+0*U}{E+A+M+U} * \left(\frac{5}{3}\right) \tag{1}$$

Example of PIs EAMU vector calculation employing weighting factors [37]

Table 2 shows an example of how EAMU vectors are computed for a specific PI. Assessments Hw3 and Hw8 are selected for measuring a specific PI ABET_PI_5_3. These assessments are weighted according to course grading policy and multiplication factor. Let's say the weights are 5% for Hw3 and 7% for Hw8. The percent-weighted score is computed as follows:

$$\begin{aligned} \text{\% weighted avg.} \quad &= \left(\frac{20}{30} * wf1 + \frac{40}{60} * wf2\right) / (wf1 + wf2) * 100 \\ &= \left(\frac{20}{30} * 5 + \frac{40}{60} * 7\right) / (5 + 7) * 100 \\ &= 66.67 \end{aligned} \tag{2}$$

The PI EAMU classification for each student in the class as indicated in the second column is obtained from this % weighted average. The PI EAMU vector (3,1,1,2) for the entire class in the last column is obtained based on the count of students belonging to each of the categories as defined by: Excellent: scores >= 90%; Adequate: scores >= 75% and < 90%; Minimal: scores >= 60% and < 75%; and Unsatisfactory: scores < 60%. In this case, there are 3 students with scores belonging to E; 1 student in A; 1 student in M; and 2 students in U; categories. Finally the weighted average of the EAMU vector for this specific PI_5_3 is 2.86, which is obtained as per Equation (1).

Table 2: Calculation of aggregated EAMU† for a PI

Student	abet_PI_5_3	Hw3 (30)	% weighted (wf=5%)	Hw8 (60)	% weighted (wf=7%)	Percent-weighted
student 1	M	20	3.33	40	4.67	66.67
student 2	U	10	1.67	8	0.93	21.67
student 3	E	30	5.00	57	6.65	97.08
student 4	U	26	4.33	10	1.17	45.83
student 5	E	28	4.67	60	7.00	97.22
student 6	E	29	4.83	53	6.18	91.81
student 7	A	29	4.83	40	4.67	79.17
	EAMU	(4,1,1,1)		(2,1,2,2)		(3,1,1,2)
	Average	3.81		2.38		2.86

†Excellent: 90%-100%; Adequate: 75%-89.99%; Minimal: 60%-74.99%; Unsatisfactory: 0-59.99%

IX. Program Term Review and CQI

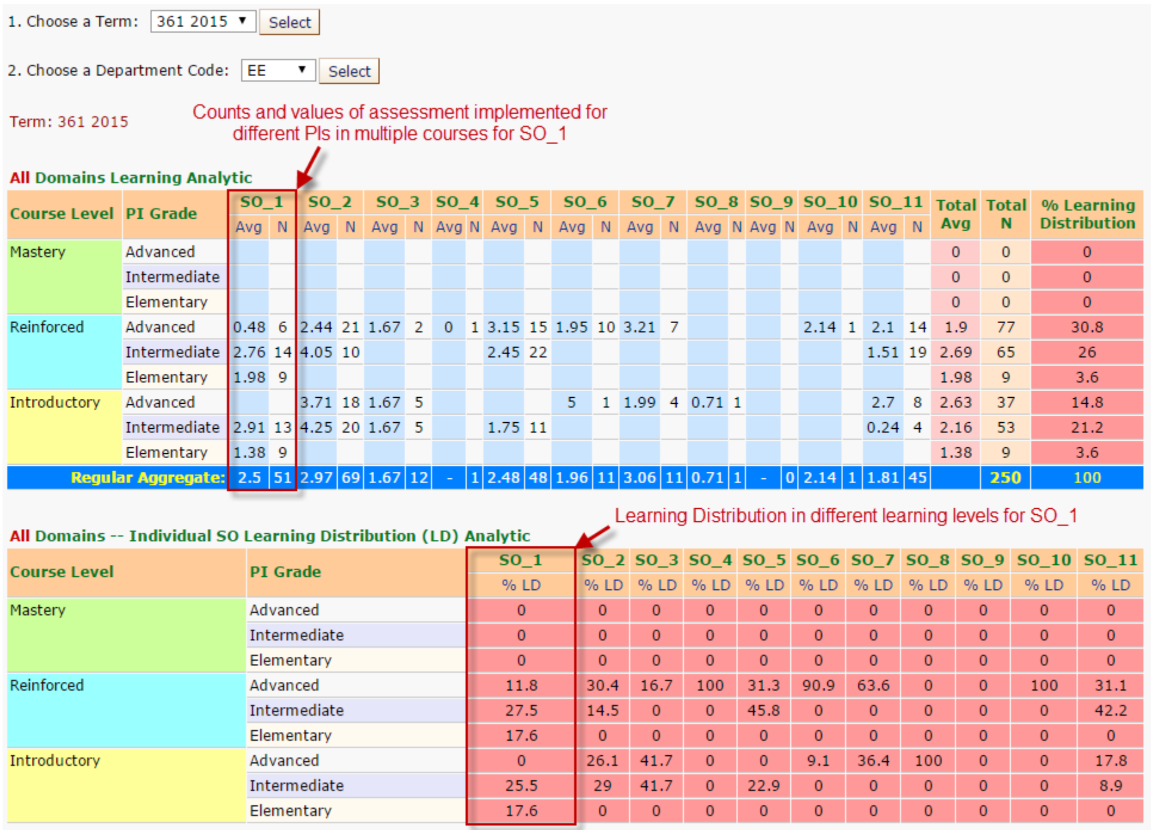
Program faculty report failing COs, their associated PIs, ABET SOs, comments on student indirect assessments and other general issues of concern in the respective *course reflections* section of the FCAR. Based upon these course reflections, new action items are proposed by the faculty. Old action items status details are electronically carried over into the current FCAR from previous offerings of this course [37]. Modifications and proposals to a course are made with consideration of the status of the old action items. The *Program Term Review* module of EvalTools® 6 consists of three parts a) *Learning Domains Evaluation* b) *PIs Evaluation* and c) *ABET SOs Evaluation* as per our specific requests and requirements. The PIs and SOs evaluation is focused on failing SOs and PIs for analysis and discussions relating to improvement [37]. Weighted average values of ABET SOs and PIs [34] with a scientific color coding scheme as per PVT heuristic rules shown in Figure 12 indicate failures for investigation. Courses contributing to failing PIs and SOs are examined [37]. The action items generated in the FCAR are at times evaluated to become tasks for the standing committees for actual CQI action.

The Faculty of Engineering has presented an elaborate *youtube video presentation* that details the automation of outcomes assessment, showing some CIMS features such as action items elevation from the FCAR to task lists of standing committees for actual CQI in [23].

X. Learning Domains Evaluation

Since assessments are equivalent to learning in the OBE model [45], the Faculty of Engineering has decided to consider the type of assessments, their frequency of implementation, and the learning level of measured specific PIs in Bloom's 3 domains for courses and overall program evaluations. At the course level, the types of assessments are classified using the course formats chart in Figure 8 to calculate their weighting factors [37], which are then applied using the setup course portfolio module of EvalTools® 6 [32]. The results can be seen in the FCAR and are used for course evaluations. The program level ABET SO evaluations employ a weighting scheme, which considers the frequency of assessments implemented in courses for a given term to measure PIs with specific learning levels of Bloom's domains. Figure 13 shows the EE program term 361 composite learning domains evaluation data for their 11 ABET SOs. For each SO, the counts of total assessments and their aggregate average values are tabulated for each learning level. The ABET SO 'a' (SO_1) is highlighted for understanding. There is no data for the mastery level in

Figure 13 because the EE program is a new program, and hence, did not offer any mastery level courses during term 361. Figure 13 also shows the overall percentage learning distribution for each learning level of the 11 ABET SOs. The details of how these entries are computed in Figure 13 are explained next.



Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		SO_8		SO_9		SO_10		SO_11		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced																							0	0	0
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced	0.48	6	2.44	21	1.67	2	0	1	3.15	15	1.95	10	3.21	7					2.14	1	2.1	14	1.9	77	30.8
	Intermediate	2.76	14	4.05	10					2.45	22											1.51	19	2.69	65	26
	Elementary	1.98	9																					1.98	9	3.6
Introductory	Advanced			3.71	18	1.67	5					5	1	1.99	4	0.71	1					2.7	8	2.63	37	14.8
	Intermediate	2.91	13	4.25	20	1.67	5			1.75	11											0.24	4	2.16	53	21.2
	Elementary	1.38	9																					1.38	9	3.6
Regular Aggregate:		2.5	51	2.97	69	1.67	12	-	1	2.48	48	1.96	11	3.06	11	0.71	1	-	0	2.14	1	1.81	45		250	100

Course Level	PI Grade	SO_1	SO_2	SO_3	SO_4	SO_5	SO_6	SO_7	SO_8	SO_9	SO_10	SO_11
		% LD	% LD	% LD	% LD	% LD	% LD	% LD	% LD	% LD	% LD	% LD
Mastery	Advanced	0	0	0	0	0	0	0	0	0	0	0
	Intermediate	0	0	0	0	0	0	0	0	0	0	0
	Elementary	0	0	0	0	0	0	0	0	0	0	0
Reinforced	Advanced	11.8	30.4	16.7	100	31.3	90.9	63.6	0	0	100	31.1
	Intermediate	27.5	14.5	0	0	45.8	0	0	0	0	0	42.2
	Elementary	17.6	0	0	0	0	0	0	0	0	0	0
Introductory	Advanced	0	26.1	41.7	0	0	9.1	36.4	100	0	0	17.8
	Intermediate	25.5	29	41.7	0	22.9	0	0	0	0	0	8.9
	Elementary	17.6	0	0	0	0	0	0	0	0	0	0

Figure 13: Learning domains evaluation for EE program term 361† showing all 3 domains' composite data with assessments counts and their aggregate average values for various learning levels and ABET SO 'a' highlighted

† Islamic University of Madinah semester naming system, where first two digits '36' refer to the local year code and the last digit refers to the semester, 1: fall, 2: spring and 3: summer.

Hierarchy-Frequency Weighting-Factors Scheme **for multiple learning and course levels**

Table 3 shows the calculation of weighting factors for various learning levels of the reinforced and introductory courses as an example. The detailed calculation for each column is discussed as follows:

Learning Distribution % (LD) column

Equation (3) shows the percentage of total assessments implemented in all courses for each learning level. Figure 13 shows that for ABET SO 'a' (SO_1), 14 assessments out of 51 were implemented in reinforced-level courses measuring intermediate level PIs for all 3 domains composite. The total assessments accounted for 27.5% of learning.

$$LD(i) = \frac{count(i)}{Total\ count} \times 100 \tag{3}$$

The *Progressive Distribution % (PD)*
Equation (4) calculates PD by summing *LD* values according to the hierarchy of the skills levels. Reinforced and advanced levels are assigned the highest value in this case since mastery level courses were not offered in term 361.

$$PD(i) = \sum_{1}^{i} LD(i) \tag{4}$$

The *Relative Distribution % (RD)*
Equation (5) calculates RD by dividing the *PD(i)* value with *LD(m):* the non-zero minimum value (learning level *'m'*) of the set of *LD* values corresponding to all the learning levels *1 to i.*

$$RD(i) = \frac{PD(i)}{Min - non - zero\ \{LD(1),\ LD(2), \ldots .LD(i)\}} \tag{5}$$

The *Weighting Factors WF(i)* for the various measured learning levels given by Equation (6) for ABET SO 'a' (SO_1) are calculated by multiplying *LD(i)* with *RD(i).*

$$WF(i) = LD(i) \times RD(i) \tag{6}$$

The philosophy behind the implementation of this *Hierarchy-Frequency Weighting-Factor Scheme WF(i)* for program learning domains evaluations is to consider a combination of two critical factors:

a) to implement a hierarchy of skills by giving prevalence to those assessments that measure skills of the highest order over others. For example, mastery-advanced level PIs will have a higher prevalence than those for the intermediate-advanced level; and
b) to consider the counts of assessments implemented in a certain learning level due to the fact that outcomes assessment is directly equivalent to learning.

Table 3: Weighting factors calculation for various learning levels of the reinforced and introductory courses for ABET SO ‘a’ program evaluation

ABET SO_1, SO 'a'	Course level- PI level	Counts(i) in term 361	%Learning Distribution [LD(i)]	% Progressive Distribution [PD(i)]	% Relative Distribution [RD(i)]	Weights WF(i) = LD(i) x RD(i)
Learning level (i)		DATA FROM EVALTOOLS	{counts(i)/total}×100	∑ LD(i)	{PD(i)}/Min{LD(i)}	{LD(i) × RD(i)}
1	REINFORCED-ADV	6	11.8	100	5.68	**67.05**
2	REINFORCED-INTER	14	27.5	88.2	5.01	**137.81**
3	REINFORCED-ELEM	9	17.6	60.7	3.45	**60.70**
4	INTRODUCTORY-ADV	0	0	43.1	2.45	**0.00**
5	INTRODUCTORY-INTER	13	25.5	43.1	2.45	**62.45**
6	INRTODUCTORY-ELEM	9	17.6	17.6	1.00	**17.60**
	TOTAL	51				

XI. ABET SOs Weighted Average Values Calculations for Program Evaluations

This section illustrates how the weighted average value of 2.5 for ABET SO ‘a’ (SO_1) highlighted in Figure 13 is obtained. The values in the rightmost column *WF(i)* in Table 3 are the weights for the 6 different learning levels for ABET SO ‘a’. Figure 14 shows the detailed list of specific PIs measured by the EE program in term 361 for ABET SO ‘a’ (SO_1) and classified according to Bloom’s 3 domains and learning levels. Table 4 shows the EAMU weighted average values, weighting factors *WF(i)* for the six learning levels, Bloom’s learning levels for specific PIs measured from reinforced and introductory level courses for ABET SO ‘a’ program evaluation.

For example, consider the ABET_PI_1_12 shown in Figure 14 below. It is classified as Cognitive-Applying per Bloom’s and is an intermediate skill level per the *3-Level Skills Grouping Methodology*. This PI is measured in an introductory course EE_201-384, Circuit Theory-I. It has an *EAMU value* of 2.86. From Tables 3 and 4, the PI weighting factor for *Introductory-Intermediate* learning level is 62.45. The column labeled *Avg*WF* displays 178.60 as the product of the EAMU weighted average value 2.86 with the PI weighting factor 62.45. The final ABET SO ‘a’ weighted average value is calculated according to Equation (7). The sum of values in column *Avg*WF* is 3289.39. This sum value is then divided by 1316.16, the sum of the column *WF*, giving 2.499 as highlighted in red in Table 4.

abet_PI_1_12: **Cognitive: Applying.** Employ basic electrical power formulations and quantities, such as complex vectors, delta/star transformation, network flow matrices (network topology and incidence matrices) and symmetrical components

abet_PI_1_22: **Cognitive: Understanding.** Explain the basic phenomena which govern the behavior of electrical machines, such as electro-mechanical energy conversion principle, electro-magnetic rotating field, synchronizing torque and armature reaction

abet_PI_1_25: **Cognitive: Understanding.** Identify characteristics of electrical circuit components and materials, such as resistance, inductance, capacitance, conductors, semiconductors and dielectrics

abet_PI_1_27: **Cognitive: Analyzing.** Apply basic laws and formulas of circuit theory, such as Ohm‘s and Kirchoff‘s laws as well as circuit theorems to simplify/analyze circuits (Thevenin and Norton theorems, superposition principle, max power transfer theorem, transformation etc.)

abet_PI_1_40: **Cognitive: Understanding.** Explain how a number with one radix is converted into a number with another radix

abet_PI_1_42:	**Cognitive: Applying** Perform mathematical operations relating to different number systems
abet_PI_1_44:	**Cognitive: Understanding.** Explain basics of electrical engineering parameters such as charge, voltage, current, energy, power, work done, resistance, capacitance, inductance, ideal sources, passive sign convention etc.
abet_PI_1_53:	**Cognitive: Analyzing.** Describe the internal architecture of 8086 microprocessor and identify the components of a computer system
abet_PI_1_54:	**Cognitive: Analyzing.** Derive the system transfer functions of electronic circuits and develop their magnitude and phase Bode diagrams
abet_PI_1_55:	**Cognitive: Evaluating.** Define the various classes of power amplifiers and calculate the maximum power efficiency of each class of amplifier
abet_PI_1_56:	**Cognitive: Analyzing.** Illustrate the characteristics and terminology of MOSFET and BJT differential amplifiers
abet_PI_1_57:	**Cognitive: Analyzing.** Illustrate the parameters and characteristics of the ideal operational amplifier
abet_PI_1_58:	**Cognitive: Applying.** Explain classification of systems/signals with respect to continuous- or discrete-time, linear or nonlinear, time-invariant or time-varying, and causal or non-causal
abet_PI_1_59:	**Cognitive: Applying.** Explain signals and perform various time domain operations on signals
abet_PI_1_60:	**Cognitive: Understanding**. Explain the operation and characteristics of synchronous/induction motors/generators
abet_PI_1_61:	**Cognitive: Understanding.** Explain the operation and characteristics of DC machines

Figure 14: List of specific PIs classified as per Bloom's 3 domains, learning levels and measured by the EE program in term 361 for ABET SO 'a' (SO_1)

Table 4: ABET SO 'a' calculation for EE program term 361 evaluation showing EAMU weighted average values, weighting factors, Bloom's learning levels for specific PIs measured in reinforced and introductory level courses

PI number	PGM	Wt. Avg.	Course code	Name	Course-level	E	A	M	U	EAMU value	WF	avg*WF	Bloom's Learning Level	3-Level Skills Grouping
abet_PI_1_12	(0,0,0,1)	2.86	EE_201_384	CIRCUIT THEORY 1	Introductory	2	3	0	2	2.86	62.45	178.607	Cognitive:Applying	Intermediate
abet_PI_1_22	(0,0,1,0)	3.52	EE_341_393	ELECTRICAL MACHINERY 1	Reinforced	6	0	1	2	3.52	60.7	213.664	Cognitive:Understanding	Elementary
abet_PI_1_25	(0,0,0,1)	0	EE_201_384	CIRCUIT THEORY 1	Introductory	0	0	0	7	0	17.6	0	Cognitive:Understanding	Elementary
abet_PI_1_27	(0,0,0,1)	1.43	EE_201_384	CIRCUIT THEORY 1	Introductory	0	1	4	2	1.43	62.45	89.3035	Cognitive:Analyzing	Intermediate
abet_PI_1_40	(0,1,0,0)	3.89	EE_261_385	DIGITAL LOGIC DESIGN	Introductory	1	2	0	0	3.89	17.6	68.464	Cognitive:Understanding	Elementary
abet_PI_1_42	(0,1,0,0)	4.44	EE_261_385	DIGITAL LOGIC DESIGN	Introductory	2	1	0	0	4.44	62.45	277.278	Cognitive:Applying	Intermediate
abet_PI_1_44	(0,0,0,1)	0.24	EE_201_384	CIRCUIT THEORY 1	Introductory	0	0	1	6	0.24	17.6	4.224	Cognitive:Understanding	Elementary
abet_PI_1_53	(0,0,0,1)	2.62	EE_361_395	MICROPROCESSORS	Reinforced	2	1	3	1	2.62	137.81	361.0622	Cognitive:Analyzing	Intermediate
abet_PI_1_54	(0,1,0,0)	3.33	EE_311_391	ELECTRONICS II	Reinforced	2	3	2	0	3.33	137.81	458.9073	Cognitive:Analyzing	Intermediate
abet_PI_1_55	(0,0,0,1)	0.48	EE_311_391	ELECTRONICS II	Reinforced	0	0	2	5	0.48	67.05	32.184	Cognitive:Evaluating	Advanced
abet_PI_1_56	(0,0,0,1)	1.9	EE_311_391	ELECTRONICS II	Reinforced	2	0	2	3	1.9	137.81	261.839	Cognitive:Analyzing	Intermediate
abet_PI_1_57	(0,1,0,0)	3.57	EE_311_391	ELECTRONICS II	Reinforced	2	4	1	0	3.57	137.81	491.9817	Cognitive:Analyzing	Intermediate
abet_PI_1_58	(0,0,0,1)	1.19	EE_301_390	SIGNALS AND SYSTEMS	Reinforced	2	1	2	9	1.19	137.81	163.9939	Cognitive:Applying	Intermediate
abet_PI_1_59	(0,1,0,0)	3.93	EE_301_390	SIGNALS AND SYSTEMS	Reinforced	6	7	1	0	3.93	137.81	541.5933	Cognitive:Applying	Intermediate
abet_PI_1_60	(0,0,0,1)	0.56	EE_341_393	ELECTRICAL MACHINERY 1	Reinforced	1	0	0	8	0.56	60.7	33.992	Cognitive:Understanding	Elementary
abet_PI_1_61	(0,0,0,1)	1.85	EE_341_393	ELECTRICAL MACHINERY 1	Reinforced	1	1	5	2	1.85	60.7	112.295	Cognitive:Understanding	Elementary
											1316.16	3289.389		
												2.499232		

$$ABET\ SO\ 'a'\ weighted\ average = \frac{\sum_{PI\_1\_12}^{PI\_1\_61} Avg \times WF}{\sum_{PI\_1\_12}^{PI\_1\_61} WF} \tag{7}$$

Figure 15 shows analytical results for the individual cognitive, affective and psychomotor—Bloom's domains of learning. The counts of assessments in various learning levels and their calculated values for all 11 ABET SOs are displayed for each learning domain. A variety of diagnostics can be applied to analyze the status of the course, curriculum delivery and student learning.

Cognitive Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		SO_8		SO_9		SO_10		SO_11		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced																							0	0	0
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced	0.48	6							3.15	15											2.33	10	1.99	31	19.9
	Intermediate	2.76	14							2.45	22											1.51	19	2.24	55	35.3
	Elementary	1.98	9																					1.98	9	5.8
Introductory	Advanced			3.57	7	1.67	5															2.78	7	2.67	19	12.2
	Intermediate	2.91	13			1.67	5			1.75	11											0.24	4	1.64	33	21.2
	Elementary	1.38	9																					1.38	9	5.8
																								2.05	156	100.2

Affective Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		SO_8		SO_9		SO_10		SO_11		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced																							0	0	0
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced							0	1			1.95	10	3.21	7					2.14	1			1.83	19	76
	Intermediate																							0	0	0
	Elementary																							0	0	0
Introductory	Advanced											5	1	1.99	4	0.71	1							2.57	6	24
	Intermediate																							0	0	0
	Elementary																							0	0	0
																								2.01	25	100

Psychomotor Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		SO_8		SO_9		SO_10		SO_11		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced																							0	0	0
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced			2.44	21	1.67	2															0.95	4	1.69	27	39.1
	Intermediate			4.05	10																			4.05	10	14.5
	Elementary																							0	0	0
Introductory	Advanced			3.81	11																	2.62	1	3.22	12	17.4
	Intermediate			4.25	20																			4.25	20	29
	Elementary																							0	0	0
																								3.04	69	100

Figure 15: Learning domains evaluation for EE program term 361 showing assessment counts and values for the individual cognitive, affective and psychomotor domains

Figure 16 shows average values calculated on a 5.0 scale for the cognitive, affective and psychomotor domains, providing a good overall indication of how the program has performed in each learning domain. The pie chart indicates the EE program term 361 outcomes assessment activity percentage distribution in the 3 Bloom's learning domains.

The appendices to this paper indicate further examples from EE, CE and ME programs for a single term 361, of the psychomotor and affective domains specific PIs, for measurement of skills classified as per Bloom's learning levels for various ABET SOs. Since programs at the Faculty of Engineering are new and started within the last 3 years, all courses in the degree plans have not been offered yet. Future research will present an extensive, summarized coverage of the cognitive, psychomotor and affective domains including all course levels, PIs for the measurement of 11 ABET SOs in multiple terms that represent a complete degree plan offering. Specific instruments, EvalTools ® 6 forum module and/or rubrics incorporating peer, employer or faculty evaluations and students' metacognitive reflection in reports have been utilized to measure skills like teamwork, design according to realistic constraints, professional and ethical responsibility, professional development, etc. Certain instruments used to measure skills like teamwork are very detailed, involving measurement of several PIs using rubrics for skills evaluations by the team leader, team members, employer, and faculty. The overall results for team work skills are a weighted average of the various evaluations. Details of such instruments used to measure affective domain skills shall be covered in future publications since they require a comprehensive presentation and lengthy discussion.

Figure 16: Learning domains evaluation histogram and pie chart for EE program term 361 showing the percentage distribution of assessment activities in Bloom's 3 learning domains

We can also collect information for learning acquired in 3 domains for the EE program, term 361, 11 ABET SOs, by using the counts of assessments and activities actually processed in various courses and combine them with the hypothetical information from Table 1 to present the comparison data in Table 5. A high-level analysis of actual assessment counts data processed by faculty members in various courses of the EE program, term 361, confirms good corroboration of the hypothetical model suggested earlier in Table 1 measurement.

Table 5: Comparison of assessment activity for EE program term 361 with hypothetical information to confirm the degree of relevance and coverage of the 11 ABET SOs for Bloom's 3 learning domains

SO_NO.	ABET SOs	DOMAINS RELEVANCE & COVERAGE								
		COGNITIVE			AFFECTIVE			PSYCHOMOTOR		
		HYPOTHETICAL	COUNTS	%	HYPOTHETICAL	COUNTS	%	HYPOTHETICAL	COUNTS	%
SO_1	a. an ability to apply knowledge of mathematics, science and engineering	H	51	100.00%	L	0	0.00%	L	0	0.00%
SO_2	b. an ability to design and conduct experiments, as well as to analyze and interpret data	H	7	10.14%	M	0	0.00%	H	62	89.86%
SO_3	c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	H	10	83.33%	H	0	0.00%	H	2	16.67%
SO_4	d. an ability to function on multidisciplinary teams	M	0	0.00%	H	1	100.00%	L	0	0.00%
SO_5	e. an ability to identify, formulate, and solve engineering problems	H	48	100.00%	L	0	0.00%	L	0	0.00%
SO_6	f. an understanding of professional and ethical responsibility	M	0	0.00%	H	11	100.00%	L	0	0.00%
SO_7	g. an ability to communicate effectively	M	0	0.00%	H	11	100.00%	M	0	0.00%
SO_8	h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	M	0	0.00%	H	1	100.00%	L	0	0.00%
SO_9	i. a recognition of the need for, and an ability to engage in life-long learning	M	0	0.00%	H	0	0.00%	L	0	0.00%
SO_10	j. a knowledge of contemporary issues	M	0	0.00%	H	1	0.00%	L	0	0.00%
SO_11	k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	H	40	88.89%	L	0	0.00%	H	5	11.11%

The combination of assessment counts, percentages and hypothetical information for each learning domain provides a wealth of detail regarding any deficiencies in the current ABET SO assessment plan and modifications that need to be implemented in the future to achieve an optimum distribution of coverages in the various learning domains. A brief analysis of the information in Table 5 related to ABET SO 'c' (SO_3), which deals with capstone design projects, shows clearly that EE courses in term 361 did not have adequate assessments to measure certain affective domain PIs. The measurement of the fulfillment of realistic constraints for capstone design projects is an important requirement for ABET accreditation. This information would drive the EE program faculty members to align future courses to measure the necessary skills associated with design activity, and therefore contribute significantly to CQI in engineering education.

XII. Conclusion

This paper presents the results of the integration of fundamental concepts of the OBE model with world-class best practices in outcomes assessment and the web-based software EvalTools® 6, deployed with significant customizations. The generation of assessments and their mapping to specific PIs for measurement followed up with failure identification and remedial action is a total faculty affair, thereby creating the ideal situation for CQI in engineering education. A novel technique using frequency counts of outcomes assessments to measure specific PIs related to revised Bloom's 3 learning domains and their learning levels in multiple course levels is explained. A wealth of diagnostic information resulting in the highest standards of CQI for engineering education remains to be uncovered using these state-of-the-art systems and processes and shall be the subject of future research. National Qualifications frameworks and international engineering educational organizations can benefit from the *Learning Domains Wheel*, learning domains evaluation using the frequency counts approach to align the development of their *learning domains categories* and specifications to apply to various engineering specializations.

Specifically, ABET SOs coverage of Bloom's domains has been studied in great detail. A PI bank containing a good number of well-defined specific PIs related to the ABET SOs has been developed for the EE, CE, and ME programs. The specific PIs measured in all course levels have provided faculty members with precise information for course and program evaluation and subsequent improvement. The current format of measuring 11 ABET SOs is definitely cumbersome for programs and institutions that utilize manual processes. The general advice provided to programs is to be very selective in using assessments for measuring these SOs to minimize overburdening faculty and programs efforts for accreditation. This is acceptable from the accreditation criteria fulfillment standpoint, but from the OBE model student-centered point of view, it does not facilitate CQI since the assessments selected tend to become summative and not formative. With the *Hierarchy-Frequency Weighting Scheme* (HFWS) and availability of digital technology, implementing formative assessments over multiple phases of curriculum delivery is much easier. This implemented assessment methodology encourages faculty to use relevant information for real-time modifications for CQI.

A minority of faculty members was initially reluctant to implement digital technology incorporating FCAR methodology and PIs classification per Bloom's 3 domains. One of the reasons for this resistance was the lack of comprehension of ABET accreditation, latest outcomes assessment processes, and experience regarding their management. Detailed training sessions followed up with extensive technical and intellectual support from the Office of Quality and Accreditation for the Faculty of Engineering significantly alleviated their reservations. Various program level sessions held for the development and classification of specific PIs actually galvanized the interest levels of faculty members by providing them with a first-hand learning experience to develop measurable learning outcomes, their PIs and assessments as per Bloom's 3 domains, and their learning levels. The most difficult aspect of continuous improvement and accreditation efforts for faculty members was to create action items for improvement based upon deficient outcomes assessment data, assign them to the concerned parties or individuals, and follow up for closing the loop. Implementing physical systems to maintain huge amounts of paper-based documentation and manual processes to access specific, on-time information for CQI activity related to closing the loop were specifically the biggest challenges faced by the faculty members.

The Continuous Improvement Management System (CIMS) offered by EvalTools ® 6 provided our faculty with efficient streamlining mechanisms for quality improvement efforts by employing very high levels of automation and paper-free digital documentation. Instant electronic access to digital records of single or multi-term outcomes assessment information from program reviews and detailed meeting minutes, action items status of 17 standing committees, essential for CQI efforts, were compelling reasons for an eventual, almost 100% faculty buy-in of the implemented digital systems and outcomes assessment methodologies. Other digital systems and tools as referenced earlier in this paper do not incorporate the FCAR methodology, CIMS systems, and advanced student and program level analytical reports, thereby seriously limiting the level of automation and streamlining available for typical quality improvement processes.

Mapping assessments to PIs, documenting reflections and action items is roughly a 4-hour job per course per term for a faculty member with an average level of experience of the established outcomes assessment methodology using EvalTools ® 6. The Office of Quality and Accreditation at the Faculty of Engineering would coordinate with faculty members for any modifications to PIs and their respective assessments. EvalTools® 6 offers LMS, AAS, OAS and CIMS systems linked to a google cloud database. Faculty of various programs and members of standing committees progressively populate digital databases with necessary information related to course materials, assessments, PIs, their measurements, analytical reports, meeting minutes, action items, etc. Latest faculty, student and course information for each program is automatically updated using an electronic interface with EvalTools® servers. Any maintenance issues related to these systems are generally minimal and moderated by the Office of Quality and Accreditation for resolution by the information technology teams of MAKTEAM *Software* Inc. and the Islamic University of Madinah.

With a majority of positive aspects, one limitation of our system, the allocation of resources to scan paper documents, is currently performed by either the lecturers or teaching assistants. Work is currently in progress to develop state-of-the-art digital systems that automate outcomes assessment development and scoring processes. This technology would integrate with existing digital systems to significantly reduce the overhead related to overall time spent by faculty in the outcomes assessment process and scanning work done by lecturers. Future research work will present details of this ground-breaking technology, which has the potential to dramatically revolutionize OBE in engineering. In conclusion, we have achieved our goal to evaluate engineering programs based on the automated measurement of PIs classified into the cognitive, affective and psychomotor learning domains of the revised Bloom's taxonomy.

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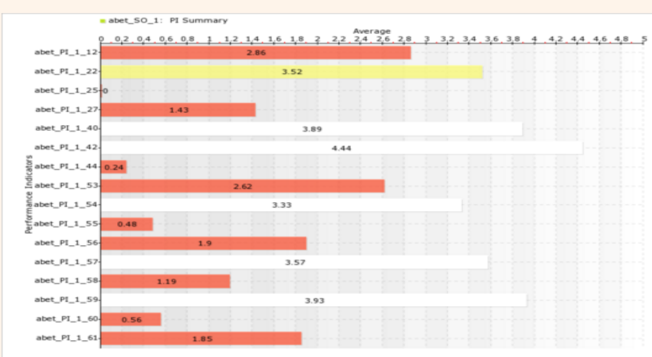
Appendix A: EE Program, term 361, ABET SO ‘b’ analytics including psychomotor domain PI measurements

abet_SO_2: an ability to design and conduct experiments, as well as to analyze and interpret data

- abet_PI_2_2: **Cognitive:** Evaluating Choose the appropriate experimental test equipment to achieve the identified objectives of the experiment
- abet_PI_2_3: **Psychomotor:** Mechanism Conduct the experiment
- abet_PI_2_4: **Cognitive:** Evaluating Analyze and interpret the data
- abet_PI_2_15: **Psychomotor:** Mechanism Demonstrate familiarity with electronic devices in laboratory environments, such as oscilloscopes, amplifiers, CRTs, LCDs, analog and digital electronic circuits, analog to digital converters and spectrum analyser
- abet_PI_2_16: **Psychomotor:** Mechanism Use basic electrical measurement and experimental tools, such as ammeters, oscilloscopes, power supplies and electrical connections
- abet_PI_2_18: **Cognitive:** Evaluating Analyze and interpret electrical engineering experimental data and output information from electrical tests and experiments
- abet_PI_2_19: **Psychomotor:** Adaptation Assemble or connect the circuit as per specifications or design requirements and choose appropriate components
- abet_PI_2_20: **Psychomotor:** Complex overt response Acquire hands on experience in programming 8086 microprocessor
- abet_PI_2_21: **Psychomotor:** Adaptation Use Emulator software to write and execute Assembly language code for 8086 microprocessor
- abet_PI_2_22: **Psychomotor:** Adaptation Design, construct and take measurements in the laboratory of RC coupled JFET and BJT multistage amplifier circuits and compare experimental results with theoretical analysis
- abet_PI_2_23: **Psychomotor:** Adaptation Design, construct, and take measurements in the laboratory of transistor amplifier circuits in order to illustrate their frequency responses and compare experimental results with theoretical analysis
- abet_PI_2_24: **Psychomotor:** Adaptation Design, construct and take measurements in the laboratory of class-A and class-AB power amplifier circuits and compare experimental results with theoretical analysis
- abet_PI_2_25: **Psychomotor:** Adaptation Design, construct and take measurements in the laboratory of linear operational amplifier circuits and compare experimental results with theoretical analysis
- abet_PI_2_26: **Psychomotor:** Adaptation Design, construct and take measurements in the laboratory of current source and current mirror circuits and compare experimental results with theoretical analysis
- abet_PI_2_27: **Psychomotor:** Adaptation Design, construct and take measurements in the laboratory of differential amplifier circuits and compare experimental results with theoretical analysis
- abet_PI_2_31: **Psychomotor:** Adaptation Investigate the performance of various logic gates and logical functions in laboratory experiments employing various test techniques and data analysis tools
- abet_PI_2_32: **Psychomotor:** Adaptation Implement digital circuits in laboratory experiments by application of Boolean function simplification methods to given logic functions and verify their functionality by comparing with expected results
- abet_PI_2_33: **Psychomotor:** Adaptation Design, construct combinational and sequential logic circuits in the laboratory and verify their functionality by taking appropriate measurements

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_2_2	(0,0,0,1)	3.1	EE_201_384	CIRCUIT THEORY 1	Introductory	1	5	0	1	3.1
abet_PI_2_3	(0,3,0,0)	4.1	EE_201_384	CIRCUIT THEORY 1	Introductory	2	5	0	0	3.81
			EE_261_385	DIGITAL LOGIC DESIGN	Introductory	2	1	0	0	4.44
			EE_361_395	MICROPROCESSORS	Reinforced	3	4	0	0	4.05
abet_PI_2_4	(0,0,1,0)	3.1	EE_201_384	CIRCUIT THEORY 1	Introductory	3	0	4	0	3.1
abet_PI_2_15	(0,1,0,0)	4.44	EE_261_385	DIGITAL LOGIC DESIGN	Introductory	2	1	0	0	4.44
abet_PI_2_16	(0,1,0,0)	4.29	EE_201_384	CIRCUIT THEORY 1	Introductory	4	3	0	0	4.29
abet_PI_2_18	(0,1,0,0)	4.52	EE_201_384	CIRCUIT THEORY 1	Introductory	5	2	0	0	4.52
abet_PI_2_19	(0,1,0,0)	3.57	EE_201_384	CIRCUIT THEORY 1	Introductory	1	6	0	0	3.57
abet_PI_2_20	(0,1,0,0)	4.05	EE_361_395	MICROPROCESSORS	Reinforced	3	4	0	0	4.05
abet_PI_2_21	(0,1,0,0)	3.81	EE_361_395	MICROPROCESSORS	Reinforced	2	5	0	0	3.81
abet_PI_2_22	(0,0,1,0)	1.67	EE_311_391	ELECTRONICS II	Reinforced	0	0	7	0	1.67
abet_PI_2_23	(0,0,0,1)	0.24	EE_311_391	ELECTRONICS II	Reinforced	0	0	1	6	0.24
abet_PI_2_24	(1,0,0,0)	5	EE_311_391	ELECTRONICS II	Reinforced	7	0	0	0	5
abet_PI_2_25	(0,0,1,0)	3.1	EE_311_391	ELECTRONICS II	Reinforced	0	6	1	0	3.1
abet_PI_2_26	(0,0,0,1)	0	EE_311_391	ELECTRONICS II	Reinforced	0	0	0	7	0
abet_PI_2_27	(0,0,1,0)	1.67	EE_311_391	ELECTRONICS II	Reinforced	0	0	7	0	1.67
abet_PI_2_31	(1,0,0,0)	5	EE_261_385	DIGITAL LOGIC DESIGN	Introductory	3	0	0	0	5
abet_PI_2_32	(0,1,0,0)	3.33	EE_261_385	DIGITAL LOGIC DESIGN	Introductory	0	3	0	0	3.33
abet_PI_2_33	(0,1,0,0)	3.33	EE_261_385	DIGITAL LOGIC DESIGN	Introductory	1	1	1	0	3.33

Overall SO Average: 2.97 EAMU: (2,9,2,5)



Note: Specific lab performance measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

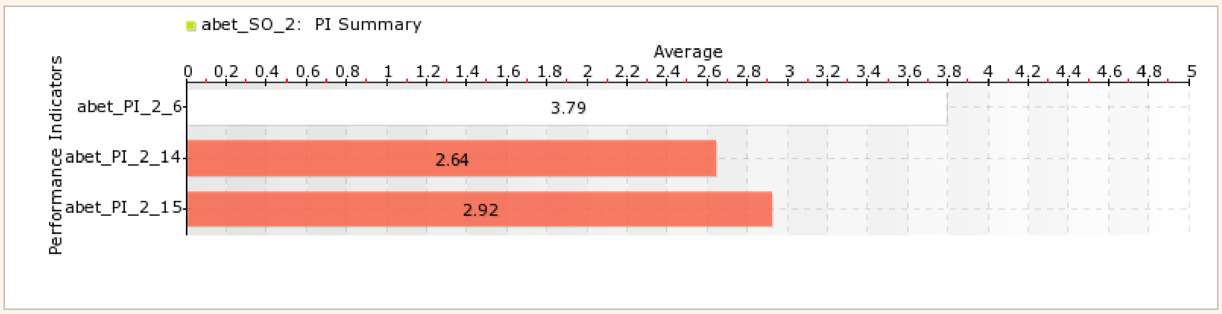
Appendix B: CE Program, term 361, ABET SO 'b' analytics including psychomotor domain PI measurements

abet_SO_2: an ability to design and conduct experiments, as well as to analyze and interpret data

abet_PI_2_6: **Psychomotor:** Adaptation Conduct laboratory experiments and field tests to determine the physical and engineering properties of soils and rocks
abet_PI_2_14: **Cognitive:** Evaluating Classify flows into Laminar and Turbulent based on experimental data and Reynold's number
abet_PI_2_15: **Psychomotor:** Adaptation Measure pressure for various fluid systems by applying the concept of working principles of manometers

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_2_6	(0,1,0,0)	3.79	CE_321_374	SOIL MECHANICS	Reinforced	3	8	0	0	3.79
abet_PI_2_14	(0,0,0,1)	2.64	CE_351_378	FLUID MECHANICS	Reinforced	5	1	2	4	2.64
abet_PI_2_15	(0,0,0,1)	2.92	CE_351_378	FLUID MECHANICS	Reinforced	4	4	1	3	2.92

Overall SO Average: 3.12 EAMU: (0,1,0,2)



Note: Specific lab performance measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

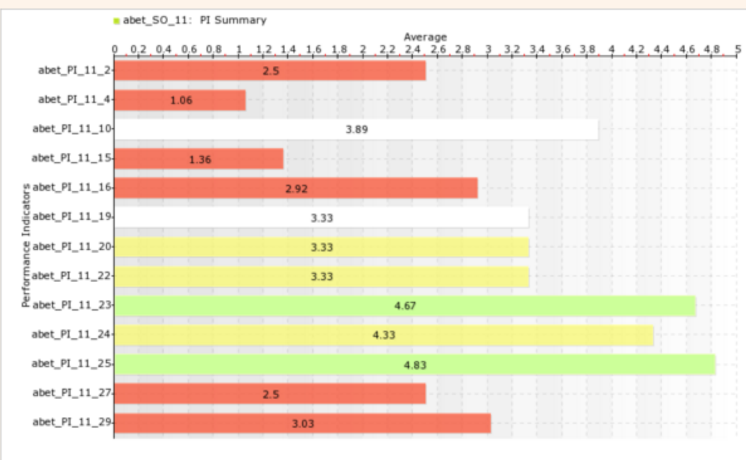
Appendix C: CE Program, term 361, ABET SO 'k' analytics including psychomotor domain PI measurements

abet_SO_11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

- abet_PI_11_2: Psychomotor: Complex overt response Draft standard technical drawings (plan, elevation) complete with notations, dimensions and communication attributes.
- abet_PI_11_4: Cognitive: Evaluating Select the appropriate types of foundations and retaining structures according to the site and structure characteristics
- abet_PI_11_10: Psychomotor: Guided response Produce standard engineering drawings in AutoCAD complete with suitable templates, dimensions and text labels.
- abet_PI_11_15: Psychomotor: Mechanism Draw free body diagrams of machines/structures under varying loads and moment.
- abet_PI_11_16: Psychomotor: Origination Identify drafting, editing, dimensioning and plotting commands in AutoCAD environment
- abet_PI_11_19: Cognitive: Analyzing Analyze determinate and indeterminate structures by using classical methods
- abet_PI_11_20: Cognitive: Analyzing Compute displacement and slopes for beams using geometric methods (double integration, moment area or conjugate beam method) and energy methods (virtual work method, and Castiglione's theorem)
- abet_PI_11_22: Cognitive: Analyzing Calculate the shear force and bending moment at various sections of the beams and/or frames and draw the bending moment (BMD) and shear force (SFD) diagrams.
- abet_PI_11_23: Cognitive: Analyzing Analyze structures using deflection methods
- abet_PI_11_24: Cognitive: Analyzing Analyze structures using Influence Line
- abet_PI_11_25: Cognitive: Analyzing Analyze indeterminate structures such as beams, frames and trusses using the Flexibility Method, Slope deflection, moment distribution, Stiffness method and computer application and finite element analysis
- abet_PI_11_27: Cognitive: Evaluating Define viscosity and calculate or read its values from tables and charts for different fluids
- abet_PI_11_29: Psychomotor: Adaptation Classify soils using standard charts and Tables such as USCS, AASHTO, and BS etc.

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_11_2	(0,0,1,0)	2.5	CE_202_2534	CIVIL ENGINEERING DRAWING	Introductory	1	4	7	0	2.5
abet_PI_11_4	(0,0,0,1)	1.06	CE_321_374	SOIL MECHANICS	Reinforced	2	0	1	8	1.06
abet_PI_11_10	(0,1,0,0)	3.89	CE_202_2534	CIVIL ENGINEERING DRAWING	Introductory	6	4	2	0	3.89
abet_PI_11_15	(0,0,0,2)	1.36	CE_201_380	STATICS	Introductory	0	1	7	1	1.67
			CE_201_397	STATICS	Introductory	1	0	2	5	1.04
abet_PI_11_16	(0,0,0,1)	2.92	CE_202_2534	CIVIL ENGINEERING DRAWING	Introductory	3	5	2	2	2.92
abet_PI_11_19	(0,1,0,0)	3.33	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	3	4	3	0	3.33
abet_PI_11_20	(0,0,1,0)	3.33	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	3	5	1	1	3.33
abet_PI_11_22	(0,0,1,0)	3.33	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	5	1	3	1	3.33
abet_PI_11_23	(1,0,0,0)	4.67	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	8	2	0	0	4.67
abet_PI_11_24	(0,0,1,0)	4.33	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	8	1	0	1	4.33
abet_PI_11_25	(1,0,0,0)	4.83	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	9	1	0	0	4.83
abet_PI_11_27	(0,0,0,1)	2.5	CE_351_378	FLUID MECHANICS	Reinforced	6	0	0	6	2.5
abet_PI_11_29	(0,0,0,1)	3.03	CE_321_374	SOIL MECHANICS	Reinforced	5	1	3	2	3.03

Overall SO Average: 3.2 EAMU: (2,2,3,6)



Note: Specific skills performance measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

Appendix D: ME Program, term 361, ABET SO ‘b’ analytics including psychomotor domain PI measurements

abet_SO_2: an ability to design and conduct experiments, as well as to analyze and interpret data

abet_PI_2_11: Psychomotor: Complex overt response Perform experiments to find the mechanical properties of metals

abet_PI_2_12: Psychomotor: Complex overt response Use the balancing machine proficiently by proper selection of slot and angle for given masses to verify the accuracy of calculated magnitude and direction of masses

abet_PI_2_13: Psychomotor: Adaptation Construct different types of cam profile from given data using various geometric instruments

abet_PI_2_14: Psychomotor: Adaptation Draw velocity polygon of linkages using graphical method to determine velocity of linkages

abet_PI_2_16: Cognitive: Analyzing Calculate, analyze and interpret flow rates using venturi meter, orifice meter and rotameter

abet_PI_2_17: Psychomotor: Adaptation Analyze velocity profile in a pipe using pitot tube in a air flow study unit.

abet_PI_2_18: Psychomotor: Adaptation Examine the impact of a jet on different types of surfaces and study relationship between jet impact and rate of change of momentum

abet_PI_2_19: Psychomotor: Adaptation Measure viscosity, terminal velocity, drag force and drag coefficient using appropriate equipment

abet_PI_2_20: Psychomotor: Adaptation Calibrate the pressure gauge and understand the relationship between area and pressure.

abet_PI_2_21: Cognitive: Analyzing Determine the fluid friction in a straight pipe

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_2_11	(1,0,0,0)	4.85	ME_211_399	MATERIALS SCIENCE	Introductory	10	1	0	0	4.85
abet_PI_2_12	(0,0,1,0)	3.06	ME_323_404	THEORY OF MACHINES	Reinforced	3	9	6	0	3.06
abet_PI_2_13	(0,1,0,0)	4.17	ME_323_404	THEORY OF MACHINES	Reinforced	10	7	1	0	4.17
abet_PI_2_14	(0,0,0,1)	2.78	ME_323_404	THEORY OF MACHINES	Reinforced	7	2	5	4	2.78
abet_PI_2_16	(0,1,0,0)	3.44	ME_375_402	FLUID MECHANICS	Reinforced	3	11	2	0	3.44
abet_PI_2_17	(0,0,1,0)	3.65	ME_375_402	FLUID MECHANICS	Reinforced	9	3	2	2	3.65
abet_PI_2_18	(0,1,0,0)	4.27	ME_375_402	FLUID MECHANICS	Reinforced	12	2	1	1	4.27
abet_PI_2_19	(0,0,1,0)	3.75	ME_375_402	FLUID MECHANICS	Reinforced	11	0	3	2	3.75
abet_PI_2_20	(0,0,0,1)	3.23	ME_375_402	FLUID MECHANICS	Reinforced	5	7	2	2	3.23
abet_PI_2_21	(0,0,0,1)	1.88	ME_375_402	FLUID MECHANICS	Reinforced	1	5	5	5	1.88

Overall SO Average: 3.56 EAMU: (1,3,3,3)

Note: Specific lab performance measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

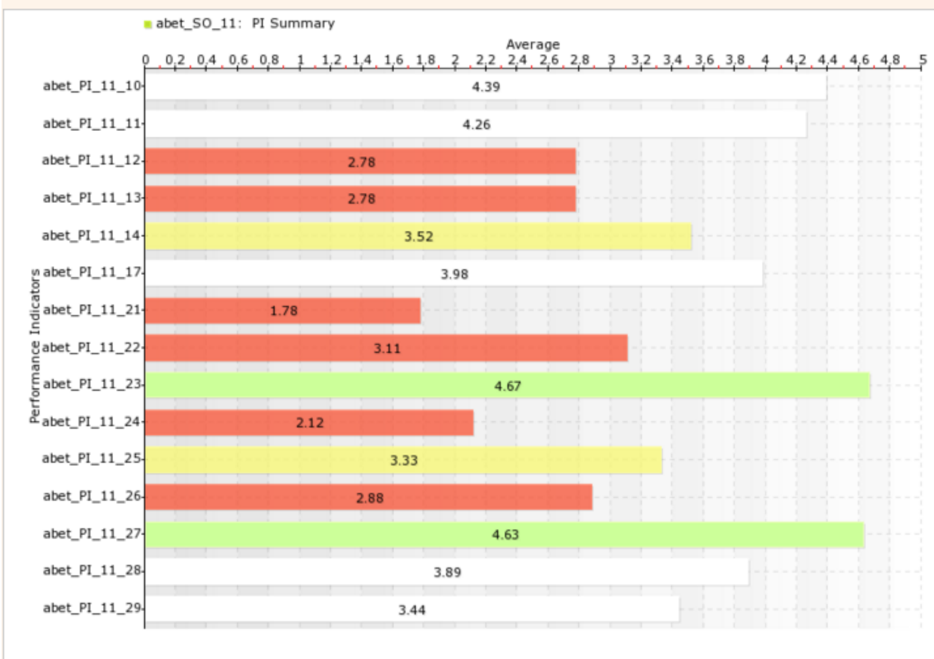
Appendix E: ME Program, term 361, ABET SO ‘k’ analytics including psychomotor domain PI measurements

abet_SO_11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

abet_PI_11_10: Psychomotor: Adaptation Study the different phase of the solution and varying composition of the material
abet_PI_11_11: Psychomotor: Adaptation Apply orthographic projection techniques to draw three views.
abet_PI_11_12: Psychomotor: Adaptation Identify drafting, editing, dimensioning and plotting commands in AutoCAD environment.
abet_PI_11_13: Psychomotor: Complex overt response Produce standard engineering drawings in AutoCAD complete with suitable templates, dimensions and text labels.
abet_PI_11_14: Psychomotor: Complex overt response Draw the sectional views of the three dimensional model in AUTOCAD
abet_PI_11_17: Psychomotor: Adaptation Construct turning moment diagrams to solve fluctuating speed problems
abet_PI_11_21: Cognitive: Analyzing Analyze Otto, diesel, dual combustion steam cycles; reheat and regenerative vapor cycles by drawing the P-v and T-s diagrams
abet_PI_11_22: Cognitive: Evaluating Analyze the performance of IC engine based on air-standard assumptions
abet_PI_11_23: Cognitive: Evaluating Evaluate the performance of compressors by computing the work input of the reciprocating compressor
abet_PI_11_24: Cognitive: Understanding Explain vacancy and interstitial imperfections by drawing crystal plane and direction
abet_PI_11_25: Psychomotor: Adaptation Draw binary phase diagram to determine the weight percentage of different materials present in alloys
abet_PI_11_26: Psychomotor: Adaptation Evaluate the carbon content in the material by applying iron carbon phase and isothermal time temperature diagram
abet_PI_11_27: Psychomotor: Adaptation Develop isometric drawings from orthographic views
abet_PI_11_28: Psychomotor: Adaptation Identify and utilize 3D modeling and editing tools in AUTOCAD to generate complex geometrical features
abet_PI_11_29: Psychomotor: Adaptation Evaluate refrigeration cycles by calculating the Coefficient of Performance (COP) by drawing the T-s diagram using various refrigerant tables

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_11_10	(0,1,0,0)	4.39	ME_211_399	MATERIALS SCIENCE	Introductory	9	1	0	1	4.39
abet_PI_11_11	(0,1,0,0)	4.26	ME_213_398	MECHANICAL ENGINEERING DRAWING	Introductory	6	2	1	0	4.26
abet_PI_11_12	(0,0,0,1)	2.78	ME_213_398	MECHANICAL ENGINEERING DRAWING	Introductory	1	5	2	1	2.78
abet_PI_11_13	(0,0,0,1)	2.78	ME_213_398	MECHANICAL ENGINEERING DRAWING	Introductory	1	5	2	1	2.78
abet_PI_11_14	(0,0,1,0)	3.52	ME_213_398	MECHANICAL ENGINEERING DRAWING	Introductory	4	3	1	1	3.52
abet_PI_11_17	(0,1,0,0)	3.98	ME_323_404	THEORY OF MACHINES	Reinforced	11	4	2	1	3.98
abet_PI_11_21	(0,0,0,1)	1.78	ME_361_401	THERMODYNAMICS II	Reinforced	2	2	6	5	1.78
abet_PI_11_22	(0,0,0,1)	3.11	ME_361_401	THERMODYNAMICS II	Reinforced	4	8	0	3	3.11
abet_PI_11_23	(1,0,0,0)	4.67	ME_361_401	THERMODYNAMICS II	Reinforced	12	3	0	0	4.67
abet_PI_11_24	(0,0,0,1)	2.12	ME_211_399	MATERIALS SCIENCE	Introductory	0	5	4	2	2.12
abet_PI_11_25	(0,0,1,0)	3.33	ME_211_399	MATERIALS SCIENCE	Introductory	5	3	1	2	3.33
abet_PI_11_26	(0,0,0,1)	2.88	ME_211_399	MATERIALS SCIENCE	Introductory	4	2	3	2	2.88
abet_PI_11_27	(1,0,0,0)	4.63	ME_213_398	MECHANICAL ENGINEERING DRAWING	Introductory	7	2	0	0	4.63
abet_PI_11_28	(0,1,0,0)	3.89	ME_213_398	MECHANICAL ENGINEERING DRAWING	Introductory	3	6	0	0	3.89
abet_PI_11_29	(0,1,0,0)	3.44	ME_361_401	THERMODYNAMICS II	Reinforced	3	10	2	0	3.44

Overall SO Average: 3.58 EAMU: (2,5,2,6)



Note: Specific skills performance measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

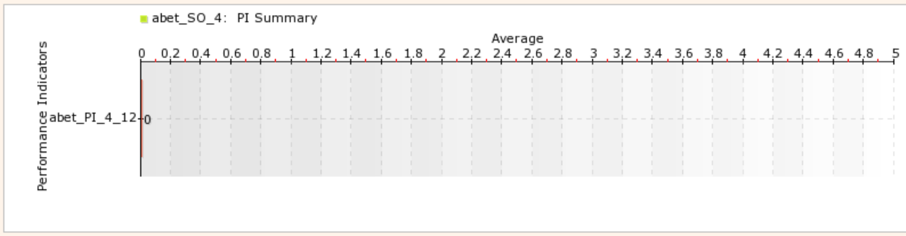
Appendix F: EE Program, term 361, ABET SO ‘d’ analytics including affective domain PI measurements

abet_SO_4: **an ability to function on multidisciplinary teams**

abet_PI_4_12: **Affective:** Internalizing values Fulfill the assigned role in the team for the design project in Electrical and Electronics Systems

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_4_12	(0,0,0,1)	0	EE_311_391	ELECTRONICS II	Reinforced	0	0	0	7	0

Overall SO Average: 0 EAMU: (0,0,0,1)



Note: Teamwork performance measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs. Students in the Electronics II class offered in term 361 EE program were not able to properly complete the teamwork requirements for the assigned project fulfillment.

Appendix G: EE Program, term 361, ABET SO ‘f’ analytics including affective domain PI measurements

abet_SO_6: an understanding of professional and ethical responsibility

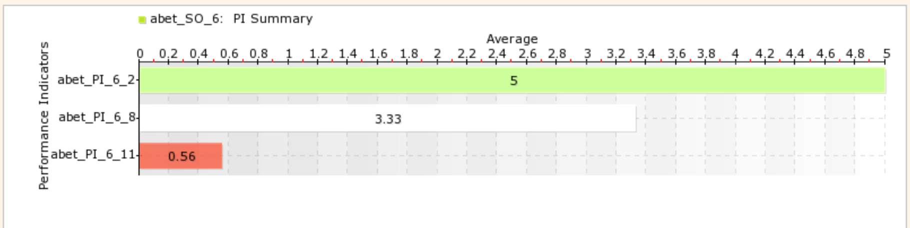
abet_PI_6_2: Affective: Internalizing values Recognize professional responsibility in design, fabrication and operation of electronic devices, boards and systems, and adherence to liability, accountability and codes of ethics applicable to electronics engineering

abet_PI_6_8: Affective: Internalizing values Explain and exhibit the meaning and implications of professional responsibility regarding design and operation of electronic systems, component or process with consideration of constraints such as liability, accountability, safety and other related codes of ethics

abet_PI_6_11: Affective: Internalizing values Recognize and prevent high risk situations in working with Electrical and Electronics Systems

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_6_2	(1,0,0,0)	5	EE_201_384	CIRCUIT THEORY 1	Introductory	7	0	0	0	5
abet_PI_6_8	(0,1,0,0)	3.33	EE_311_391	ELECTRONICS II	Reinforced	0	7	0	0	3.33
abet_PI_6_11	(0,0,0,1)	0.56	EE_341_393	ELECTRICAL MACHINERY 1	Reinforced	0	0	3	6	0.56

Overall SO Average: 1.96 EAMU: (1,1,0,1)



Note: Professional and ethical responsibility measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

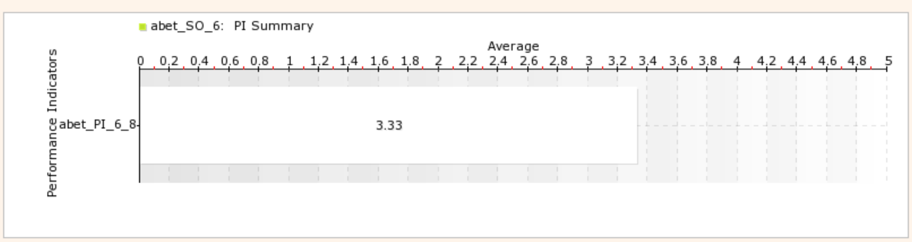
Appendix H: ME Program, term 361, ABET SO ‘f’ analytics including affective domain PI measurements

abet_SO_6: an understanding of professional and ethical responsibility

abet_PI_6_8: Affective: Internalizing values Explain the health and safety regulations for mechanical engineers while operating thermodynamic systems

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_6_8	(0,1,0,0)	3.33	ME_361_401	THERMODYNAMICS II	Reinforced	4	8	2	1	3.33

Overall SO Average: 3.33 EAMU: (0,1,0,0)



Note: Professional and ethical responsibility measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

Appendix I: EE Program, term 361, ABET SO ‘g’ analytics including affective domain PI measurements

abet_SO_7: an ability to communicate effectively

abet_PI_7_1: Affective: Organize values into priorities Present technical information with proper format and organization

abet_PI_7_4: Affective: Internalizing values Communicate orally

abet_PI_7_9: Affective: Internalizing values Write technical reports in a correct, clear and coherent way

abet_PI_7_11: Affective: Internalizing values Employ writing skills on Signals and Systems in technical reports and presentations exhibiting proper organization and technical format and implemented using MATLAB.

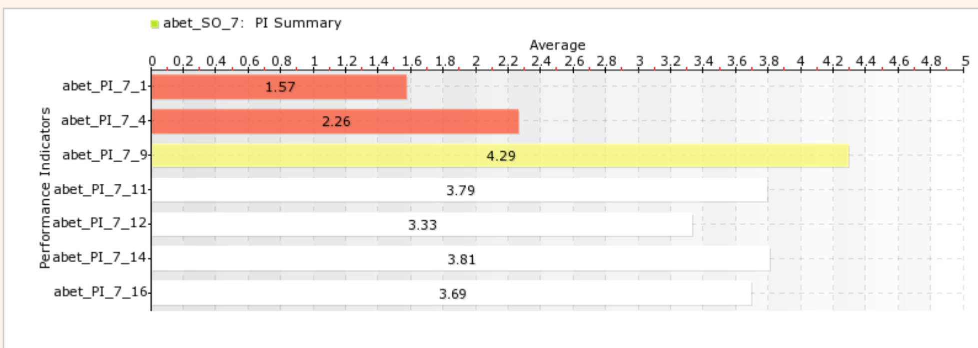
abet_PI_7_12: Affective: Internalizing values Employ writing and oral communication skills on AC/DC machines in technical reports and presentations exhibiting proper organization and technical format.

abet_PI_7_14: Affective: Internalizing values Present technical information related to Electrical and Electronics Systems in proper format and organization with correct terminologies

abet_PI_7_16: Affective: Internalizing values Employ oral communication skills on Signals and Systems in technical reports and presentations exhibiting proper organization and technical format and implemented using MATLAB

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_7_1	(0,0,0,2)	1.57	EE_261_385	DIGITAL LOGIC DESIGN	Introductory	0	0	0	3	0
			EE_361_395	MICROPROCESSORS	Reinforced	0	2	4	1	1.9
abet_PI_7_4	(0,0,1,1)	2.26	EE_261_385	DIGITAL LOGIC DESIGN	Introductory	0	0	1	2	0.56
			EE_361_395	MICROPROCESSORS	Reinforced	2	0	5	0	2.62
abet_PI_7_9	(0,0,1,0)	4.29	EE_201_384	CIRCUIT THEORY 1	Introductory	6	0	0	1	4.29
abet_PI_7_11	(0,1,1,0)	3.79	EE_201_384	CIRCUIT THEORY 1	Introductory	0	6	1	0	3.1
			EE_301_390	SIGNALS AND SYSTEMS	Reinforced	5	9	0	0	3.93
abet_PI_7_12	(0,1,0,0)	3.33	EE_341_393	ELECTRICAL MACHINERY 1	Reinforced	0	9	0	0	3.33
abet_PI_7_14	(0,1,0,0)	3.81	EE_311_391	ELECTRONICS II	Reinforced	2	5	0	0	3.81
abet_PI_7_16	(0,1,0,0)	3.69	EE_301_390	SIGNALS AND SYSTEMS	Reinforced	4	9	1	0	3.69

Overall SO Average: 3.06 EAMU: (0,4,1,2)



Note: Written and oral skills measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

Appendix J: CE Program, term 361, ABET SO ‘g’ analytics including affective domain PI measurements

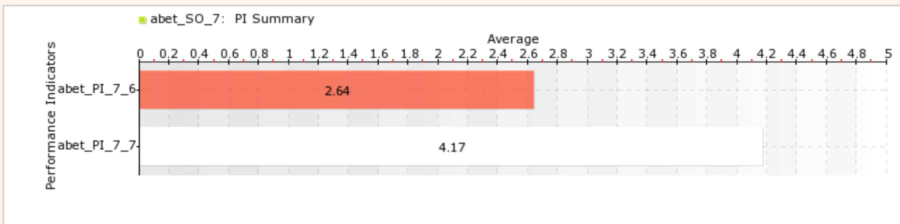
abet_SO_7: **an ability to communicate effectively**

abet_PI_7_6: Affective: Organize values into priorities Write technical reports in a correct, clear and coherent way

abet_PI_7_7: Affective: Internalizing values Employ writing skills on analysis and design in technical reports and presentations exhibiting proper organization and technical format and implemented using relevant software.

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_7_6	(0,0,1,0)	2.64	CE_202_2534	CIVIL ENGINEERING DRAWING	Introductory	1	6	4	1	2.64
abet_PI_7_7	(0,1,0,0)	4.17	CE_312_379	STRUCTURAL ANALYSIS 1	Reinforced	5	5	0	0	4.17

Overall SO Average: 3.66 EAMU: (0,1,0,1)



Note: Written and oral skills measurement instruments and/or rubrics are employed to facilitate the measurement and scoring of the above-listed PIs.

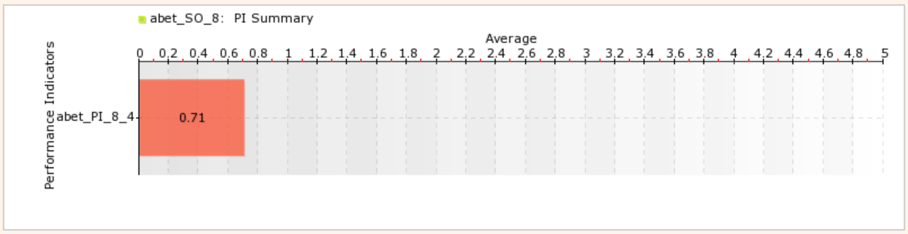
Appendix K: EE Program, term 361, ABET SO ‘h’ analytics including affective domain PI measurements

abet_SO_8: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

abet_PI_8_4: Affective: Organize values into priorities Examine environmental/economic tradeoffs, health and safety/economic tradeoffs of an engineering design of prototype

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_8_4	(0,0,0,1)	0.71	EE_201_384	CIRCUIT THEORY 1	Introductory	0	0	3	4	0.71

Overall SO Average: 0.71 EAMU: (0,0,0,1)



Note: Instruments and/or rubrics for students’ forum/report writing are employed to facilitate the measurement and scoring of the above-listed PIs.

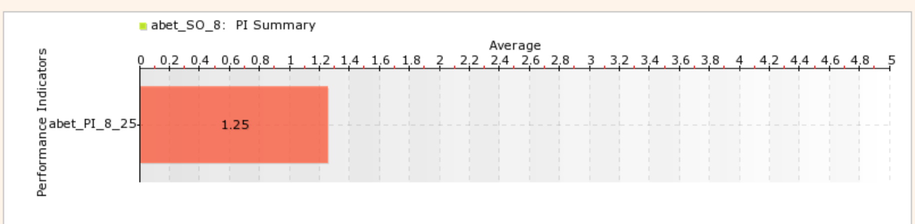
Appendix L: CE Program, term 361, ABET SO ‘h’ analytics including affective domain PI measurements

abet_SO_8: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

abet_PI_8_25: Affective: Organize values into priorities Relate the use of Bernoulli Equation and the Continuity Equation to real life situations.

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_8_25	(0,0,0,1)	1.25	CE_351_378	FLUID MECHANICS	Reinforced	2	0	3	7	1.25

Overall SO Average: 1.25 EAMU: (0,0,0,1)



Note: Instruments and/or rubrics for students’ forum/report writing are employed to facilitate the measurement and scoring of the above-listed PIs.

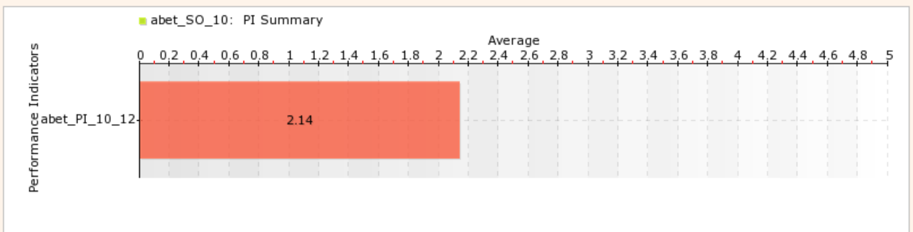
Appendix M: EE Program, term 361, ABET SO ‘j’ analytics including affective domain PI measurements

abet_SO_10: a knowledge of contemporary issues

abet_PI_10_12: Affective: Internalizing values Compare and contrast performance parameters of the state-of-the-art microprocessors / microcontrollers

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_10_12	(0,0,0,1)	2.14	EE_361_395	MICROPROCESSORS	Reinforced	2	0	3	2	2.14

Overall SO Average: 2.14 EAMU: (0,0,0,1)



Note: Instruments and/or rubrics for students’ forum/report writing are employed to facilitate the measurement and scoring of the above-listed PIs.

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Quality improvement with automated engineering program evaluations using performance indicators based on Bloom's 3 domains

Publisher: IEEE

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Abstract:
In this paper, we present examples of quality improvement efforts to enhance student learning in engineering education by employing a novel program evaluation methodology that automates ABET Student Outcomes (SOs) data measurement and analysis based on the classification of specific performance indicators per Bloom's 3 domains and their learning levels. The learning levels are further categorized based on a 3-Level Skills Grouping Methodology that groups together learning levels of related proficiency. Program evaluations use aggregate values of ABET SOs as an overall performance index. These values are calculated by assigning weights to measured specific performance indicators according to the Frequency-Hierarchy Weighting-Factors Scheme, which incorporates a hierarchy of measured skills, course levels in which they are measured, and counts of assessments implemented for their measurement. The number of assessments processed for measurement of performance indicators associated with the 3 categories of skills in multiple course levels is counted to calculate percentage learning distribution in the elementary, intermediate and advanced levels for the 3 learning domains. Learning distributions obtained for measured ABET SOs are compared to ideal models to verify standards of achievement for required types of skills, proficiency levels and align engineering curriculum delivery to attain highest levels of holistic learning.

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Quality Improvement with Automated Engineering Program Evaluations Using Performance Indicators Based on Bloom's 3 Domains

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Abstract— In this paper, we present examples of quality improvement efforts to enhance student learning in engineering education by employing a novel program evaluation methodology that automates ABET Student Outcomes (SOs) data measurement and analysis based on the classification of specific performance indicators per Bloom's 3 domains and their learning levels. The learning levels are further categorized based on a 3-Level Skills Grouping Methodology that groups together learning levels of related proficiency. Program evaluations use aggregate values of ABET SOs as an overall performance index. These values are calculated by assigning weights to measured specific performance indicators according to the Frequency-Hierarchy Weighting-Factors Scheme, which incorporates a hierarchy of measured skills, course levels in which they are measured, and counts of assessments implemented for their measurement. The number of assessments processed for measurement of performance indicators associated with the 3 categories of skills in multiple course levels is counted to calculate percentage learning distribution in the elementary, intermediate and advanced levels for the 3 learning domains. Learning distributions obtained for measured ABET SOs are compared to ideal models to verify standards of achievement for required types of skills, proficiency levels and align engineering curriculum delivery to attain highest levels of holistic learning.

Keywords— Outcomes Assessments; Bloom's Domains; Learning Domains; ABET; Student Outcomes; Skills; Learning Levels; Performance Indicators;

I. INTRODUCTION

Multiple research papers published by the National Institute of Learning Outcomes Assessment (NILOA) [11,12] and others [2,13,14] clearly state that in many higher education institutions, actual Continuous Quality Improvement (CQI) and accreditation efforts are minimally integrated and that, ideally, CQI instead of accreditation standards should be the prime driver for outcomes assessment [18]. The indispensable necessity of digital technology to automate and streamline outcomes assessment for accreditation is explained in many research papers [15,16,17,18,27,28,30]. State-of-the-art digital technology-based outcomes assessment systems would definitely help fulfill accreditation standards and achieve excellent CQI results. In this paper, we present the results of integration of fundamental concepts of the Outcomes Based Education (OBE) model with world-class best practices in outcomes assessment and web-based software EvalTools® 6, deployed with significant customizations.

The current format of measuring ABET, Engineering and Accreditation Commission (EAC), 11 SOs is definitely cumbersome for programs and institutions that utilize manual processes. The general advice provided to programs is to be very selective in using assessment for measuring these SOs to minimize overburdening faculty and program efforts for accreditation [18,35]. This is acceptable from the accreditation criteria fulfillment standpoint, but from the OBE model student-centered point of view, it does not facilitate CQI. These assessments tend to become summative and not formative, since educational assessment refers to all activities which provide information to be used as feedback to revise and improve instruction and learning strategies [1,10]. The learning outcomes data measured by most engineering institutions are rarely classified into all three learning domains of the revised Bloom's taxonomy [18,29] and their corresponding categories of the levels of learning. Generally, institutions classify courses of a program curriculum into three levels: introductory, reinforced, and mastery, with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for an effective program evaluation. This approach presents a major deficiency for CQI in a student-centered, OBE model, because performance information collected at just the mastery level is at the final phase of a typical quality cycle and occurs too late for implementation of remedial efforts.

Instead, student outcomes and performance criteria progressing from the elementary to advanced levels should be measured at the course level for all courses spanning the entire curriculum [18,31,32]. A holistic approach for a CQI model would require systematic measurement of specific Performance Indicators (PIs), in all 3 domains of learning of Bloom's taxonomy and their corresponding categories of learning levels, for all course levels of a given program's curriculum. Therefore, a digital PI bank containing a good number of well-defined specific PIs, classified per Bloom's 3 learning domains and learning levels, related to the ABET SOs, was developed at the Faculty of Engineering for the EE, CE, and ME programs. The specific PIs measured in all course levels have provided faculty members with precise information for course and program evaluation and subsequent improvement.

In the OBE model, assessments form the basis of learning, giving precise information for improvement, and thus are formative. Since assessment is an essential element of the educational process and is the basis of CQI, a novel technique has been implemented to estimate learning distribution achieved by an engineering program for a given term in Bloom's 3 domains and their learning levels. The learning levels in each domain are further categorized based on a 3-Level Skills Grouping Methodology that groups together learning levels of related proficiency to form 3 broad skills levels categories, namely: elementary, intermediate and advanced. Hence the number of assessments processed for the measurement of performance indicators associated with the 3 categories of skills in multiple course levels is counted. The assessments counts information is used to calculate percentage distribution of learning in the elementary, intermediate and advanced levels for the cognitive, affective and psychomotor domains of learning. Specifically, the ABET SOs coverage of Bloom's 3 domains has been studied in great detail. The percentage learning distribution individual and composite are available for specific and overall combined information related to the measured ABET SOs.

The complete assessment strategy for each measured ABET SO and estimation of program level competencies is provided in the 3 phase *SOs*, *PIs* and *learning domains* evaluation modules' term summary. The term summary contains detailed information on the type of assessments used, their course levels, counts, learning distributions and skill levels of the associated performance indicators measured and can be referred to in our previous work [18,28]. Any existing deficiencies in current assessment models for measured ABET SOs are identified through a detailed 3 phase program term review process conducted by faculty members. In particular, the programs' term review *learning domains* evaluation, which is presented in this paper, estimated learning distributions in Bloom's 3 domains and their 3 skills levels are compared with target ideal values to generate several CQI activities such as the modification or development of: teaching and learning activities; course outcomes; course topics; and assessments and associated PIs to correct the existing learning distribution deficiencies. This assessment methodology, *Hierarchy-Frequency Weighting-Factors Scheme* combined with digital technology, promotes the easy development and usage of formative assessments, making each phase of the course, curriculum delivery transparent to all stakeholders and provides precise information of where and why performance weaknesses exist for timely remedial actions. This implemented assessment methodology encourages faculty to use relevant information for real-time modifications. The generation of assessments and their mapping to specific PIs for measurement followed up with failure identification and remedial action is a total faculty affair, thereby creating the ideal situation for CQI in engineering education [18].

The alignment of student teaching and learning processes, by implementation of outcomes assessments to cover the 3 broad skills levels in all of the 3 Bloom's domains according to preset target percentage distribution levels presents an exciting, new frontier in holistic quality improvement methodologies to achieve the highest education standards for engineering programs world-wide. Therefore, the focus of this research is to present CQI efforts in engineering education using state-of-the-art, digital technology-based, automated outcomes assessment systems to implement proper alignment of program curriculum and course delivery according to ideal learning distributions scenarios required for various engineering specializations.

II. Engineering Program Evaluations

A. Assessment Methodology

The Faculty of Engineering at the Islamic University of Madinah has studied various options for developing its assessment methodology and systems [2,3,4,5,14,15,16,17,31] to establish actual CQI and not just to fulfill ABET accreditation requirements [35]. The following points summarize the essential elements chosen by the faculty to implement state-of-the-art assessment systems for achieving realistic CQI in engineering education [18]:

1. OBE assessment model
2. ABET, EAC outcomes assessment model employing Program Educational Objectives (PEOs), 11 EAC SOs and PIs to measure Course Outcomes (COs)
3. Measurement of outcomes information in all course levels of a program curriculum: introductory, reinforced and mastery.
4. The Faculty Course Assessment Report (FCAR) utilizing the Excellent, Adequate, Minimal, and Unsatisfactory (EAMU) performance vector methodology [24,25,26,27,28]
5. Well-defined performance criteria for course and program levels
6. A digital database of specific PIs [20] classified as per Bloom's revised 3 domains of learning and their associated levels (according to the *3-Level Skills Grouping Methodology*)
7. Unique Assessments mapping to one specific PI [28]
8. Scientific Constructive Alignment for designing assessments to obtain realistic outcomes data representing information for one specific PI per assessment [9,22,28]
9. Integration of direct, indirect, formative and summative outcomes assessments for course and program evaluations
10. Calculation of program and course level ABET SOs, COs data based upon weights assigned to various types of assessments, PIs and course levels
11. Course, program, and student level measurement and analysis of ABET SOs [28]
12. The *Program Term Review* module of EvalTools® 6 consisting of 3 parts a) *Learning Domains Evaluation* b) *PIs Evaluation* and c) *ABET SOs Evaluation* [18,28]
13. A student academic advising module related to measured outcomes data
14. Electronic integration of the Administrative Assistant System (AAS), the Learning Management System (LMS), the Outcomes Assessment System (OAS) and the Continuous Improvement Management System

(CIMS), facilitating faculty involvement for realistic CQI [23,28]

15. Electronic integration of Action Items (AIs) generated from program outcomes term reviews with the Faculty of Engineering standing committees' meetings, tasks, lists and overall CQI processes (CIMS feature)
16. Customized web-based software EvalTools® 6 facilitating all of the above [23]

B. COs, Specific PIs and Associated Assessments Classification Based upon the Revised Bloom's Taxonomy, 3 Domains and Their Learning Levels.

The design flow outlined in Section II.A adopted by the Faculty of Engineering for the creation of holistic learning outcomes and their performance indicators for all courses corresponding to introductory, reinforced and mastery levels spanning the curriculum has been mostly reported in [18]. But first, some of the key concepts needed, to lead into further details on the estimation of learning distribution based upon frequency counts of outcomes assessments used to measure specific PIs in the Bloom's 3 domains and their learning levels for multiple course levels, are given.

In past research [33], Bloom's learning levels in each domain were grouped based on their relation to the various teaching and learning strategies. With some adjustments, a new *3-Level Skills Grouping Methodology* was developed by the Faculty of Engineering, for each learning domain with a focus on grouping activities which are closely associated to a similar degree of skills complexity. Fig. 1 exhibits this new grouping [18].

As stated in several research papers [7,20,21,28,31,32], PIs should be specific in order to collect precise learning outcomes information related to various course topics and phases of a curriculum, while addressing multiple levels of proficiency of a measured skill. Fig. 2 indicates an ideal *learning level distribution model* for COs and PIs for the introductory, intermediate and mastery level courses. The measurement of outcomes and PIs designed following such an ideal distribution will result in a comprehensive database of learning outcome information, which will facilitate a thorough analysis of each phase of the learning process, and a comparatively easier mechanism for early detection of the root cause of student performance failures at any stage of a student's education [18, 28].

Ideally, all courses should measure the elementary, intermediate and advanced level skills with their COs, specific PIs and associated assessments. However, introductory level courses should measure a greater proportion of the elementary level skills with their COs, PIs and assessments. On the other hand, mastery level courses should measure more of the advanced, but fewer intermediate and elementary level skills [18]. The design of COs and their PIs was meticulously completed by using appropriate action verbs and subject content, thus rendering the COs, their associated PIs, and assessments at a specific skill level—elementary, intermediate or advanced. Fig. 3 shows an example from a civil engineering course, in which CO_2: *Describe the composition of soil and solve volume-mass relationship equations for soils*; and its associated specific PI_5_34: *Determine the physical properties of soil using given parameters*; measured by assessment, Mid Term Q9, are of similar skills complexity and therefore at the same level of learning. The corresponding category of learning is *intermediate-cognitive-applying.* Therefore COs would be measured by PIs and assessments strictly following the *3-Level Skills Grouping Methodology* [18].

Skills Level	Cognitive Domain (Bloom, 1856; Anderson & Krathwohl, 2001)	Affective Domain (Krathwohl, Bloom & Masia, 1973)	Psychomotor Domain (Simpson, 1972)
Elementary	1. Knowledge 2. Comprehension	1. Receiving phenomena 2. Responding to phenomena	1. Perception 2. Set 3. Guided response
Intermediate	3. Application 4. Analysis	3. Valuing	4. Mechanism 5. Complex overt response
Advanced	5. Evaluation 6. Creation	4. Organizing values into problems 5. Internalizing	6. Adaptation 7. Origination

Fig.1. 3-Level skills grouping methodology of Bloom's revised taxonomy

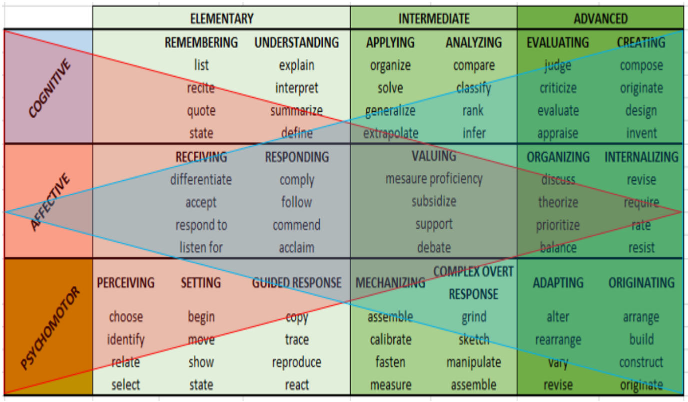


Fig.2. An ideal learning level distribution scenario for COs, PIs and associated assessments for introductory (indicated by shaded red triangle looking L to R) to mastery (indicated by a shaded blue triangle looking R to L) level courses

Details with illustration on examples of specific PIs EAMU vector calculation employing weighting factors is given in [18,25,28].

C. Hierarchy-Frequency Weighting-Factors Scheme for multiple learning and course levels

The philosophy behind the implementation of this Hierarchy-Frequency Weighting-Factor Scheme (HFWFS) for program learning domains evaluations is to consider a combination of two critical factors: (a) to implement a hierarchy of skills by giving prevalence to those assessments that measure skills of the highest order over others. For example, mastery-advanced level PIs will have a higher prevalence than those for the reinforced-advanced level; and (b) to consider the counts of assessments implemented in a certain learning level due to

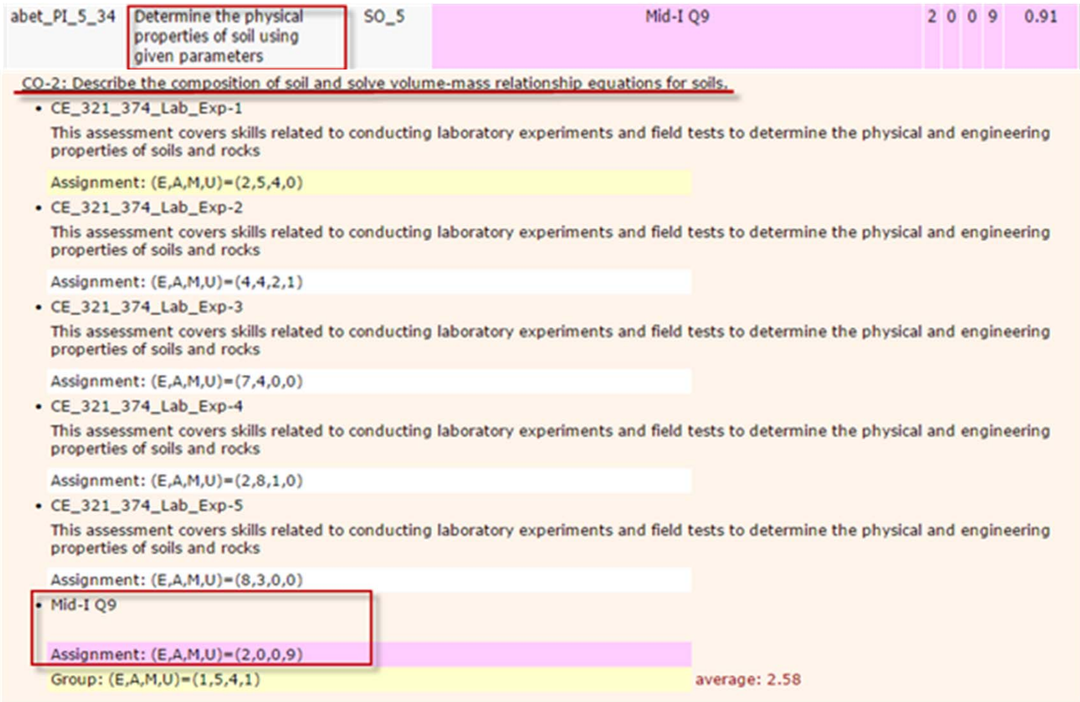


Fig. 3. Example of a civil engineering course showing CO_2, PI_5_34 and assessment Mid Term Q9 assigned to *intermediate-cognitive-applying* skill level based on the *3-Level Skills Grouping Methodology*.

Table 1: Weighting factors calculation for various learning levels of the reinforced and introductory courses for ABET SO 'a' program evaluation

ABET SO_1, SO 'a'	Course level- PI level	Counts(i) in term 361	%Learning Distribution [LD(i)]	% Progressive Distribution [PD(i)]	% Relative Distribution [RD(i)]	Weights WF(i) = LD(i) x RD(i)
Learning level (i)		DATA FROM EVALTOOLS	{counts(i)/total}×100	∑ LD(i)	{PD(i)}/Min{LD(i)}	{LD(i) × RD(i)}
1	REINFORCED-ADV	6	11.8	100	5.68	**67.05**
2	REINFORCED-INTER	14	27.5	88.2	5.01	**137.81**
3	REINFORCED-ELEM	9	17.6	60.7	3.45	**60.70**
4	INTRODUCTORY-ADV	0	0	43.1	2.45	**0.00**
5	INTRODUCTORY-INTER	13	25.5	43.1	2.45	**62.45**
6	INRTODUCTORY-ELEM	9	17.6	17.6	1.00	**17.60**
	TOTAL	51				

the fact that outcomes assessment is directly equivalent to learning. Table 1 shows the calculation of weighting factors for various learning levels of the reinforced and introductory courses, which are then applied to measured PIs in given course levels to compute the final program ABET SO 'a' value [18].

The detailed calculation for each column in Table 1 is reported in [18] and also shown below:

Learning Distribution % (LD)

Eqn. (1) shows the percentage of total assessments implemented in all courses for each learning level. Fig. 4 shows that for ABET SO 'a' (SO_1), 14 assessments out of 51 were implemented in reinforced-level courses measuring intermediate level PIs for all 3 domains composite. Assessments in this level accounted for 27.5% of learning.

$$LD(i) = \frac{count(i)}{Total\ count} \times 100 \tag{1}$$

The *Progressive Distribution % (PD)*

Eqn. (2) calculates PD by summing *LD* values according to the hierarchy of the skills levels. Reinforced course and advanced skill levels are assigned the highest value in this case since mastery level courses were not offered in term 361.

$$PD(i) = \sum_{1}^{i} LD(i) \tag{2}$$

The *Relative Distribution % (RD)*

Eqn. (3) calculates RD by dividing the *PD(i)* value with *LD(m):* the non-zero minimum value (learning level *'m'*) of the set of *LD* values corresponding to all the learning levels *1 to i.*

$$RD(i) = \frac{PD(i)}{Min - non - zero\ \{LD(1),\ LD(2), \ldots .LD(i)\}} \tag{3}$$

The *Weighting Factors WF(i)* for the various measured learning levels given by Eqn. (4) for ABET SO 'a' (SO_1) are calculated by multiplying *LD(i)* with *RD(i).*

$$WF(i) = LD(i) \times RD(i) \tag{4}$$

III. CONTINUOUS IMPROVEMENT

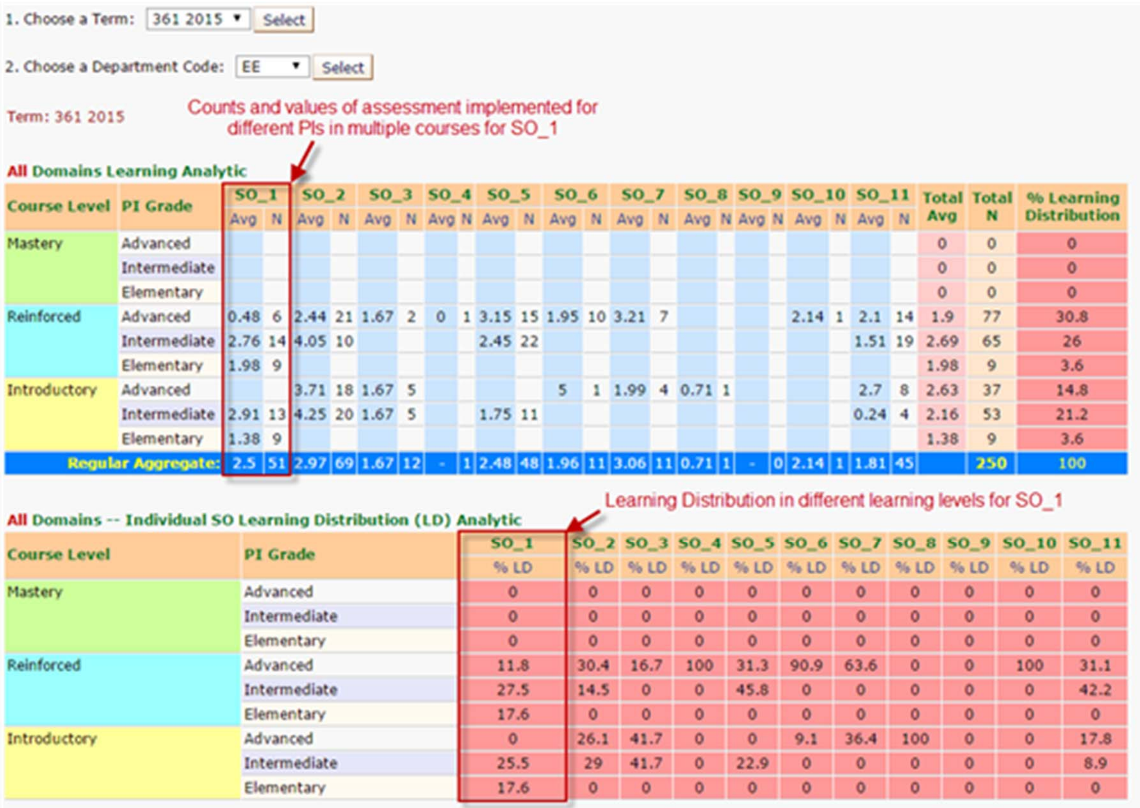
A. Program-Level Learning Domains Evaluations

Since assessments are equivalent to learning in the OBE model [34], the Faculty of Engineering has decided to consider the type of assessments, their frequency of implementation, and the learning levels of measured specific PIs in Bloom's 3 domains for courses and overall program evaluations. At the course level, the types of assessments are classified using the course formats chart to calculate their weighting factors [18,28], which are then applied using the *setup course portfolio* module of EvalTools® 6 [23]. The results can be seen in the FCAR and are used for course evaluations. The program level ABET SO evaluations employ a weighting scheme HFWFS, which considers the frequency of assessments implemented in courses for a given term to measure PIs related to specific learning levels of Bloom's domains [18]. This research focusses on some examples of CQI activities generated from the engineering program term review: *Learning Domains Evaluations*.

Fig. 4 shows the EE program term 361 composite learning domains evaluation data for their 11 ABET SOs. For each SO, the counts of total assessments and their aggregate average values are tabulated for each learning level [18].

Fig. 5 shows analytical results for the individual cognitive, affective and psychomotor— Bloom's domains of learning. The counts of assessments in various learning levels and their calculated values for all 11 ABET SOs are displayed for each learning domain. The ABET SO 'a' (SO_1) is highlighted for understanding. There is no data for the mastery level in Figs. 4 or 5 because the EE program is a new program, and hence, mastery level courses were not offered during term 361. Fig. 4 also shows the overall percentage learning distribution in each learning level for all the 11 ABET SOs. The details of how these entries are computed are explained in detail in our previous work [18]. Fig. 6 shows average values calculated on a 5.0 scale for the cognitive, affective and psychomotor domains, providing a good overall indication of how the program has performed in each learning domain. The pie chart indicates the EE program term 361 outcomes assessment activity percentage distribution in the 3 Bloom's learning domains [18].

A detailed term review report for each program was compiled with information on efforts for improvement targeting proper coverage of each ABET SO to achieve curriculum delivery according to the *Ideal Learning Distribution Model*. Fig. 7 shows portions of composite and individual ABET SOs learning domain evaluations review reports for the EE program for a specific term, in which the ABET SOs coverages of the Bloom's 3 domains and their learning levels, categorized as per the 3-Skills Level Methodology, are studied and discussed. On the left, a composite learning domains evaluation section is indicated, where the overall percentage distribution of learning in the 3 domains, ABET SOs coverages are analyzed and comments entered with possible suggestions for improvement of any deficiencies. On the right, portions of individual SO learning domain evaulations are shown with examples of deficiencies in certain ABET SOs such as "d" and "e". ABET SO_4 or "d", with just one assessment and a zero aggregate



All Domains Learning Analytic

Course Level	PI Grade	SO_1 Avg	SO_1 N	SO_2 Avg	SO_2 N	SO_3 Avg	SO_3 N	SO_4 Avg	SO_4 N	SO_5 Avg	SO_5 N	SO_6 Avg	SO_6 N	SO_7 Avg	SO_7 N	SO_8 Avg	SO_8 N	SO_9 Avg	SO_9 N	SO_10 Avg	SO_10 N	SO_11 Avg	SO_11 N	Total Avg	Total N	% Learning Distribution
Mastery	Advanced																							0	0	0
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced	0.48	6	2.44	21	1.67	2	0	1	3.15	15	1.95	10	3.21	7					2.14	1	2.1	14	1.9	77	30.8
	Intermediate	2.76	14	4.05	10					2.45	22											1.51	19	2.69	65	26
	Elementary	1.98	9																					1.98	9	3.6
Introductory	Advanced			3.71	18	1.67	5					5	1	1.99	4	0.71	1					2.7	8	2.63	37	14.8
	Intermediate	2.91	13	4.25	20	1.67	5			1.75	11											0.24	4	2.16	53	21.2
	Elementary	1.38	9																					1.38	9	3.6
Regular Aggregate:		2.5	51	2.97	69	1.67	12	-	1	2.48	48	1.96	11	3.06	11	0.71	1	-	0	2.14	1	1.81	45		250	100

All Domains -- Individual SO Learning Distribution (LD) Analytic

Course Level	PI Grade	SO_1 % LD	SO_2 % LD	SO_3 % LD	SO_4 % LD	SO_5 % LD	SO_6 % LD	SO_7 % LD	SO_8 % LD	SO_9 % LD	SO_10 % LD	SO_11 % LD
Mastery	Advanced	0	0	0	0	0	0	0	0	0	0	0
	Intermediate	0	0	0	0	0	0	0	0	0	0	0
	Elementary	0	0	0	0	0	0	0	0	0	0	0
Reinforced	Advanced	11.8	30.4	16.7	100	31.3	90.9	63.6	0	0	100	31.1
	Intermediate	27.5	14.5	0	0	45.8	0	0	0	0	0	42.2
	Elementary	17.6	0	0	0	0	0	0	0	0	0	0
Introductory	Advanced	0	26.1	41.7	0	0	9.1	36.4	100	0	0	17.8
	Intermediate	25.5	29	41.7	0	22.9	0	0	0	0	0	8.9
	Elementary	17.6	0	0	0	0	0	0	0	0	0	0

Fig. 4. A given term learning domains evaluation for EE program showing all 3 domains' composite data with assessments counts and their aggregate average values for various learning levels and ABET SO 'a' highlighted.

Cognitive Domain Learning Analytic

Course Level	PI Grade	SO_1 Avg	SO_1 N	SO_2 Avg	SO_2 N	SO_3 Avg	SO_3 N	SO_4 Avg	SO_4 N	SO_5 Avg	SO_5 N	SO_6 Avg	SO_6 N	SO_7 Avg	SO_7 N	SO_8 Avg	SO_8 N	SO_9 Avg	SO_9 N	SO_10 Avg	SO_10 N	SO_11 Avg	SO_11 N	Total Avg	Total N	% Learning Distribution
Mastery	Advanced																							0	0	0
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced	0.48	6							3.15	15											2.33	10	1.99	31	19.9
	Intermediate	2.76	14							2.45	22											1.51	19	2.24	55	35.3
	Elementary	1.98	9																					1.98	9	5.8
Introductory	Advanced			3.57	7	1.67	5															2.78	7	2.67	19	12.2
	Intermediate	2.91	13			1.67	5			1.75	11											0.24	4	1.64	33	21.2
	Elementary	1.38	9																					1.38	9	5.8
																								2.05	156	100.2

Affective Domain Learning Analytic

Course Level	PI Grade	SO_1 Avg	SO_1 N	SO_2 Avg	SO_2 N	SO_3 Avg	SO_3 N	SO_4 Avg	SO_4 N	SO_5 Avg	SO_5 N	SO_6 Avg	SO_6 N	SO_7 Avg	SO_7 N	SO_8 Avg	SO_8 N	SO_9 Avg	SO_9 N	SO_10 Avg	SO_10 N	SO_11 Avg	SO_11 N	Total Avg	Total N	% Learning Distribution
Mastery	Advanced																							0	0	0
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced							0	1			1.95	10	3.21	7					2.14	1			1.83	19	76
	Intermediate																							0	0	0
	Elementary																							0	0	0
Introductory	Advanced											5	1	1.99	4	0.71	1							2.57	6	24
	Intermediate																							0	0	0
	Elementary																							0	0	0
																								2.01	25	100

Psychomotor Domain Learning Analytic

Course Level	PI Grade	SO_1 Avg	SO_1 N	SO_2 Avg	SO_2 N	SO_3 Avg	SO_3 N	SO_4 Avg	SO_4 N	SO_5 Avg	SO_5 N	SO_6 Avg	SO_6 N	SO_7 Avg	SO_7 N	SO_8 Avg	SO_8 N	SO_9 Avg	SO_9 N	SO_10 Avg	SO_10 N	SO_11 Avg	SO_11 N	Total Avg	Total N	% Learning Distribution
Mastery	Advanced																							0	0	0
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced			2.44	21	1.67	2															0.95	4	1.69	27	39.1
	Intermediate			4.05	10																			4.05	10	14.5
	Elementary																							0	0	0
Introductory	Advanced			3.81	11																	2.62	1	3.22	12	17.4
	Intermediate			4.25	20																			4.25	20	29
	Elementary																							0	0	0
																								3.04	69	100

Fig. 5. Learning domains evaluation for EE program term 361 showing assessment counts and values for the individual cognitive, affective and psychomotor domains

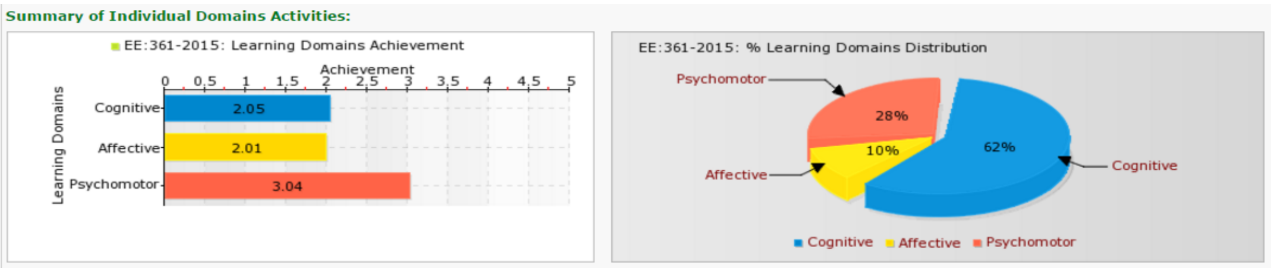


Fig. 6. Learning domains evaluation histogram and pie chart for EE program term 361 showing the percentage distribution of assessment activities in Bloom's 3 learning domains

value as shown in Fig. 5, deals with team work skills related mostly to the affective domain. The assessment for this SO was not properly implemented and required the creation of specific instruments, PIs, rubrics and strategies targeting select capstone courses with significant elements of teamwork related to design projects. The other example, ABET SO_5 or "e", dealing with problem solving as shown in Fig. 4, had no assessments for the introductory and reinforced courses, for measurement of elementary skills in either of the 3 domains. Problem solving in the EE curriculum primarily involves cognitive activities such as application, analysis or evaluation and some psychomotor activities such as mechanism, complex overt response or adaption corresponding to the intermediate and advanced levels. The review comments therefore indicate difficulty in measuring the elementary level skills for ABET SO_5 or "e" in the past term.

In general, for all programs, ABET outcomes "b" and "c" corresponding to various aspects of conducting experiments and design work per realistic constraints cover all 3 learning domains. Several PIs were developed for the experimental and design work to cover all 3 domains. Special instruments containing PIs, rubrics and assessment strategies with a focus on analysis of final design to fulfill realistic constraints are in the developmental phase for measurement of various skills levels in all 3 learning domains in the senior design courses. In all programs, affective domain ABET SOs like "f," "h," "i," or "j," corresponding to professional ethics, impact of engineering solutions on the environment, lifelong learning, contemporary issues etc., were usually covered by the intermediate and advanced level skills dealing with valuing, organizing values into priorities, or internalizing. In the past term, affective domain, elementary skills were not measured for these SOs.

All skills levels in the affective and psychomotor domains are difficult to measure for an engineering curriculum since they require specific, complex instruments with significant amounts of resources allocation for implementation of valid assessment processes. An important observation is that the comprehensive coverage of all the Bloom's learning levels for

Action	Review Date
COMPOSITE LEARNING DOMAINS EVALUATION: All the domains of learning have reached appropriate levels of coverage. However, the affective domain assessments can increase to 20% in the future. SO1,2,3,5 and 11 were covered for the cognitive domain. SO4,6,7 and 10 were covered for the affective domain. However, SO4 needs proper assessment with a course containing a capstone design project for measurement. The program faculty shall endeavor to develop and utilize additional assessments to cover the affective domain in 300 and 400 level courses for term 362. SOs 3,4,6,9,10 will also be targeted for measurement in the future terms. Psychomotor has percentage distribution of 28% in term 361 due to several lab courses and practical activities. SO2, SO3 and SO11 have been covered in the psychomotor domain cognitive has coverage of 64% with ABET SO1, SO2, SO3, SO5, SO11 have been covered for the cognitive domain.	2016-03-01

INDIVIDUAL SO LEARNING DOMAINS EVALUATIONS:

SO_4:

Team work skills were not measured in 361 since the EE program intends to use capstone design courses for appropriate measurement of team work skills.

A new team work measurement instrument has been recently developed and available for implementation.

SO_5:

Introductory level courses have not measured the advanced and elementary skills.

Introductory level courses in the EE program are focused more on the application and analysis level

Reinforced level course have no elementary skills assessments since much of the activity is related to application and analysis of basic principles in problem solving.

Fig. 7. Portions of EE program learning domains evaluation reports for alignment of course and curriculum delivery as per Ideal Learning Distribution Model; column on right shows 3-skills levels coverage deficiencies in ABET SOs 4 ("d") and 5 ("e") extracted from report for all 11 SOs

each ABET SO is not a trivial process and requires multi-term measurement and analysis of all courses and relevant assessments processed in a complete cycle of any engineering curriculum. Specifically, elementary skills involve activities that deal with: remembering, understanding in the cognitive domain which are more relevant for the ABET SO "a": *Application of the principles of math, science and engineering*; receiving, responding in the affective domain corresponding to students' responses, emotional attitudes, interests to elementary phases of teaching and learning that do not involve critical thinking; and perceiving, setting or guided response in the psychomotor domain corresponding to students' natural and learned set responses to stimuli and capability to immediately replicate teacher's instructions. Introductory drawing courses in CE program covered aspects of guided response skills in the psychomotor domain. Since many of Bloom's affective and psychomotor elementary skills may not be within the scope or focus of measurement for most engineering specializations, it could be recommended, to develop alternate learning levels models for the realistic measurement of skills, for the affective and psychomotor domains in engineering education.

B. Course-Level Learning Distribution Alignment

Fig. 8 shows a course delivery alignment example, where an introductory level course, Electronics, EE_212_1487, in a

Class: EE_212_1487 ELECTRONICS 1
Size: 9

3 Bloom's domains and 3 skills levels grouping indicator for course-level alginment

Course Outcomes:

The existing defined assignments:

	Cognitive	Affective	Psychomotor
Count	1	1	1
Percent %	33.3	33.3	33.3

	Elementary	Intermediate	Advanced
Count	0	1	2
Percent %	0	33.3	66.7

0% -- Need to add Elementary skills

Select		Order	Assignment/Activities	Standards CO	Standards PI	Standards SO	Available Period	Files Uploaded	Last Modified
Edit	Delete	1	Homework: HW-1	CO 1	abet_PI_1_10	abet_SO_1	2016-02-11 : 2016-02-18 grade release:2016-02-25		2016-04-04 10:03
Edit	Delete	2	Homework: HW-2				2016-02-25 : 2016-03-03 grade release:2016-03-10		2016-04-10 17:43
Edit	Delete	3	Homework: HW-3				2016-03-24 : 2016-03-31 grade release:2016-04-01		2016-02-24 8:59
Edit	Delete	4	Homework: HW-4				2016-04-07 : 2016-04-14 grade release:2016-04-21		2016-02-24 9:01
Edit	Delete	5	Homework: HW-5				2016-04-21 : 2016-04-28 grade release:2016-05-05		2016-02-24 9:03
Edit	Delete	6	Quiz: QZ-1				2016-02-18 : 2016-02-18 grade release:2016-02-25		2016-02-24 9:07

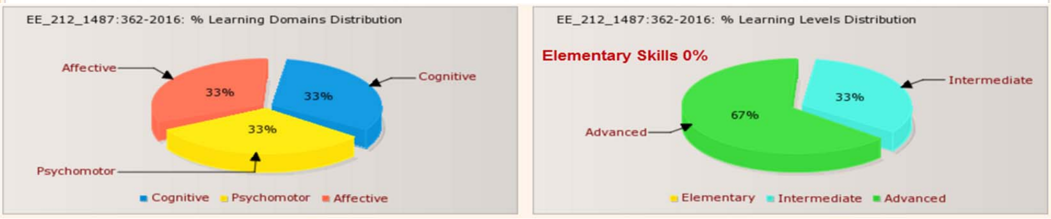


Fig. 8. Example of course-level learning domains realtime evaluation showing elementary skills not covered at a certain phase of course delivery

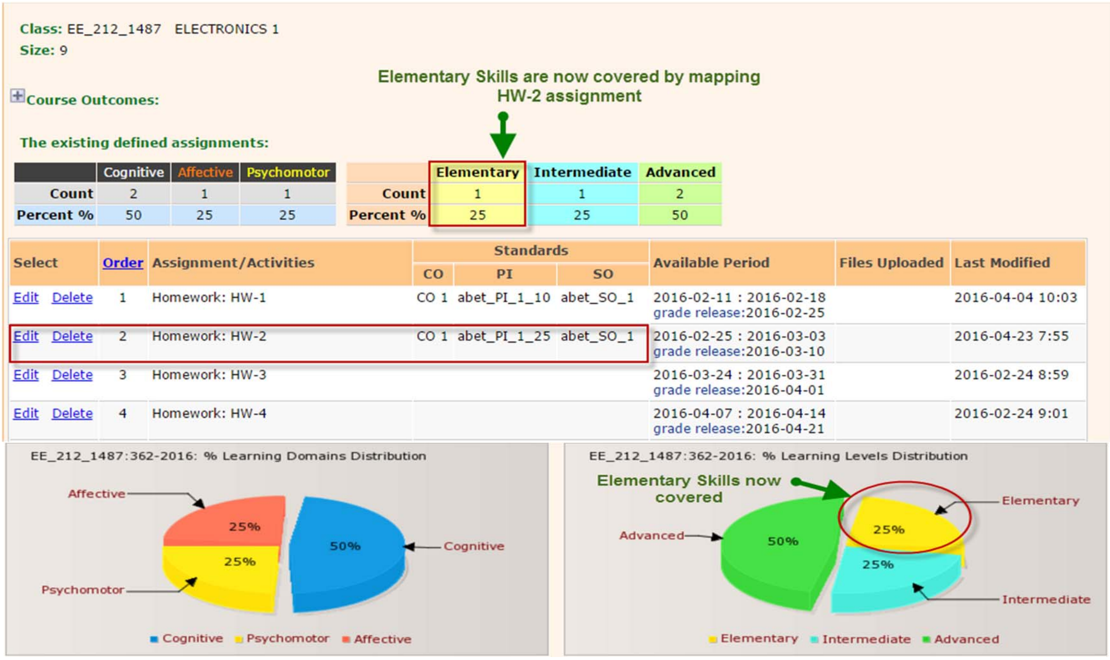


Fig. 9. Course-level learning domains realtime evaluation showing deficiency in measurement of elementary skills overcome by mapping existing assignment HW2 to elementary ABET_PI_1_25.

realtime, course-level learning domains evaluation, did not cover elementary skills with its existing set of assignments.

To cover elementary skills, either existing assignments need to be identified and mapped to elementary skills PIs for measurement or additional assessments, PIs need to be created. In this case, as indicated in Fig. 9, an existing assignment, HW2, was relevant, and mapped to elementary skills corresponding to ABET_PI_1_25 (cognitive-understanding): *Describe the characteristics of electrical circuit components and materials, such as resistance, inductance, capacitance, conductors, semiconductors and dielectrics;* to achieve realtime comprehensive coverage of learning disributions. For another EE course, Signals and Systems, which was just covering the cognitive domain, advanced and intermediate skills, additional COs, PIs were introduced to cover elementary and psychomotor domain skills to achieve holistic learning distributions. A course outcome, CO1: *Describe continuous-time and discrete-time signals and perform various operations on signals like transformation of independent variable;* was introduced and mapped to ABET_PI_1_59 (cognitive-understanding): *Explain signals and perform various time domain operations on signals;* using existing assignment HW1 to cover the required elementary skills. Another course outcome, CO2: *Represent CT and DT signals in complex exponential and sinusoidal form;* was added to cover missing psychomotor skills measured by ABET_PI_1_80 (psychomotor-complex overt response): *Represent diagrammatically, complex exponential and sinusoidal forms of continuous-time and discrete-time signals;* using existing assignments QZ-1 and Mid Term Exam-1 Q1.

In summary, a large number of changes were introduced at the Faculty of Engineering in every aspect of curriculum delivery for all programs, EE, ME or CE, and it was beyond the scope of this paper to list all the details of modifications. The focus of this paper was to therefore show that a combination of analytical data from program-level ABET SOs and course-level COs learning domains evaluations facilitates planned plus realtime alignment of course topics, course outcomes, assessments, PIs, rubrics, teaching and learning strategies to attain ideal learning distributions in Bloom's 3 domains and therefore highest levels of CQI in engineering education.

IV. CONCLUSION

This paper presents a novel outcomes assessment methodology using customizations in web-based software EvalTools® 6 modules to analyze program learning distribution information in Bloom's 3 domains based on the counts of assessments processed in multiple course and skills levels of an engineering curriculum. This learning distributions information provides a wealth of detail to engineering programs regarding any deficiencies in their current ABET SOs assessment plans and helps steer any future or realtime modifications to achieve an optimum distribution of coverages in the various learning domains and their learning levels. These CQI activities would result in the required alignment of program, course learning outcomes, associated PIs with assessments, teaching and learning strategies to produce necessary skill levels and learning domain coverages specific to the various engineering specializations. Engineering programs employing this approach would generate and classify COs, their PIs using the 3 levels skills grouping method in a relatively easier process and make outcomes assessments the focus for effective pedagogy as required by an ideal OBE model while implementing constructive alignment throughout the curriculum delivery process. Application of this methodology and digital systems would help develop holistic curriculum delivery processes with learning outcomes forming the fundamental ingredients of every aspect of engineering education to produce quality graduates for the industry with necessary skills levels related not only to the cognitive but also to the affective and psychomotor domains.

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Specific, Generic Performance Indicators and Their Rubrics for the Comprehensive Measurement of ABET Student Outcomes

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Dr. William G. Spady, International Network for OBE

Dr. Spady has been a leading pioneer in Outcome Based thinking and implementation for 45 years. As a Ph.D. graduate of the U. of Chicago in 1967, he was introduced to the seminal work of Benjamin Bloom in 1968 and transformed its fundamentals into a comprehensive paradigm-shifting system of educational transformation that he has shared through his 8 books, dozens of published papers, and countless presentations and workshops to educational institutions on 4 continents. He regards OBE as a powerful, future-focused ever-evolving approach to learner empowerment, and regrets that it has been so badly misunderstood and misrepresented across the world.

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Specific, Generic Performance Indicators and Their Rubrics for the Comprehensive Measurement of ABET Student Outcomes

Abstract**:** In this research, we present the essential principles of an authentic outcome based educational model related to the development of learning outcomes, performance indicators and their rubrics with a focus on measurement of specific skills related to Bloom's 3 learning domains and their learning levels for engineering specializations. An analysis of culminating ABET Engineering Accreditation Commission student outcomes is made with reference to Bloom's 3 learning domains and their learning levels. A hypothetical model is presented for this analysis. The correlation of ABET student outcomes, course learning outcomes and performance indicators is clearly outlined. The necessity of the use of performance indicators is highlighted especially in reference to the measurement of course learning outcomes, development of assessments, teaching and learning activities. The importance of scientific constructive alignment of learning outcomes, performance indicators, assessments, teaching and learning strategies is discussed. A novel hybrid rubric for accurate assessment and scoring of student performances is also presented. Actual examples of implementation of this theory to program, course and student level performance evaluations using state of the art web based digital technology are shown. In summary, the benefits of specific performance indicators over generic ones are explained in detail with respect to support of authentic OBE principles, scientific constructive alignment, accurate measurement of student performances in specific engineering learning activities, performance failure analysis and continuous quality improvement.

I. Introduction

Several established accreditation and quality assurance agencies both international and regional such as International Engineering Alliance (IEA), Washington Accord [1], European Commission, Bologna Process [2] , Accreditation Board of Engineering Technology (ABET) [3], Middle States Commission of Higher Education (MSCHE) [4] and National Commission of Academic Accreditation and Assessment (NCAAA) [5] are based on an Outcome-Based Education (OBE) model and require higher education institutions and engineering programs to show student achievement in terms of established learning outcomes. It is clearly stated in multiple research papers published by the National Institute of Learning Outcomes Assessment (NILOA) [25,26] and others [6,28,29] that in many higher education institutions, actual Continual Quality Improvement (CQI) and accreditation efforts are minimally integrated and that ideally CQI instead of accreditation standards should be the prime driver for outcomes assessment. Unfortunately, accreditation was the prime driver for outcomes assessment and the topic of more than 1,300 journal articles between 2002 and 2004 [6]. To substantiate this finding, Mohammad and Zaharim stated in their 2012 research [38] that engineering education in Malaysia underwent a major transformation starting in 2004 due to the requirement imposed by the Washington Accord agreement. Assessment and evaluation of program outcomes (PO) became mandatory for all engineering programs in Malaysia. However, the typical PO assessment model practised by many engineering programs resulted in vague assessment methods that failed to produce effective CQI. The major issue was the lack of clear performance criteria to measure the POs. They proposed a new model based on measuring each PO using specific performance criteria. The new model is expected to allow objective evaluation of whether the students have achieved the criteria and subsequently facilitate CQI implementation within the programs. Kalaani & Haddad in a 2014 work [37] presented the CLO form in Table 6 of their paper measuring 36 specific performance criteria for just one typical electrical engineering course. A glance at open courseware from the Massachusetts Institute of Technology for a typical circuits and electronics course indicates 16 Course Outcomes (COs) [60] which naturally imply the necessary standards in current engineering education of specialized knowledge and student skills which can be measured by a corresponding number of their specific Performance Indicators (PIs). The several references indicated strongly suggest that performance criteria should be specific to collect precise learning outcome information related to various topics, phases of a curriculum while addressing various levels of proficiency of a measured skill.

Additionally, the learning outcomes data measured by most engineering institutions are rarely classified into all three learning domains of the revised Bloom's taxonomy [52] and their corresponding categories of the levels of learning. Generally, institutions classify courses of a program curriculum into three levels: introductory, reinforced, and mastery, with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for an effective program evaluation [48,49]. This approach presents a major deficiency for CQI in a student-centered OBE model because performance information collected at just the mastery level is at the final phase of a typical quality cycle and is too late for implementation of remedial efforts. Instead, student outcomes and performance criteria progressing from the elementary to advanced levels should be measured at the course level for all courses spanning the entire curriculum [56,57]. McGourty, Sebastian and Swart, in their 1997 [28] and 1998 [29] research work have explained the critical nature of course level outcome assessments. The accreditation and quality assurance agencies listed here do not explicitly establish requirements for implementing specific PIs to measure varying levels of students' skills in all course levels and learning domains. Whereas holistic approach for a CQI model would require a systematic measurement of specific PIs in all three of Bloom's domains of learning and their corresponding categories of learning levels for all course levels of a program's curriculum. Some major reasons why specific PIs are not specified as essential assessment criteria for accreditation are the requirements of detailed processes for their implementation using digital technology and established widespread use of primitive, but lengthy manual assessment models such as the traditional rubric based Gloria Rogers' (GR) model [48] employing generic PIs which is supported by popular Learning Management Systems (LMS) such as Blackboard [33]. By not specifying the implementation of both specific and generic PIs in outcomes assessment processes, accreditation would be at odds with the basic philosophy of authentic OBE and result in dramatically negative effects on CQI. In the coming sections of this paper we will present generic and specific PIs, their necessity, hybrid rubrics, the methodology and technology required for their implementation, effects on CQI.

II. Outcomes Assessment Methodology and Automation Technology

The Figure 1 shows a process flow for a FCAR + specific PIs classified per Bloom's 3 domains and 3-levels skills assessment model adopted by the Faculty of Engineering at the Islamic University of Madinah, Saudi Arabia. ABET criteria for program accreditation have been implemented in the assessment model, which requires that programs make decisions using assessment data collected from students and other program constituencies, thus ensuring a quality program improvement process. Quantitative and qualitative methods are developed to ensure students have satisfied the COs which are measured using a set of specific PIs/assessments and consequently the program level ABET SOs [20]. The noteworthy aspect of this model is that course faculty are involved in most CQI processes whether at the course or program level.

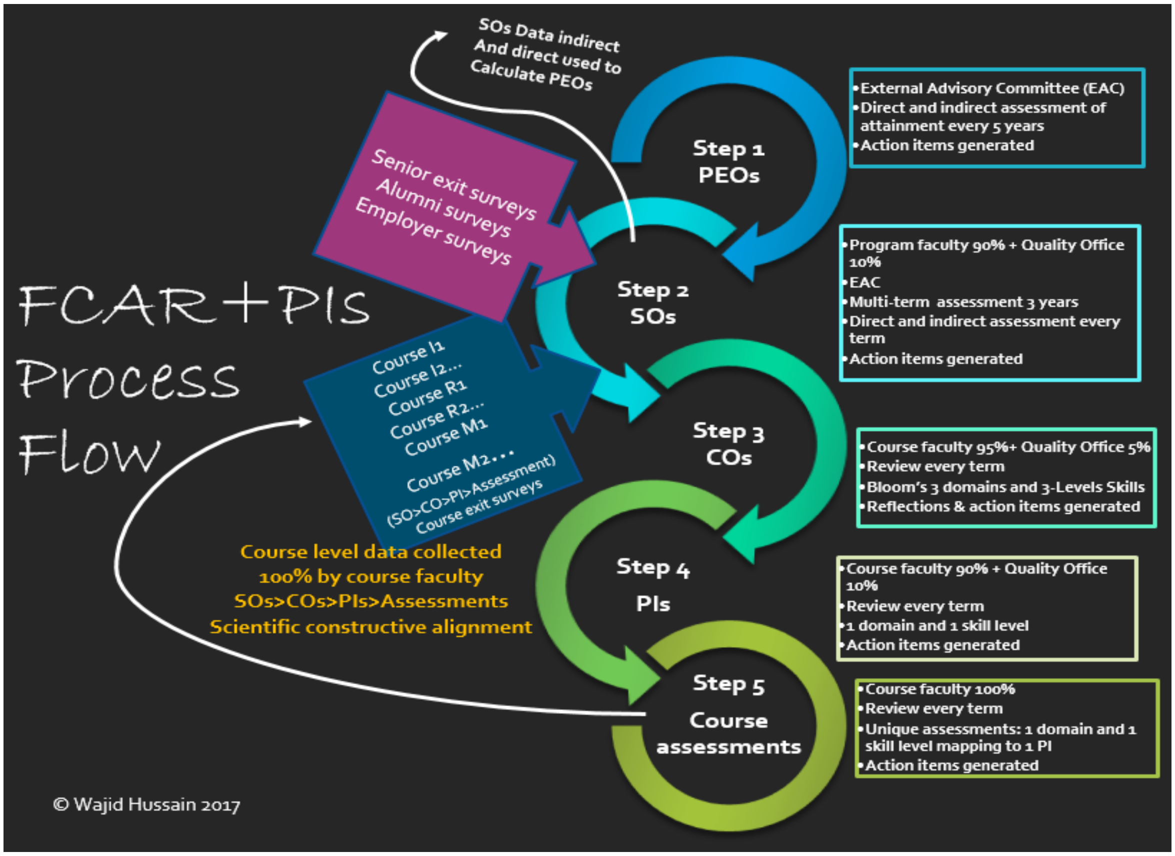


Figure 1: FCAR + specific PIs assessment model process flow indicating course faculty involvement in almost all phases of CQI cycle

Course faculty are directly involved in the teaching and learning process interacting closely with all the enrolled students. An ideal CQI cycle, would therefore include the course faculty in most levels of its process, to generate and execute action items that can directly target real time improvement in student performances for ongoing courses. Models that involve program faculty or assessment teams that are not directly involved with the enrolled students will definitely not support real time CQI which is an essential element of an authentic OBE system [7,8,10,12].

A "design down" [7,8] mapping model was developed as shown in Figure 2 exhibiting authentic OBE design down flow from goals, PEOs, SOs, course objectives, COs to specific PIs. This figure illustrates trends in levels of breadth, depth, specificity and details of technical language related to the development and measurement of the various components of a typical OBE "design down" [7,8] process.

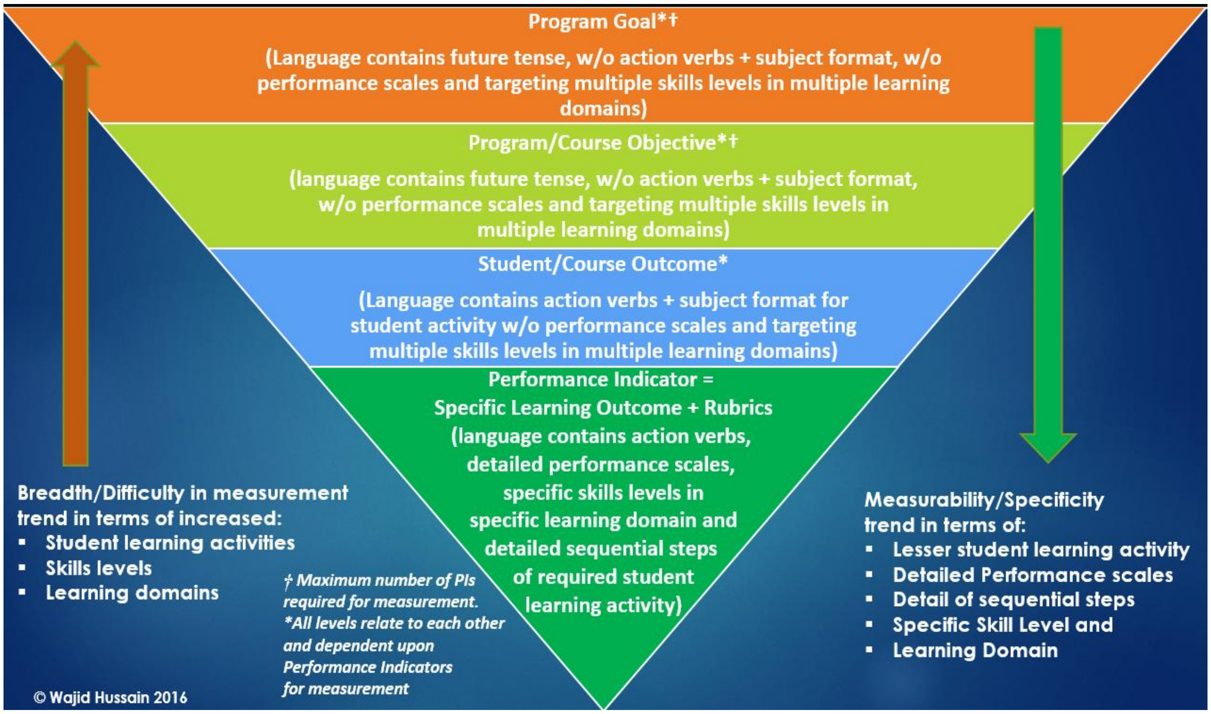


Figure 2: OBE Design down mapping from goals, PEOS, SOs, COs to PIs

FCAR, EAMU Performance Vector Methodology and Web-based Software EvalTools® 6. EvalTools® 6 [43] is chosen as the platform for outcomes assessment instead of Blackboard® [33] since it is the only tool that employs the Faculty Course Assessment Report (FCAR) and *EAMU performance vector methodology* [42,44,45,46,47,48,49,50,51]. This methodology facilitates the use of existing curricular assignments for outcomes assessment to achieve a high level of automation of the data collection process. The EvalTools® 6 FCAR module provides summative/formative options and consists of the following components: course description, COs indirect assessment, grade distribution, course reflections, old action items and new action items; COs direct assessment; PIs assessment ; student outcomes assessment; assignment list; and learning domains and skills levels assessment distribution [35,49,50,51,63,64]. The FCAR uses the EAMU performance vector, conceptually based on a performance assessment scoring rubric, developed by Miller and Olds [59], to categorize aggregate student performance. Heuristic rules and indicator levels for EAMU performance vector have been explained in research work related to the FCAR [44,45].

III. Specific, Generic PIs and Rubrics (Holistic, Analytic and Hybrid)

In an OBE model, assessments related to specific PIs, measure the level of teaching and learning achievement, and help outline future actions related to course delivery, syllabus, teaching and learning strategies for CQI [19,21,22,24,25,31,55]. By performing an exhaustive design and classification exercise of several hundred PIs (90% specific) related to COs and ABET SOs for the Electrical Engineering (EE), Mechanical Engineering (ME) and Civil Engineering (CE) programs, the Faculty of Engineering has observed that ABET SOs exhibit relevance and coverage of the revised Bloom's learning domains as shown in Table 1[49]. In Table 1, 'H' High; 'M': Medium; or 'L": Low; refer to the degree of relevance and coverage of an ABET SO for a learning domain, which is estimated by the type, number of activities and assessments processed in different courses of a program in a given term for the measurement of PIs related to this learning domain. Our earlier work [49] has discussed the relevance and coverage information shown in Table 1 in two phases. For the initial phase, information was hypothetically generated based on theoretical grounds as a result of semantic analysis of the language of the 11 ABET SOs and their classified PIs. In the second phase, this hypothetical information was practically confirmed with actual SOs measurement data for a given term using PIs associated to the 3 domains, assessments and their counts information from various courses. Detailed set of appendices were also attached to provide specific assessment information in 3 domains for each ABET SO [49].

Table 1: Hypothetical relevance and coverage of ABET SOs to Bloom's 3 learning domains

SO_NO.	ABET SOs	DOMAINS RELEVANCE & COVERAGE		
		COGNITIVE	AFFECTIVE	PSYCHOMOTOR
SO_1	a. an ability to apply knowledge of mathematics, science and engineering	H	L	L
SO_2	b. an ability to design and conduct experiments, as well as to analyze and interpret data	H	M	H
SO_3	c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	H	H	H
SO_4	d. an ability to function on multidisciplinary teams	M	H	L
SO_5	e. an ability to identify, formulate, and solve engineering problems	H	L	L
SO_6	f. an understanding of professional and ethical responsibility	M	H	L
SO_7	g. an ability to communicate effectively	M	H	M
SO_8	h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	M	H	L
SO_9	i. a recognition of the need for, and an ability to engage in life-long learning	M	H	L
SO_10	j. a knowledge of contemporary issues	M	H	L
SO_11	k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	H	L	H

ABET explains both kinds of PIs, generic or specific, their rubrics and provides some information to differentiate between the two as shown in training presentation material publicly available on their website [3]. But, almost all of the examples of PIs and rubrics displayed are generic and target the predominantly affective domain ABET SOs for assessment. The reasons for this are firstly, there are hundreds of specific engineering activities related to any engineering specialization that would definitely require a good number of specific PIs, rubrics to adequately measure them. Secondly, appropriate technology would definitely be required to manage this vast amount of information. It would be challenging choice for ABET or any quality assurance agency to prescribe the specific PIs model, supporting technology for automation and achieve effective CQI or continue with the traditional manual GR model with generic PIs and compromise authentic OBE and CQI.

Gloria Rogers does mention that PIs should be measured in course work but their training materials do not indicate COs in the process flow charts. An obvious reason, for the COs not appearing above PIs in the process flow chart, is that the GR traditional rubrics assessment model is implemented for measurement of the PIs and SOs data by employing independent raters, who typically assess student work after courses are completed [3,48]. This process flow model, has thus mostly proposed to programs, the GR assessment model, generic PIs and an independent raters system of scoring [48]. For authentic OBE, students in the course are the focus of the faculty, and so, faculty members teaching the course must be directly involved in the outcomes assessment process. They should apply constructive alignment based on outcomes, use formative and summative assessments, conduct evaluations, choose the best teaching and learning strategies for improved performances, and provide real time feedback to students for effective CQI.

Independent raters definitely do not interact with students, cannot understand the intricacies of the teacher-student relationship, and do not support formative assessments for CQI. The argument in favor of independent raters, is to have unbiased scoring of assessments. But, the important thing to note, as per our earlier discussions, and referred research [69], was that generic rubrics have the least reliability, and therefore, keep the door open to biased scorings and human factors. On the other hand, specific PIs and hybrid rubrics, present very high reliability and when coupled with objective evidence to verify proper application of these specific hybrid rubrics, it becomes almost impossible for biased scoring to happen. Finally, independent rater scoring is an additional effort, beyond curricular scoring, and is a manual process that can never be automated. Dissecting curricular grades, to extract outcomes information is a totally automatable process, and we can effectively leave scoring in faculty hands, while not doubling the efforts or required resources for collecting outcomes data. Therefore, assessment models, supporting generic rubrics and independent rating systems do not facilitate implementation of the 4 OBE power principles of *clarity of focus, expanded opportunity, high expectations* and *design down* [7,8,10,12], and are in total conflict with authentic, student centered, OBE methodology.

The IEA confirms the necessity of measurement of graduate attributes and specific professional competencies for qualifying graduates and practicing engineers, which is expressed clearly in statements extracted from publicly available documentation on their website [2]. Appendix A.1 and A.2 show profiles listed by the IEA for practicing engineer, engineering technologist and technician detailing types of engineering knowledge and a range of problem solving activities. The profiles indicate a very complex process using specific PIs for assessment of these attributes in qualifying graduates. Problem solving and design for various engineering specializations or for even certain course content is very specific process and can vary drastically depending upon content specific factual, conceptual and procedural knowledge. McCade has also echoed a great amount of detail on the subject of problem solving being a very comprehensive engineering activity, which comprises of several sub activities not limited to design, experimentation, analysis, evaluation etc. [58].

The Faculty of Engineering has developed 290 specific PIs through a very exhaustive and elaborate ongoing process to comprehensively measure engineering activities corresponding to various skills levels related to problem solving in introductory, reinforced and mastery level courses for ABET SO 'e' [49]. To be exact, 100 for CE, 74 for EE, 84 for ME and 32 for General Engineering (ENGR) programs courses. In fact, all developed specific and generic PIs corresponding to ABET SOs 'a-k' have been classified as per the 3 Bloom's domains and their learning levels. The PIs database is proprietary information owned by the Faculty of Engineering and therefore cannot be listed in the appendices of this paper. Therefore, just portions of these PIs lists can be shown to present concepts employed for their development, classification and implementation for outcomes measurement. Figure 3 indicates two joined portions of the list of specific PIs for the CE program showing PIs of index number [1-8] and [95-100] classified into affective, psychomotor and cognitive domains of Bloom's taxonomy and their learning levels. An elaborate youtube video was produced by the Office of Quality and Accreditation at the Faculty of Engineering in 2016 [62] presenting the importance of specific PIs for establishing the four power principles of OBE [7,8,10,12] ; *Clarity of Focus*: clear mapping to precise student learning activity; *Expanded Opportunity*: timely remedial action; *Design Down*: from PEOs all the way to PIs; and *High Expectations*: Hybrid Rubrics [65,66,67] scales clearly defining the highest standards for student performances.

[abet_SO_5] an ability to identify, formulate, and solve engineering problems

- [abet_PI_5_1] Cognitive: Applying Apply concepts, governing math or physics equations and methods to solve a technical problem
- [abet_PI_5_2] Cognitive: Analyzing Demonstrate effective problem solving techniques
- [abet_PI_5_3] Psychomotor: Adaptation Conduct site investigations
- [abet_PI_5_4] Cognitive: Analyzing Conduct lateral earth pressure and slope stability analysis
- [abet_PI_5_5] Cognitive: Evaluating Apply momentum conservation concept to evaluate forces of moving bodies
- [abet_PI_5_6] Cognitive: Creating Model the hydrological processes
- [abet_PI_5_7] Affective: Organize values into priorities Outline traffic flow characteristics, including capacity, speed and safety considerations
- [abet_PI_5_8] Cognitive: Analyzing Compute the internal and external forces and/or deformations, slope, deflections for beams, frames and trusses for determinate structures
- [abet_PI_5_95] Cognitive: Analyzing Determine the type of stress by examining loading conditions and compute the tensile and compressive stresses developed due to axial and bending moments
- [abet_PI_5_96] Cognitive: Analyzing Determine the type of strain by examining the loading conditions and compute shear stresses developed due to transverse loading and/or torsion.
- [abet_PI_5_97] Cognitive: Analyzing Determine the type of strain by examining the loading conditions and compute normal strain, and expansion/contraction due to axial loading
- [abet_PI_5_98] Cognitive: Analyzing Determine the type of strain by examining the loading conditions and compute shear strain, and angle of twist developed due to torsion
- [abet_PI_5_99] Cognitive: Analyzing Determine principal stresses and maximum shear stress for a given state of stress at a point by apply the stress transformation equations
- [abet_PI_5_100] Cognitive: Analyzing Calculate the maximum deflection of a beam and its location for various cases of loadings using integration techniques

Figure 3: Faculty of Engineering CE program Specific PIs for comprehensive measurement of SO 'e' on problem identification, formulation and solving

Adelman's thorough work strengthens our argument that the required language of learning outcomes for the cognitive and psychomotor learning activities should be specific [27]. He assertively states that verbs describing a cognitive or psycho-motor operation act on something, i.e. they have a specific nominal context. The nominal context can be discipline/field-specific, e.g. error analysis in chemistry; an art exhibit in 2-D with 3 media. Field-specific statements are endemic to learning outcome statements in Tuning projects. Finally, without a specific nominal context you do not have a learning outcome statement.

ABET talks about rubrics being an assessment scale that describe the levels of achievement for each PI and allow setting up thresholds for acceptable student performance [3]. Specific or generic rubrics are used for assessment of activities that are either task specific as in the cognitive, psychomotor domains or general as in the affective domain [3].

The reasons for rubrics in general are given as:

1. Formative and Summative application to assessments
2. A medium to define expectations for students, faculty and program
3. Increase inter and intra-rater reliability for assessments
4. A feedback process for learning performance for students, faculty and program

Holistic rubrics relating to a certain SO or PI do not contain individual dimensions but rather a set of performance criteria which are applied in parallel for scoring assessments by seasoned raters. On the other hand, analytic rubrics relating to SOs contain specific dimensions which are in fact the PIs needed to adequately measure the SO. Both rubrics contain descriptors for all scales, but the difference is again that the analytic rubric has descriptors for each PI or dimension. Analytic rubrics can specifically indicate areas of weakness in performance for the various dimensions or PIs corresponding to a certain SO. In both cases of rubrics, the nature of examples provided by ABET as shown in Figure 4 are very simplistic, addressing affective domain SOs like team work, while expressing the dimensions such as *research and gather information* or *listening to other teammates* with descriptors containing extremely superficial, vague and non-technical language without actually providing details steps of what students have to demonstrate to accurately assess these dimensions or PIs. The *research and gather information* PI/dimension contains one descriptor for each scale like *does not collect any information that relates to the topic:* for the *Unsatisfactory scale;* and *collects a great deal of information, all relates to the topic:* for the *Exemplary scale.* The point to note is that the engineering activity related to the PI *research and gather information,* PI *Listen to other team mates* and two other PIs is not as trivial as is represented by the descriptors in Figure 4. Actually, even the language of these 4 PIs needs improvement as per the "*clarity of focus"* power principle of authentic OBE. But, we will leave this issue for the sake of brevity and continue our discussion on the topic of rubrics.

SO: Function effectively in multidisciplinary teams Dimension/PI	**Unsatisfactory 1**	**Developing 2**	**Satisfactory 3**	**Exemplary 4**
Research and gather information	Does not collect any information that relates to the topic	Collects very little information--some relates to the topic	Collects some basic information--most relates to the topic	Collects a great deal of information, all relates to the topic
Fulfill team roles duties	Does not perform any duties of assigned team role	Performs very little duties	Performs nearly all duties	Performs all duties of assigned team role
Share in work of team	Always relies on others to do the work	Rarely does the assigned work--often needs reminding	Usually does the assigned work--rarely needs reminding	Always does the assigned work without having to be reminded
Listen to other team mates	Is always talking – never allows anyone to speak	Usually does all the talking – rarely allows others to speak	Listens – but sometimes talks too much	Listens and speaks a fair amount

Figure 4: Analytic rubrics showing different dimensions/PIs and 4 scales for measuring ABET SO ''d' Function effectively on multidisciplinary teams [3]

Let us consider some typical engineering activities required for the proper assessment of just one dimension/PI *research and gather information.* Figure 5 shows some detail of engineering activities such as methods used for locating information; number of professional citations; engineering consultants contacted; engineering data collected from site/field visits; selection and assimilation of appropriate research information into team project efforts etc. Each of these five complex engineering activities is expressed with several descriptors in all 4 scales containing specific and clear technical language required for the comprehensive assessment and scoring of the PI *research and gather information*. This added detail in rubric development is a necessary requirement without which the rubrics actually lose the reliability and validity needed to precisely assess specific engineering activities. It shall be ironical, if for the new proposed ABET EAC SO, such as "an ability to recognize the ongoing need to acquire new knowledge, to choose appropriate learning strategies, and to apply this knowledge" we still resort to few simplistic and generic PIs to comprehensively complete its assessment.

SO: Function effectively in multidisciplinary teams Dimension/PI		**Unsatisfactory 1**	**Developing 2**	**Satisfactory 3**	**Exemplary 4**
Research and gather information	1.	Only one method used for locating information	2 methods used for locating information	3 methods used for locating information	5 or more methods used for locating information
	2.	Less than 2 professional citations	3 professional citations	4 professional citations	5 or more professional citations
	3.	No engineering consultants contacted	No engineering consultants contacted	1 engineering consultant contacted	2 engineering consultants contacted
	4.	No site/field visits	No site/field visits	No site/field visits	Engineering Data collected from Site/field visits
	5.	Inaccurate selection and assimilation of appropriate research information	Partially correct selection and assimilation of appropriate research information	Accurate selection and partial assimilation of appropriate research information	Accurate selection and complete assimilation of appropriate research information

Figure 5: Analytic rubrics showing just one PI research and gather information with 5 descriptors as performance criteria for each scale for measuring ABET SO 'd'

Now, as the discussion for assessment of several hundred engineering activities in any specialization continues and the conviction of the need for implementing a combination of a majority of specific and a minority of generic PIs deepens, we see more clearly that neither the holistic nor analytic rubrics can actually apply to accurately assess engineering student learning activities. Since the purpose of rubrics as stated earlier is validity: precise alignment with assessments; and reliability: accuracy of scoring details of student performance; Holistic rubrics will create major issues for reliability and analytic rubrics need several PIs, specific and generic, plus each PI or dimension, in fact should contain several descriptors for each scale as shown in the example of Figure 5.

To elucidate this point further let's take an example of two introductory, 200 level, courses from the Faculty of Engineering, EE program, *EE_261: Digital Logic Design* and *EE_282: Electromagnetic Field Theory*. An assessment for course *EE_261: Digital Logic Design* is related to implementing a Boolean function using specified logic gates, creating the truth table and expressing the same Boolean function in sum of min-terms form. To solve problems for this assessment, students need fundamental knowledge of Boolean algebra, creating truth tables, understanding of logic gates and knowledge of implementing digital circuits using logic gates. The other assessment for course *EE_282: Electromagnetic Field Theory* is related to computing the potential at various coordinates with given charge placed in free space. Problem solving for this assessment requires fundamental knowledge of electromagnetic theory coupled with basic math skills. The problem solving mechanisms for these various topics in the two 200 level EE courses are completely different, involving varying types of factual, conceptual and procedural engineering knowledge.

Now, the big question is, whether one generic set of problem solving rubrics could accurately apply to properly assess and precisely score both of these very different engineering activities, and deliver the validity, inter and intra-rater reliability required by the purpose of rubrics. What would happen to the quality of assessments if we should apply a generic set of PIs and rubrics to assess engineering activities from two courses, one from the senior and another from the junior levels? To expand the complexity of the problem further. How could we apply small set of generic rubrics to problem solving activities that relate to various learning levels of Bloom's cognitive domain? Activities could range from *applying*: pure and simple application of appropriate theory, math skills; *analyzing*: identify the problem, select appropriate theory and apply, derive/formulate, solve, apply math skills; *evaluating*: identify, select appropriate theory, derive/formulate, solve then interpret and evaluate the end result; or even *creating*: which involves complex combination of applying, analyzing, evaluating from the cognitive domain targeting application of theory, identification, solving problems, conducting experimentation, designing prototype, manufacturing, evaluating etc.

The ultimate level of complexity would be engineering activity that targets all learning levels in the cognitive, psychomotor and the affective domains of Bloom's taxonomy [49, 52]. Employing generic PIs and rubrics that cannot classify and assess complex engineering activity like design (see SO 'c' in Table 1.) and then finally give one score to a vast combination of skills relating to all 3 domains and several learning levels is nothing but a cocktail dessert with absolutely bad taste for CQI [10,11]. Such applications render the entire set of OBE power principles [7,8,10,11,12] void and the consequences are huge amounts of work, data collected, vague results, evaluation, feedback, CQI rendered ineffective and meaningless.

Prior to introducing the *Hybrid Rubrics,* we would like to once again reinforce the necessity of specific PIs and rubrics, with a reference to an exhaustive empirical research that reviewed 75 studies on rubrics, and summarized their benefits, with the top most benefit coming from rubrics that are *analytic, topic-specific, and complemented with exemplars and/or rater training* [69]:

The Hybrid Rubric:

The hybrid rubric is a combo of the holistic and analytic rubrics developed to address the issues related to validity: precision, accuracy of assessment alignment with outcomes, PIs; and inter, intra-rater reliability: detail of specificity of acceptable student performances; when dealing with assessment of complex and very specialized engineering activities. The hybrid rubric is an analytic rubric embedded with a holistic rubric to cater to the assessment of several descriptors that represent all the required major steps of specific student learning activity for each PI/dimension listed. Figure 6 shows an ABET SO 'e', problem solving, specific PI "*Simplify a given algebraic Boolean expression by applying the k-map and express in POS form*" and its hybrid rubric. The hybrid rubric also contains a column to indicate the percentage of total score allocation for each descriptor (major step of learning activity) corresponding to a certain PI. The scales implemented are obtained from Estell's FCAR [44,45], E, A, M and U performance vectors [59] that stand for the

Excellent: (100-90)%, Adequate: (89-75)%, Minimal (74-60)% and Unsatisfactory: (0-60)% categories respectively. The Office of Quality and Accreditation at the Faculty of Engineering has developed elaborate, step by step, instructional videos for developing hybrid rubrics for the CE [65], EE[66] and ME[67] programs. The appendix B provides a documented sample of hybrid rubrics development process from a workshop organized by the office of quality and accreditation for the CE program.

PI_5_1: SIMPLIFY A GIVEN ALGEBRAIC BOOLEAN EXPRESSION BY APPLYING THE K-MAP AND EXPRESS IN POS FORM

SCORING	UNSATISFACTORY (0-60%)	MINIMAL (60-75%)	ADEQUATE (75-90%)	EXCELLENT (90-100%)
1. 20%	1. **UNABLE/ABLE TO** Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.
2. 20%	2. **UNABLE/ABLE TO** Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.
3. 35%	3. **UNABLE TO** Apply **OR INCORRECT** K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **MOST** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **MOST** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **SOME** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and obtaining prime implicants with max coverages
4. 25%	4. **UNABLE TO** Obtain AN UNsimplified POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain AN **UNsimplified** POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain **AN ALMOST** simplified POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain simplified POS Boolean expression by ANDing the minterms from prime implicants

Figure 6: A specific PI and hybrid rubric for assessing ABET SO ‘e’ “*Ability to identify, formulate and solve engineering problems*”

The co-author’s past famous work - four power principles of authentic OBE [7,8,10,12] are applied here as guidelines for the development and implementation of specific PIs and hybrid rubrics:

1. ***Clarity of focus***: Subject specialists within a program form sub-groups to select appropriate course content, topics, learning activities and their skills/complexity levels based on student standards for the development of specific PIs and their hybrid rubrics. The language of specific PIs and hybrid rubrics should have sufficient transparency in meaning to promote easy faculty comprehension and application resulting in perfect implementation of scientific constructive alignment and use of the “unique assessments” philosophy [22,24,38,35, 49, 50,,51, 63,64,70], where a single assessment does not map to more than one specific PI. The language of the specific PIs and descriptors should have an approximate correspondence with student learning activities, so both, students and faculty, can clearly understand the various scales of performance expectations.

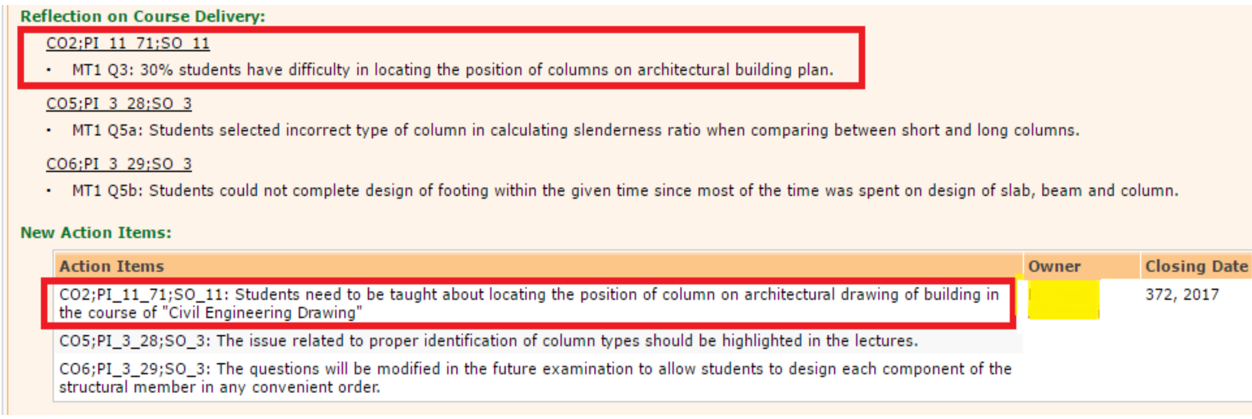
2. ***High expectations***: The Excellent scale 'E', of the hybrid rubric, should clearly identify required steps for excellent performance in using a specific *major method*, say 'M_i', for performing a certain task. A *major method* would be a complex engineering activity involving several unique steps for completing a specific task. There should be only one specific hybrid rubric designed to assess one major method or technique applied to complete a particular task. Any alternative *major methods*, say 'M_1, M_2..M_n', that complete the same task, let's say 'T', and deemed necessary curricular content by the instructor, should be assessed independently, with rubrics of their own. This would eradicate the possibility of producing "excellent" performing engineering graduates who have partial knowledge of necessary curricular content or lack required engineering skills.
3. ***Expanded opportunity***: Use hybrid rubrics and their descriptors to be consistent in rating assessments. Give the student prior notice on what is expected by rehearsing examples of problems indicated in the developed hybrid rubrics. Provide clear feedback on student graded work highlighting performance issues. Use criterion based standards and provide opportunities to improve based on some minimal required expectations. Weighted averaging should be used to scientifically score combination of assessments or performances of students [48,49,50,51]. Pure averaging to conduct quantitative evaluation of outcomes assessment should be strictly avoided [12].
4. ***Design down***: Develop PIs, hybrid rubrics in perfect alignment with institutional mission, PEOs, SOs and COs. For this mission statements and PEOs should be designed scientifically avoiding the use of vague and redundant language. Learning outcome and PIs information should be used for implementation of scientific constructive alignment to develop and align assessments, their teaching/learning strategies, scoring, evaluation, feedback and CQI efforts.

IV. Program, Course and Student Level CQI.

Contrary to the GR model's selective sampling of few courses, students for program evaluations as highlighted [3], the Faculty of Engineering has collected outcomes assessment data for *ALL* students, in *ALL* courses, by using the automated FCAR + specific PIs methodology. The principles of authentic OBE *"success and learning for ALL"* are implemented to conduct comprehensive course, student level evaluations resulting in holistic CQI. In this section we present few samples of program, course and student level evaluations and CQI.

Program Level Evaluation and CQI: The *Program Term Review* module of EvalTools® 6 consists of three parts i) *Learning Domains Evaluation* ii) *PIs Evaluation* and iii) *ABET SOs Evaluation* as per our specific requests and requirements. The PIs and SOs evaluation is focused on failing SOs and PIs for analysis and discussions relating to improvement [35,49,50,51,63,64]. Weighted average values of ABET SOs and PIs [45] with a scientific color coding scheme as per PVT heuristic rules shown in Figure 21 indicate failures for investigation. Courses contributing to failing PIs and SOs are examined [35,49,50,51,63,64]. The Faculty of Engineering has presented elaborate *youtube video presentations* that detail the automation of outcomes assessment, showing some Continuous Improvement Management System (CIMS) features such as action items elevation from the FCAR to task lists of standing committees for actual CQI [35,63,64].

Course Level Evaluation and CQI: Faculty members electronically port old action items status details from previous offerings of a certain course into the current FCAR. Modifications and proposals to a course are made with consideration of the status of the old action items. Program faculty report failing COs, their associated PIs, ABET SOs, comments on student indirect assessments and other general issues of concern in the respective *course reflections* section of the FCAR. Based upon these course reflections, new action items are proposed by the faculty [49,50,51]. The course reflections and action items maintain headings related to format CO_*N1*; PI_*N2*_*N3*; SO_*N2*; where *N1*: CO index; *N2*: ABET SO index (1 being 'a' and 11 being 'k'); and *N3*: PI index. Additionally, course reflections have to also mention the failing assessments in abbreviated form.



Reflection on Course Delivery:

CO2;PI_11_71;SO_11

- MT1 Q3: 30% students have difficulty in locating the position of columns on architectural building plan.

CO5;PI_3_28;SO_3

- MT1 Q5a: Students selected incorrect type of column in calculating slenderness ratio when comparing between short and long columns.

CO6;PI_3_29;SO_3

- MT1 Q5b: Students could not complete design of footing within the given time since most of the time was spent on design of slab, beam and column.

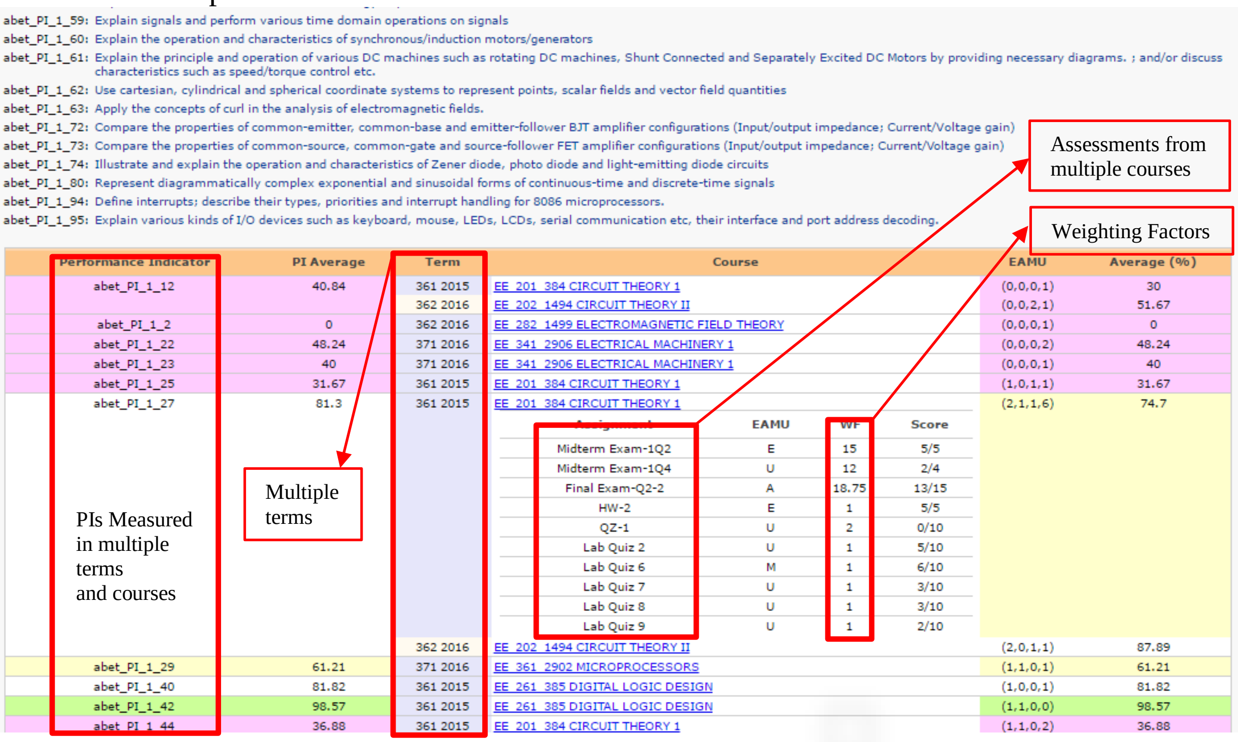
New Action Items:

Action Items	Owner	Closing Date
CO2;PI_11_71;SO_11: Students need to be taught about locating the position of column on architectural drawing of building in the course of "Civil Engineering Drawing"		372, 2017
CO5;PI_3_28;SO_3: The issue related to proper identification of column types should be highlighted in the lectures.		
CO6;PI_3_29;SO_3: The questions will be modified in the future examination to allow students to design each component of the structural member in any convenient order.		

Figure 7: Course CE_416, Reinforced Concrete Design-I, showing easy identification of root cause failures and CQI activity using specific PIs

Figure 7 shows for a CE course CE_416, Reinforced Concrete Design-I, the CO_2: *"Locate the position of columns, identify and designate the structural reinforced concrete members for the structural system"*; and PI_11_71: "*Locate the position of columns, identify and designate the structural reinforced concrete members (Slabs, beams, columns and footings) for the structural system by classifying the panel types of slabs*" is assessed using Mid Term-1 Q3 abbreviated as MT1 Q3 and corresponds to SO_11 or SO 'k': "*an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*"; The performances in this assessment have failed and therefore, the failing CO, PI and ABET SO are headlined for reflections and action items. The reason for failure is documented in the reflections section. In this case, the reason was observed as, 30% students had difficulty in locating the position of columns on architectural building plans. It was noted, that a course offered earlier, *Civil Engineering Drawing*, never covered fundamental activity such as locating columns in architectural building plans. Therefore, the action item suggested, was to teach students about locating the position of columns on architectural drawings of buildings in course on *Civil Engineering Drawing*. However, this action item would have to be elevated to the program level since it is not the scope of faculty for redressal. Elevations are easily facilitated using CIMS technology provided by software EvalTools 6 ® [35,43,49,50,51,68].

Student Level Evaluation and CQI: The Faculty of Engineering has implemented a student advising system employing the FCAR + specific PIs classified per Bloom's domains and *3-Levels Skills Grouping* methodology, and EvalTools 6 ®. A youtube video also presents some detail of the features of this module and how individual student skills data is collected by using specific PIs, course assessments and integrated by faculty into academic advising [62]. Figure 8 illustrates a list of ABET SOs calculated from PIs measurements for a typical student evaluation. The student skills SOs data is realistic and corresponds closely with actual student performances since 15 essential elements of precision assessment [49,51,70] have been implemented to ensure outcomes data is as accurate as possible.



abet_PI_1_59: Explain signals and perform various time domain operations on signals
abet_PI_1_60: Explain the operation and characteristics of synchronous/induction motors/generators
abet_PI_1_61: Explain the principle and operation of various DC machines such as rotating DC machines, Shunt Connected and Separately Excited DC Motors by providing necessary diagrams. ; and/or discuss characteristics such as speed/torque control etc.
abet_PI_1_62: Use cartesian, cylindrical and spherical coordinate systems to represent points, scalar fields and vector field quantities
abet_PI_1_63: Apply the concepts of curl in the analysis of electromagnetic fields.
abet_PI_1_72: Compare the properties of common-emitter, common-base and emitter-follower BJT amplifier configurations (Input/output impedance; Current/Voltage gain)
abet_PI_1_73: Compare the properties of common-source, common-gate and source-follower FET amplifier configurations (Input/output impedance; Current/Voltage gain)
abet_PI_1_74: Illustrate and explain the operation and characteristics of Zener diode, photo diode and light-emitting diode circuits
abet_PI_1_80: Represent diagrammatically complex exponential and sinusoidal forms of continuous-time and discrete-time signals
abet_PI_1_94: Define interrupts; describe their types, priorities and interrupt handling for 8086 microprocessors.
abet_PI_1_95: Explain various kinds of I/O devices such as keyboard, mouse, LEDs, LCDs, serial communication etc, their interface and port address decoding.

Performance Indicator	PI Average	Term	Course	EAMU	Average (%)
abet_PI_1_12	40.84	361 2015	EE 201 384 CIRCUIT THEORY 1	(0,0,0,1)	30
		362 2016	EE 202 1494 CIRCUIT THEORY II	(0,0,2,1)	51.67
abet_PI_1_2	0	362 2016	EE 282 1499 ELECTROMAGNETIC FIELD THEORY	(0,0,0,1)	0
abet_PI_1_22	48.24	371 2016	EE 341 2906 ELECTRICAL MACHINERY 1	(0,0,0,2)	48.24
abet_PI_1_23	40	371 2016	EE 341 2906 ELECTRICAL MACHINERY 1	(0,0,0,1)	40
abet_PI_1_25	31.67	361 2015	EE 201 384 CIRCUIT THEORY 1	(1,0,1,1)	31.67
abet_PI_1_27	81.3	361 2015	EE 201 384 CIRCUIT THEORY 1	(2,1,1,6)	74.7
		362 2016	EE 202 1494 CIRCUIT THEORY II	(2,0,1,1)	87.89
abet_PI_1_29	61.21	371 2016	EE 361 2902 MICROPROCESSORS	(1,1,0,1)	61.21
abet_PI_1_40	81.82	361 2015	EE 261 385 DIGITAL LOGIC DESIGN	(1,0,0,1)	81.82
abet_PI_1_42	98.57	361 2015	EE 261 385 DIGITAL LOGIC DESIGN	(1,1,0,0)	98.57
abet_PI_1_44	36.88	361 2015	EE 201 384 CIRCUIT THEORY 1	(1,1,0,2)	36.88

Assignment	EAMU	WF	Score
Midterm Exam-1Q2	E	15	5/5
Midterm Exam-1Q4	U	12	2/4
Final Exam-Q2-2	A	18.75	13/15
HW-2	E	1	5/5
QZ-1	U	2	0/10
Lab Quiz 2	U	1	5/10
Lab Quiz 6	M	1	6/10
Lab Quiz 7	U	1	3/10
Lab Quiz 8	U	1	3/10
Lab Quiz 9	U	1	2/10

Figure 8: SO_1, 'a', individual student's skills data measured by multiple raters using several PIs in multiple courses, types of assessments, terms and applying weighting factors WF

V. Conclusion

The demand for higher education is ever on the increase, with student achievement and accountability posing the biggest challenges to improving the quality of higher education. In order to meet these challenges, an OBE model for student learning, along with several quality standards in higher education have been adopted by accreditation agencies and educational institutions over the past two decades. With thousands of institutions and programs in a tight race for rank and accreditation, the prevalent understanding and implementation of authentic OBE and CQI needs clarification. This paper has presented research detailing some aspects of traditional assessment models that are in conflict with the principles and purpose of authentic OBE models and have widened the gap between accreditation and actual CQI in engineering education. Lack of clarity, and specificity, in the language of learning outcomes, PIs, rubrics and manual processes are at the crux of the CQI problem as explained in the various sections of this paper.

Quality assurance agencies such as IEA, ABET, MSCHE etc. have achieved a great deal in terms of establishing a major paradigm shift from curricular based education systems to OBE in the United States and worldwide by reaching out to several thousands of programs and institutions. The benefits of partial and incremental implementation of OBE philosophy over more than two decades has significantly transformed the face of education today. Faculty culture, teaching and learning strategy, curriculum content and delivery, students' skills, and employers' outlook have all been reformed to a very fertile state, ready to embrace standards of authentic OBE systems. The dilemma facing ABET, and other quality assurance agencies is that they have clear intent to implement authentic OBE philosophy, for achieving student success, but due to practical limitations related to manual processes, documentation, reporting, and resources, they cannot propose measurement of outcomes, specific PIs, evaluation, feedback and CQI efforts for all students, as the gold standard for accreditation. We have currently reached a juncture, where the greatest setback to OBE implementation is the gap that exists between outcomes assessment processes and CQI efforts. The author has been in many programs' accreditation rooms that remain locked up, are given limited access, opened by assigned personnel or the independent raters and contain student objective evidence records. It is practically impossible, for CQI to be achieved, when outcomes information is not instantly accessible, remains locked up, and piled up within thousands of documents.

The purpose of quality assurance agencies and educational institutions is not fulfillment of minimum accreditation requirements, but establishing essential OBE standards that promote holistic CQI, learning and success for all. In conclusion, this is the right moment for quality assurance agencies and educational institutions to embark on a quest to seek solutions that incorporate such outcomes assessment methodology, which supports implementation of state of the art technology to streamline and automate assessment, evaluation, reporting and CQI to fulfill accreditation criteria that are fully aligned with authentic OBE. The assessment model using FCAR, specific PIs classified per Bloom's 3 domains and 3-levels skills, their hybrid rubrics integrated with state of the art, web based software, such as EvalTools 6 ®, present a viable solution to educational institutions for the implementation of accreditation requirements that fully support the principles of authentic OBE and holistic CQI.

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Appendix A: IEA profiles for graduate attributes and competencies

1. IEA knowledge profile for practicing engineers, engineering technologist and technicians

5.1 Knowledge profile

A Washington Accord programme provides:	**A Sydney Accord programme** provides:	**A Dublin Accord programme** provides:
WK1: A systematic, theory-based understanding of the **natural sciences** applicable to the discipline	**SK1:** A systematic, theory-based understanding of the **natural sciences** applicable to the sub-discipline	**DK1:** A descriptive, formula-based understanding of the **natural sciences** applicable in a sub-discipline
WK2: Conceptually-based **mathematics**, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline	**SK2:** Conceptually-based **mathematics**, numerical analysis, statistics and aspects of computer and information science to support analysis and use of models applicable to the sub-discipline	**DK2:** Procedural **mathematics**, numerical analysis, statistics applicable in a sub-discipline
WK3: A systematic, theory-based formulation of **engineering fundamentals** required in the engineering discipline	**SK3:** A systematic , theory-based formulation of **engineering fundamentals** required in an accepted sub-discipline	**DK3:** A coherent procedural formulation of **engineering fundamentals** required in an accepted sub-discipline
WK4: Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.	**SK4:** Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline	**DK4:** Engineering **specialist knowledge** that provides the body of knowledge for an accepted sub-discipline
WK5: Knowledge that supports **engineering design** in a practice area	**SK5:** Knowledge that supports **engineering design** using the technologies of a practice area	**DK5:** Knowledge that supports **engineering design** based on the techniques and procedures of a practice area
WK6: Knowledge of **engineering practice** (technology) in the practice areas in the engineering discipline	**SK6:** Knowledge of **engineering technologies** applicable in the sub-discipline	**DK6:** Codified **practical engineering knowledge** in recognised practice area.
WK7: Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability	**SK7: Comprehension of** the role of technology in society and identified issues in applying engineering technology: ethics and impacts: economic, social, environmental and sustainability	**DK7: Knowledge** of issues and approaches in engineering technician practice: ethics, financial, cultural, environmental and sustainability impacts
WK8: Engagement with selected knowledge in the **research literature** of the discipline	**SK8:** Engagement with the **technological literature** of the discipline	
A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 4 to 5 years of study, depending on the level of students at entry.	A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 3 to 4 years of study, depending on the level of students at entry.	A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 2 to 3 years of study, depending on the level of students at entry.

2. IEA problem solving profile for practicing engineers, engineering technologist and technicians

4 Common Range and Contextual Definitions

4.1 Range of Problem Solving

References to the Knowledge Profile are shown thus: (WK3, WK4 ...)

In the context of both Graduate Attributes and Professional Competencies:			
Attribute	***Complex Engineering Problems*** have characteristic WP1 and some or all of WP2 to WP7:	***Broadly-defined Engineering Problems*** **have characteristic SP1 and some or all of SP2 to SP7:**	***Well-defined Engineering Problems*** have characteristic DP1 and some or all of DP2 to DP7:
Depth of Knowledge Required	**WP1:** Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6 or WK8 which allows a fundamentals-based, first principles analytical approach	**SP1:** Cannot be resolved without engineering knowledge at the level of one or more of SK 4, SK5, and SK6 supported by SK3 with a strong emphasis on the application of developed technology	**DP1:** Cannot be resolved without extensive practical knowledge as reflected in DK5 and DK6 supported by theoretical knowledge defined in DK3 and DK4
Range of conflicting requirements	**WP2:** Involve wide-ranging or conflicting technical, engineering and other issues	**SP2:** Involve a variety of factors which may impose conflicting constraints	**DP2:** Involve several issues, but with few of these exerting conflicting constraints
Depth of analysis required	**WP3:** Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	**SP3:** Can be solved by application of well-proven analysis techniques	**DP3:** Can be solved in standardised ways
Familiarity of issues	**WP4:** Involve infrequently encountered issues	**SP4:** Belong to families of familiar problems which are solved in well-accepted ways	**DP4:** Are frequently encountered and thus familiar to most practitioners in the practice area
Extent of applicable codes	**WP5:** Are outside problems encompassed by standards and codes of practice for professional engineering	**SP5:** May be partially outside those encompassed by standards or codes of practice	**DP5:** Are encompassed by standards and/or documented codes of practice
Extent of stakeholder involvement and conflicting requirements	**WP6:** Involve diverse groups of stakeholders with widely varying needs	**SP6:** Involve several groups of stakeholders with differing and occasionally conflicting needs	**DP6:** Involve a limited range of stakeholders with differing needs
Interdependence	**WP 7:** Are high level problems including many component parts or sub-problems	**SP7:** Are parts of, or systems within complex engineering problems	**DP7:** Are discrete components of engineering systems
In addition, in the context of the Professional Competencies			
Consequences	**EP1:** Have significant consequences in a range of contexts	**TP1:**Have consequences which are important locally, but may extend more widely	**NP1:** Have consequences which are locally important and not far-reaching
Judgement	**EP2:** Require judgement in decision making	**TP2:** Require judgement in decision making	

Appendix B: Hybrid Rubrics Example:
Civil Engineering Hybrid rubrics development workshop

OFFICE OF QUALITY & ACCREDITATION WORKSHOP 1Oth OCTOBER 2016, 8-9:30 AM

PROGRAM:	CIVIL ENGINEERING
PROGRAM COORDINATOR:	[redacted]
ABET COORDINATOR:	[redacted]

1	COURSE TITLE:	CE 312 STRUCTURAL ANALYSIS I
2	COURSE OUTCOME:	Explain the various classical methods used to analyze indeterminate and determinate structures
3	PERFORMANCE INDICATOR:	Use different methods for analysis of indeterminate structures
4	ABET STUDENT OUTCOME:	an ability to identify, formulate, and solve engineering problems
5	HIGHEST EXPECTATION STUDENT ACTIVITY (SEQUENTIAL WITH ALL GRADABLE MAJOR STEPS INDICATED) :	1. Determine the method for the given cases of indeterminate structural components 2. Formulate the mathematical solution for the given indeterminate structural components 3. Apply the suggested method by properly labeled free hand sketches

RUBRIC DEVELOPMENT

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
30%	1. Explain all applicable methods like slope deflection, force deformation method, moment distribution accurately for the given cases of indeterminate structural components	1. Explain applicable methods like slope deflection, force deformation method, moment distribution accurately for the given cases of indeterminate structural components	1. Explain at least one of the applicable methods like slope deflection, force deformation method, moment distribution accurately for the given cases of indeterminate structural components	1. Unable to explain even one of the applicable methods like slope deflection, force deformation method, moment distribution accurately for the given cases of indeterminate structural components OR
30%	2. Formulate the mathematical solution accurately for the given indeterminate structural components by applying the selected method	2. Formulate at least two of given methods' mathematical solution accurately for the given indeterminate structural components by applying the selected method	2. Formulate at least one of given methods' mathematical solution accurately for the given indeterminate structural components by applying the selected method	2. Unable to formulate at least one of given methods' mathematical solution accurately for the given indeterminate structural components by applying the selected method OR
40%	3. Apply the suggested method by properly labeled free hand sketches. All the labels should thoroughly indicate all parameters in the applied formula	3. Apply the suggested method by properly labeled free hand sketches. Majority of the labels should thoroughly indicate most parameters in the applied formula	3. Apply the suggested method by properly labeled free hand sketches. Some of the labels should thoroughly indicate most parameters in the applied formula	3. Unable to apply the suggested method by properly labeled free hand sketches. Some of the labels should thoroughly indicate most parameters in the applied formula

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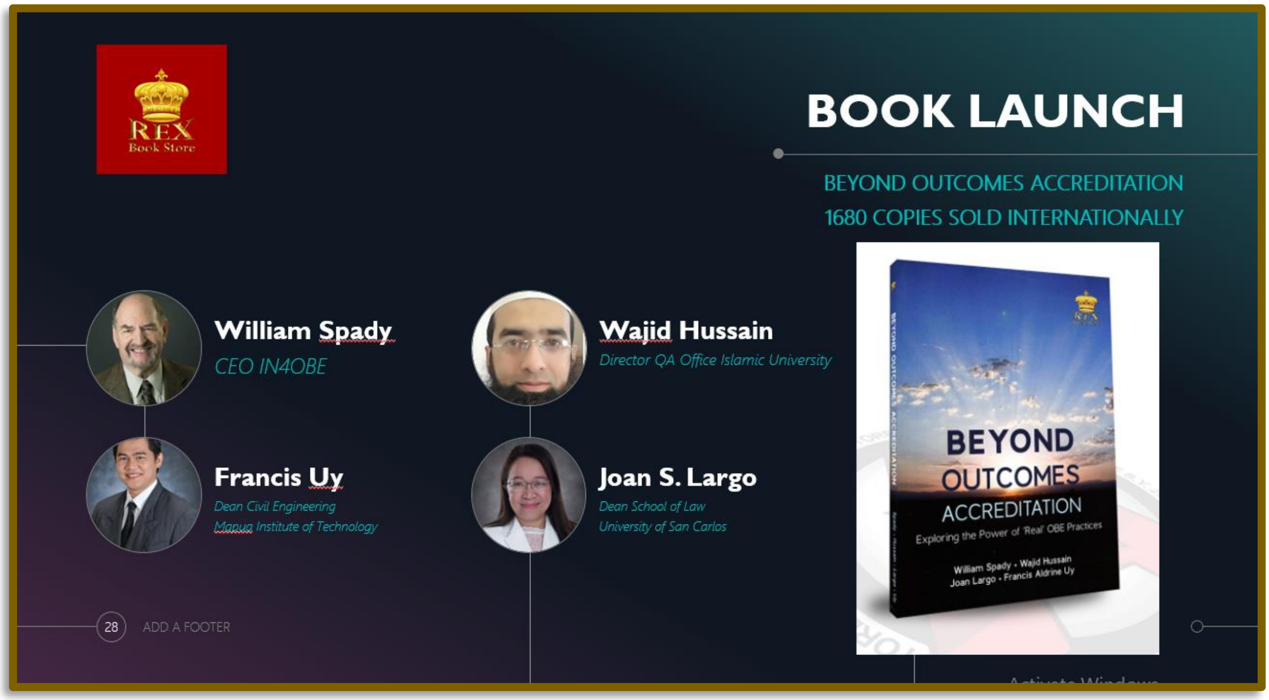

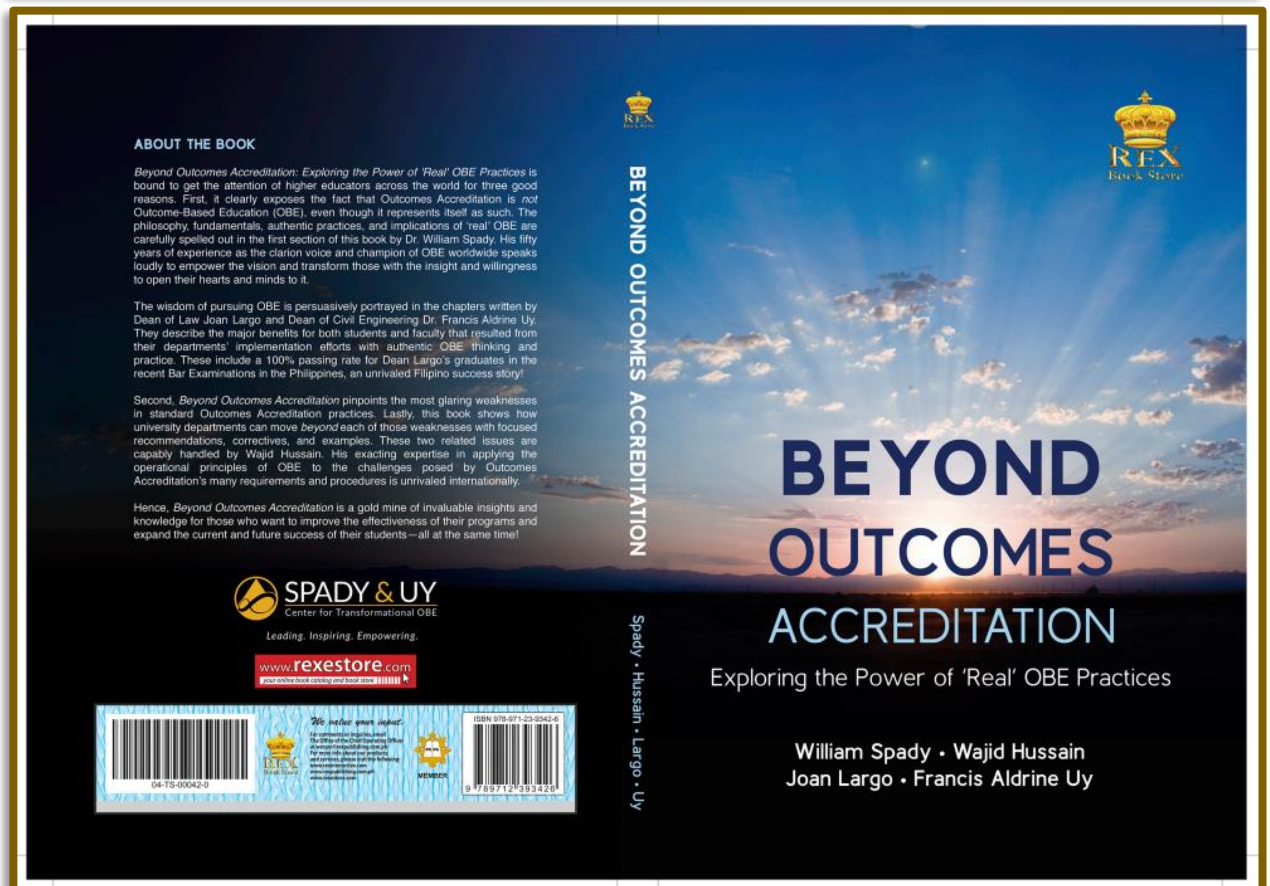

BEYOND OUTCOMES ACCREDITATION

Exploring the Power of 'Real' OBE Practices

William Spady • Wajid Hussain
Joan Largo • Francis Aldrine Uy

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Chapter

7

Moving Beyond Outcomes Accreditation: Tight Alignment of Outcomes Among All Levels of Curriculum and Instruction

Wajid Hussain

Several terms are utilized by quality assurance and accreditation agencies throughout the world to indicate culminating, enabling, or discrete learning outcomes. Terminologies such as Program Outcomes (POs), Student Outcomes (SOs), Course Outcomes (COs), Performance Indicators (PIs), Key Performance Indicators (KPIs), etc. are very common outcomes accreditation jargon while some agencies even prescribe measurement of program objectives which are broad statements that indicate attributes graduates of any higher education program should have in the field several years after graduation. Unfortunately, none of the popular accreditation agencies, which we have studied, provide the necessary framework of technical detail required to write the various types of learning outcomes mentioned above with an acceptable level of semantics and syntax essential for precise measurement of student performances. This has resulted in outcomes that are technically inaccurate, do not align with student activities, and in many situations, cases of very poor use of the English language. This dearth of necessary standards for writing outcomes has produced deficient outcomes accreditation processes and auditors or evaluators lacking adequate training. Therefore, in most cases, the quality and correctness of the written language of learning outcomes and proper application by institutions or programs are not thoroughly checked. What then finally remains of outcomes accreditation is a skeleton of ritualistic processes called "outcomes assessment, data collection, evaluation, feedback and CQI," which if examined deeply and not superficially would be disconnected, concocted in some form, and producing inaccurate results. Ultimately, the focus of outcomes accreditation becomes CBO with minimal involvement or integration of outcomes in the various parts and phases of the educational process.

For the fulfillment of typical accreditation criteria and specific quality standards, all major aspects that relate to the operational functionality of an educational institution or program are examined. In general, aspects related to students: transcripts, credit hours, enrollment, transfer, advising, and grading policy; infrastructure: facilities, labs, and library; faculty: research, industry, and teaching experience; allocated budget and institutional support are examined. The quality standards prescribed for majority of these aspects are almost entirely based on the CBO model and minimally connected to student outcomes. Ironically, in the OBE model, all processes and systems should actually be based and revolve around student outcomes.

As an interesting introduction and explanation of this topic, let us specifically mention one critical aspect of accreditation criteria which is totally deficient of OBE, the faculty! Accreditation criteria related to faculty qualification in higher education concentrate on faculty CVs with appropriate industry, research, or teaching experience in a specific specialization of a discipline. These criteria never mention any requirements in qualifications related to faculty knowledge of OBE and their experience in effective implementation of outcomes into teaching and learning. We have never seen in years of accreditation history any accreditation agency examining the faculty's knowledge of writing outcomes with clarity of focus, application of design down, expanded opportunity and high expectations to curriculum delivery, assessment and learning/teaching strategies. The following sections of this chapter shall present several details of the various limitations of outcomes accreditation criteria or processes.

OA Doesn't Provide Guiding Frameworks for Clearly Defining Life-Performance Roles and Systematically Aligning Them with All Levels of Curriculum and Instruction

OA standards do not provide guiding frameworks that help institutions clearly define life performance roles for students graduating from their specialized programs. Let us consider a few cases of accredited schools or programs from the many available publicly on the Internet. Many ABET-accredited and some world-famous programs write their Program Educational Objectives (PEOs) vaguely and do not align them properly with the SOs in a technically accurate mapping matrix. This basically informs us that the *Clarity of Focus* and *Design Down* power principles are not accurately implemented for this top-level phase of a typical ABET accreditation process.

Sufficient detail defining acceptable language of PEOs is not available in the supporting materials for ABET accreditation. The incorrect language of PEOs makes the entire *Design Down* mapping process difficult, resulting in vague and imprecise correspondence to the SOs. The situation is further exacerbated, with ABET actually revising its policy of thorough assessment of graduates' attainment of the PEOs, to a superficial review, of whether the PEOs are consistent with the institutional or program mission statements and removal of the requirement of employer feedback. Figure 7.1 actually shows an anonymous ABET-accredited ETAC program with one PEO: *Successful Career in Electrical Engineering Technology;* mapping to all possible ABET ETAC SOs and making qualitative or quantitative assessment of this PEO difficult and vague.

PROGRAM EDUCATIONAL OBJECTIVES

Program Educational Objectives		a	b	c	d	e	f	g	h	i
PEO1	Success career in the field of EEET	✓	✓	✓	✓	✓	✓	✓	✓	✓
PEO2	Pursuing professional development through self-learning or advanced degrees.						✓	✓		✓
PEO3	Contributing members of the society.				✓				✓	✓

Figure 7.1: Sample of vague PEOs description from a recent ABET-accredited ETAC program

A world-famous ABET-accredited engineering program from California states on its website just two PEOs: one of them is *Graduates of the program will have successful technical or professional careers*. Another popular accredited engineering program in Turkey, its PEO states: *Our civil engineering graduates will address the challenges they will face in their careers*.

Such generic and vague language of PEOs makes it very difficult to accurately map them to ABET SOs for assessment and monitoring of student achievements after graduation, and confirming full alignment of existing education processes and standards to well-defined and specific program goals. Lack of a guiding framework is the main culprit that has resulted in vague program objectives as shown in the above-mentioned examples. From the many years of experience in performing design down, alignment, and assessment of ABET SOs, we can stipulate a framework for developing PEOs to achieve engineering graduates attributes in 4 major life performance roles such as:

1. Application of engineering theory to problem-solving, design with fulfillment of safety, ethics, and economic constraints;
2. Soft skills such as team work, leadership, and communication;
3. Lifelong learning and research; and
4. Regional and international contribution and entrepreneurship skills.

Frameworks that explain the hierarchy from objectives and goals to actual student performances are desperately required for systematic alignment in outcomes accreditation processes. These frameworks would help define and differentiate objectives and goals from culminating, enabling, and discrete outcomes and help align them to actual student activities resulting in precision assessment. A design down mapping model was developed, as shown in Figure 7.2, exhibiting ‘real’ OBE design down flow from goals, PEOs, SOs, course objectives, and COs to specific PIs.

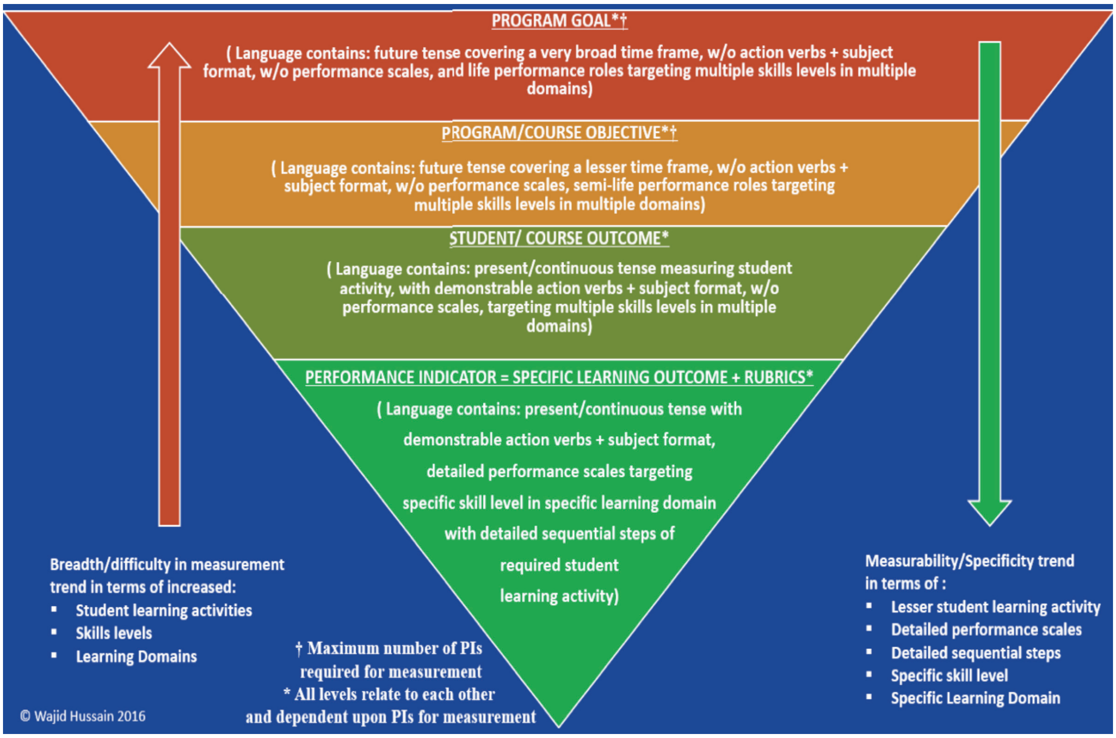


Figure 7.2: OBE design down mapping from goals, PEOs, SOs, and COs to PIs

These two frameworks will ease program efforts to create practical educational objectives that align realistically to ABET SOs for precise measurement of student learning activities. An example of implementation of the above framework for PEOs development and SOs alignment by the Faculty of Engineering at the Islamic University available on the public domain is referenced in Figure 7.3 for clarity. Electrical Engineering PEOs electronically mapped to ABET SOs for eventual assessment of graduate attainment of ABET PEOs. The PEOs are not vaguely mapped to all ABET SOs creating redundancy, but to appropriate SO selections.

EE department's program educational objectives:

PEO1	Successfully integrate the fundamentals of electrical engineering, skills, tools and design practices to develop innovative solutions to complex technological problems within a context of economical, societal, ethical and environmental constraints.
PEO2	Advance their careers as measured by leadership, communication skills, ability to work with multi-disciplinary and multi-cultural teams, promotions, salaries, career satisfaction, awards, recognitions, entrepreneurial activities, development of products or processes, patents, and/or publications.
PEO3	Participate in life-long learning to acquire new expertise, as measured by post-graduate education, continuing education and/or licensure, registration with professional societies.
PEO4	Contribute to the society, profession and economic development of the local and global community/industry as measured by professional/ community service, applied and basic research, recognition in their chosen fields for leadership, integrity and sensitivity to global societal issues within the context of Islamic values.

Correlation Among PEOs and Student Learning Outcomes:

1 ABET Student Outcomes

	Outcomes	PEO1	PEO2	PEO3	PEO4
SO1	an ability to apply knowledge of mathematics, science, and engineering	✓			
SO2	an ability to design and conduct experiments, as well as to analyze and interpret data	✓			
SO3	an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	✓	✓		✓
SO4	an ability to function on multidisciplinary teams		✓		✓
SO5	an ability to identify, formulate, and solve engineering problems	✓			
SO6	an understanding of professional and ethical responsibility	✓			✓
SO7	an ability to communicate effectively		✓		✓
SO8	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	✓	✓	✓	
SO9	a recognition of the need for, and an ability to engage in life-long learning		✓	✓	✓
SO10	a knowledge of contemporary issues			✓	✓
SO11	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	✓			✓

Figure 7.3: Electronic mapping of EE ABET PEOs to SOs

OA Standards of Learning Outcomes Statements Are Often Inconsistent, Poorly Implemented, and Monitored

The history of ABET starting with the Engineers' Council for Professional Development (ECPD) in 1932, has been a very dynamic one, with the last major change, EC2000, in 1996, when there was a major shift, from a bean counting approach to actual assessment of student outcomes with measurement of corresponding PIs for program evaluation. An interesting paper by Gloria Rogers in the 1996 ASEE conference shows how the criteria actually transformed from the curricular objectives in the 1996 cycle to the proposed changes of EC2000. It is clear from the mapping figure provided in this research paper that the ABET SOs for EC2000 took much of their language from the curricular objectives of the previous cycle, and needed scrutiny for use of the correct language required of learning outcomes necessary for effective CQI and student achievement.

The standards of the language of learning outcomes used in higher education today are observed to be even more deficient than the language of PEOs discussed earlier. We have studied the language of outcomes of scores of accredited institutions, programs, and courses on the public domain; some of them world-famous. They use abstract, immeasurable, non-demonstrable language; non-specific, without nominal, field specific content; extremely broad and vague outcomes that combine too many kinds and types of student learning activities; most often, critical English language semantic and syntax errors exist; they mix outcomes which are student-centered with objectives that are teacher-centered; they do not implement any form of mastery learning or taxonomic hierarchy learning concepts advocated by Bloom; ALL course outcomes often correspond to just one skill level analyzed or evaluated; outcomes activities do not match with course objectives and content, that is, outcomes are NOT aligned with actual student learning activities; they confuse outcomes with their PIs.

At this point, it is relevant to refer to a thorough National Institute of Learning Outcomes Assessment (NILOA) research paper by Adelman in 2015, who is a senior associate at the Institute for Higher Education Policy. The paper was produced through extensive research and provides guidelines and tools for writing learning outcomes statements, with language-centered principles heavily focused on syntax and semantics. The author refines the understanding of action verbs with the suffix 'operational' to measure observable learning activities subject to judgment and explains that verbs like *'recall'* reflect an internal cognitive state of mind that need further elaboration using other verbs and subject content for objectivity to be achieved in learning outcome statements. The paper presents convincing evidence to use learning outcomes statements in present tense without the noun *'ability'* since with *'upon successful completion of the course, students will possess the ability to…'* puts learning in the past with the work to be demonstrated by students in the future. Operational action verbs are the fulcrum of learning outcome statements, and when used properly with adverbs and adjectives, nominal content becomes transparent, providing students with critical information related to the required learning achievement. A technically viable and real OBE-compliant introduction to learning for ALL students would be *'Students achieve the intended learning outcomes of this course by successfully performing the following…'*

Learning outcome statements for specific disciplines should offer a profile. Those profiles are loaded with the nouns (the intuitions) of learning outcome statements with field-specific reference.

Adelman (2015) and we both argue against the use of abstract verbs such as *'understand,' 'aware,'* etc. since these do not tell anything about the operationalization of *'understanding'* or *'awareness'* and not measurable. Tautology also has no place in learning outcome statements.

Words such as ‘ability,’ ‘capacity,’ ‘teamwork,’ and ‘communicate,’ and one phrase ‘critical thinking’ are guaranteed to impede transparency and cloud student acceptance, and they should be followed with active operational verbs and very specific subject content details to relate to demonstrable student activity. Some examples below present vague learning outcomes statements since they need additional active operational verbs and subject content to be able to demonstrate certain measurable student learning activity:

- ‘*acquire* understanding of…’
- ‘*recognize* the importance of…’
- ‘*function* effectively in groups…’
- ‘*familiarize* with the process of…’
- ‘*gain* the knowledge of…’
- ‘*maintain* a pragmatic approach to…’

Summarizing statement provided by Adelman on a learning outcome statement is that it has forms (operational verbs) and intuitions (concrete nouns). It is declarative, not imperative (unless you want the outcome to be a criterion of a degree), and never subjunctive (learning outcomes are not potential—they are actual).

This is an interesting quote from Adelman on learning outcomes statements and accreditation agencies:

> “An authentic learning outcomes statement does not rely on the proxies of course or credit or curricular segment completion, let alone the provision of opportunity to learn or Grade Point Averages, none of which have anything to do with the specifics of student learning. Unfortunately, such proxies are too frequent in accreditation requirements that institutions express explicit standards for learning. In examination of 47 accrediting association standards documents from 37 regional, national, and specialized organizations, I found only 18 that included standards for the type of student learning outcome statements described here, while 18 employed proxies, and 11 did not mention student learning at all (Adelman, 2014c). Clearly, accrediting bodies have to take student learning outcome standards more seriously.”

Now the proposed ABET Engineering Accreditation Commission (EAC) changes incorporate verbs into the learning outcome statements but have combined multiple SOs from the earlier list of EAC 11 SOs to form the new single SOs statements. The new proposed SO *‘An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics’* combines the two earlier ABET SO ‘a’ *‘An ability to apply knowledge of mathematics, science, and engineering’* and SO ‘e’ *‘An ability to identify, formulate, and solve engineering problems.’*

With the earlier SO ‘a’ *‘An ability to apply knowledge of mathematics, science, and engineering,’* we were able to measure the students’ factual and conceptual knowledge of principles, theory of engineering, math, and science using specific PIs, targeting activities like explanation, derivation, and direct application of fundamental theories in basic problems. The failing PIs for this SO helped identify deficiencies in fundamental engineering knowledge. Subsequently, other PIs related to advanced learning activities like problem-solving also failed since they required the fundamental knowledge of engineering, math, and science principles. Remedial actions could be immediately applied when failures in SO 'a' PIs were observed.

Now, for the new composite SO 'An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics,' using the GR assessment model which does not employ specific PIs, it would be a comparatively very difficult process to identify performance failures related to lack of understanding of fundamental knowledge. Failure analysis would require detailed examination of objective evidence. It would be too late for on-time remedial action since lecture sessions for this fundamental theory would already be covered much earlier relative to when this SO was actually assessed. This new composite SO, thus, does not support the mastery learning concept of 'real' OBE and its power principle of "expanded opportunity" to improve learning for ALL students.

Some of the other SOs which measure elementary skills related to factual/conceptual/procedural knowledge have also been combined with the other related SOs to create several of the new proposed composite SOs, which expect students to perform very complex learning activities. Without specific PIs, the task of properly measuring these SOs for on-time effective remedial actions will be even more difficult. Therefore, the approach employed in developing SOs does not support the taxonomic hierarchy-learning concept advocated by Bloom, where students master basic concepts and skills then proceed to advanced learning. We and Adelman share the same concern that accrediting bodies should take student learning outcomes more seriously. Qualified training programs that educate faculty, auditors, and evaluators adequate standards of learning outcome statements should be extensively promoted.

OA Doesn't Provide Guiding Frameworks that Adequately Define Learning Domains and Their Levels for Classifying Outcomes

Some accreditation agencies regulate mandatory national qualifications frameworks that prescribe categories of learning domains which seem very relevant for the industry- and career-related requirements but are practically difficult to implement when dealing with classification, measurement of outcomes, their PIs for realistic final results, and CQI efforts. An important observation is that Bloom's 3 learning domains present an easier classification of specific PIs for realistic outcomes assessment versus other models that categorize learning domains as knowledge, cognitive, interpersonal, communication/IT/numerical, and/or psychomotor skills.

A hypothetical Learning Domains Wheel as shown in Figure 7.4 was developed to analyze the popular learning domains models available, including Bloom's, with a perspective of realistic measurement of outcomes based on valid PIs classification that does not result in a vague indicator mechanism for CQI in engineering education.

The learning domains categories mentioned in this chapter specifically refer to broad categories with well-defined learning levels selected for the classification of specific PIs. The Learning

Domains Wheel was implemented with Venn diagrams to represent details of the relationship of popular learning domains categories, interpersonal skills, and the types of knowledge.

The cognitive domain involves acquiring factual, conceptual knowledge dealing with remembering facts and understanding core concepts. Procedural and metacognitive knowledge deals essentially with problem-solving, which includes problem identification, critical thinking, and metacognitive reflection. Remembering facts, understanding concepts, and problem-solving are essential core and universal cognitive skills that would apply to all learning domains.

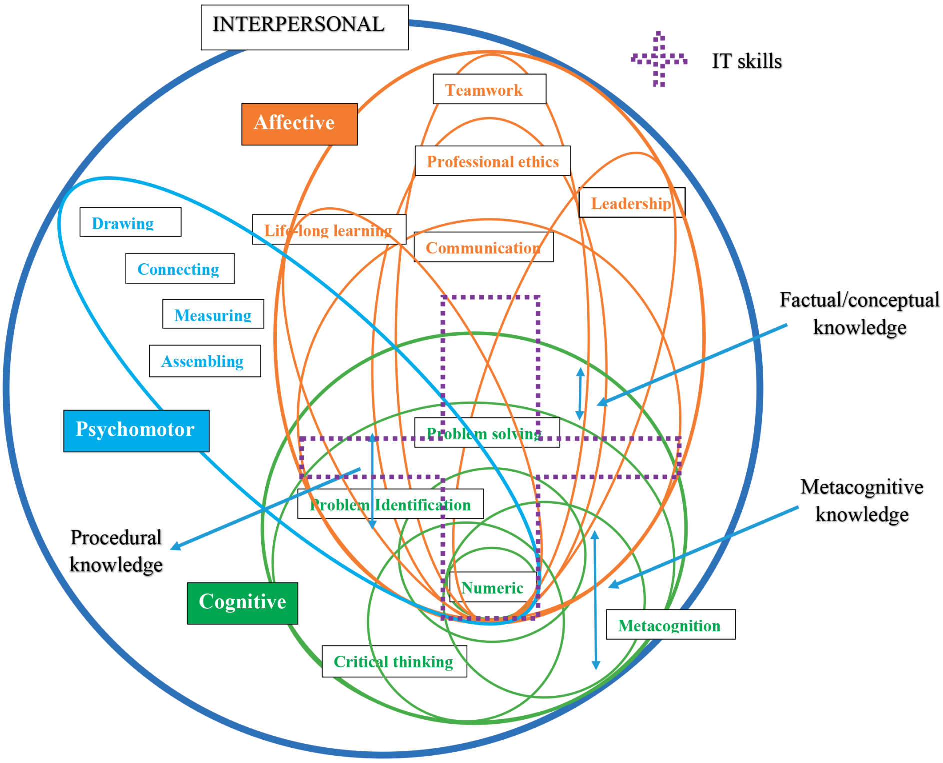


Figure 7.4: The Learning Domains Wheel for snapshot analysis and selection of learning domains categories to achieve realistic outcomes measurement with easier PIs classification process

Problem identification, definition, critical thinking, and metacognitive reflection are some of the main elements of problem-solving skills. These main elements of problem-solving skills apply to all levels of learning for the three domains. Activities related to any learning domain require operational levels of four kinds of knowledge: factual, conceptual, procedural, and metacognitive that are proportional to the expected degree of proficiency of skills for proper completion of tasks. For example, successfully completing psychomotor tasks for solving problems involves acquiring very specialized proportions of factual, conceptual, procedural, and metacognitive knowledge of various physical processes with accepted levels of their activities skills proficiency. Similarly, an affective learning domain activity, such as implementing a code of professional ethics, involves acquiring factual, conceptual, procedural, and metacognitive knowledge related to industry standards, process of application, level of personal responsibility and impact on stakeholders. Hence, the psychomotor and affective domains skills overlap with the cognitive domain for the necessary factual, conceptual, procedural, and metacognitive areas of knowledge.

The *learning domains categories* such as interpersonal, IT, knowledge, cognitive, communication, numerical skills, etc., exhibit significant areas of overlap as shown in the *Learning Domains Wheel* in Figure 7.4. A top-level grasp of the relationship of these categories demonstrates the process of the selection of learning domain categories.

For example, interpersonal skills, as shown in Figure 7.4, is too broad a category, thereby presenting serious problems in PIs classification and realistic outcomes measurement when grouped with other skills sets such as *learning domains categories*. Numerical skills are used for decision-making activities in the affective domain and also for the proper execution of psychomotor actions in physical processes. Numerical skills are an absolute subset of cognitive skills for any engineering discipline. IT skills cover some areas of psychomotor (connection, assembly, measurement, etc.), affective (safety, security, etc.), and cognitive (knowledge of regional standards, procedural formats, etc.) domains. Leadership and management skills require effective communication and teamwork.

This large overlap of skills within multiple learning domains presents a serious dilemma to engineering programs in the outcomes, PIs classification, and measurement process. A difficult choice must be made whether to select the most appropriate *learning domain category* and discard the others or repeat mapping similar outcomes, PIs to multiple *learning domain categories* for each classification. Defining the learning levels for the overlapping categories to precisely classify PIs would also be challenging.

Finally, *learning domain categories* with significant areas of overlap would result in the repeated measurement of common PIs in multiple domains and the accumulation of too many types of outcomes, PIs in any single *learning domain category*, thus obscuring specific measured information. Therefore, for practical reasons, the categories of learning domains have to be meticulously selected with a primary goal of implementing viable outcomes, PIs classification process to achieve realistic outcomes measurement for program evaluation.

Crucial guidelines were logically derived from the Learning Domains Wheel for the selection of the *learning domains categories* as follows:

1. Very broad *learning domains categories* consist of many skills sets that will present difficulty in the classification of outcomes, PIs when grouped with other categories and will result in the redundancy of outcomes data; for example, interpersonal skills grouped with IT, communication or psychomotor, etc.
2. Avoid selection of any two skills sets as *learning domains categories* when one is an absolute subset of another. Just select either the most relevant one or the one which is a whole set. For example, select cognitive or numeric skills, but not both; if both are required, select cognitive as a category since it is a whole set. Numeric skills, its subset, can be classified as a cognitive skill.

3. If selecting a certain skills set that is a whole set as a *learning domains category*, then it should not contain any other skills sets which are required to be used as learning domains categories; e.g., do not select affective as a *learning domains category* since it is a whole set if you also plan on selecting teamwork skills as a category.
4. A *learning domain category* could contain skills sets which will not be utilized for PIs classification; e.g., affective *learning domain category* containing leadership, teamwork, and professional ethics skills sets; leadership, teamwork, and professional ethics will NOT be a learning domain category but will be classified as affective domain skill sets.

Bloom's 3 domains—cognitive, affective, and psychomotor—are not absolute subsets of one another. They can easily contain skills sets corresponding to outcomes that do not categorize as learning domains and are prescribed by popular accreditation agencies. Therefore, Bloom's 3 learning domains satisfy selection guidelines derived from the *Learning Domains Wheel* and facilitate a relatively easier classification process for outcomes and their specific PIs. Calculation of term-wide weighted average values for outcomes using this classification of specific PIs would result in realistic outcomes data since most of the PIs would uniquely map to each of the 3 domains with minimal overlap and redundancy.

OA's Outcomes, Performance Indicators, and Their Rubrics Are Too Vague and Generic for Achieving Assessment Accuracy That Promotes Improved Student Performance

Quality assurance and accreditation agencies rarely propose specific PIs and their detailed rubrics as the preferred model for achieving the required validity and reliability in outcomes assessment. ABET actually talks about both kinds of PIs, generic or specific, their rubrics, and provides some information to differentiate between the two as shown in training presentation material publicly available on their website.

However, a look at the training and educational materials on ABET's website indicate that almost all of the examples of PIs and rubrics displayed are generic and target the predominantly affective domain ABET SOs for assessment. The reasons for this are firstly, there are hundreds of specific engineering activities related to any engineering specialization that would definitely require a good number of specific PIs, rubrics to adequately measure them. Secondly, appropriate technology would definitely be required to manage this information. It would be challenging for ABET or any quality assurance agency to prescribe the specific PIs model and technology for automation and achieve effective CQI or continue with the traditional manual GR model with generic PIs and compromise 'real' OBE and CQI.

Adelman's thorough work strengthens our argument that the required language of learning outcomes for the cognitive and psychomotor learning activities should be specific. He assertively states that verbs describing a cognitive or psychomotor operation act on something, that is, they have a specific nominal context. The nominal context can be discipline/field-specific, for example, error analysis in chemistry or an art exhibit in 2D with 3 media. Field-specific statements are endemic to learning outcome statements in Tuning projects. Finally, without a specific nominal context, you do not have a learning outcome statement.

ABET talks about rubric, being an assessment scale, which describes the levels of achievement for each PI and allows setting up thresholds for acceptable student performance. Examples in training slides show, ABET detailing reasons for specific and generic rubrics for assessment of activities that are task-specific as in the cognitive and psychomotor domains or general as in the affective domain.

The reasons for rubrics in general are given as follows:

1. Formative and summative application to assessments
2. A medium to define expectations for students, faculty, and program
3. Increases inter- and intra-rater reliability for assessments
4. A feedback process for learning performance for students, faculty, and program

Holistic rubrics relating to a certain SO or PI do not contain individual dimensions but rather a set of performance criteria which are applied in parallel for scoring assessments by seasoned raters. On the other hand, analytic rubrics relating to SOs contain specific dimensions, which are in fact, the PIs needed to adequately measure the SO. Both rubrics contain descriptors for all scales, but the difference is again that the analytic rubric has descriptors for each PI or dimension. Analytic rubrics can specifically indicate areas of weakness in performance for the various dimensions or PIs corresponding to a certain SO.

In both cases of rubrics, the nature of examples provided by ABET as shown in Figure 7.5 is very simplistic, addressing affective domain SOs like teamwork, while expressing the dimensions such as *Research and gather information* or *Listening to other teammates* with descriptors containing extremely superficial, vague, and non-technical language without actually providing detailed steps of what students have to demonstrate to accurately assess these dimensions or PIs. The *Research and gather information* PI/dimension contains one descriptor for each scale like *does not collect any information that relates to the topic* for the *Unsatisfactory scale* and *collects a great deal of information; all relates to the topic for the Exemplary scale*. The amount, sources, and quality of information to be collected for these four scales are utterly ambiguous and present serious difficulty to both the student and faculty in the case of realizing adequate performance and its assessment. The point to note is that the engineering activity related to the PI *Research and gather information*, PI *Listen to other teammates*, and two other PIs is not as trivial as is represented by the descriptors in Figure 7.5. Actually, even the language of these 4 PIs needs improvement as per the '*clarity of focus*' power principle of 'real' OBE. But, we will leave this issue for the sake of brevity and continue our discussion on the topic of rubrics.

SO: Function effectively in multidisciplinary teams **Dimension/PI**	**Unsatisfactory** **1**	**Developing** **2**	**Satisfactory** **3**	**Exemplary** **4**
Research and gather information	Does not collect any information that relates to the topic	Collects very little information—some relates to the topic	Collects some basic information—most relates to the topic	Collects a great deal of information, all relates to the topic
Fulfill team roles duties	Does not perform any duties of assigned team role	Performs very little duties	Performs nearly all duties	Performs all duties of assigned team role
Share in work of team	Always relies on others to do the work	Rarely does the assigned work—often needs reminding	Usually does the assigned work—rarely needs reminding	Always does the assigned work without having to be reminded
Listen to other team mates	Is always talking—never allows anyone to speak	Usually does all the talking—rarely allows others to speak	Listens but sometimes talks too much	Listens and speaks a fair amount

Figure 7.5: Analytic rubrics showing different dimensions/PIs and 4 scales for measuring ABET SO ''d' Function effectively on multidisciplinary teams

Let us consider some typical engineering activities required for the proper assessment of just one dimension/PI *Research and gather information*. Figure 7.6 shows some details of engineering activities such as methods used for locating information; number of professional citations; engineering consultants contacted; engineering data collected from site/field visits; selection and assimilation of appropriate research information into team project efforts, etc. Each of these five complex engineering activities is expressed with several descriptors in all 4 scales containing specific and clear technical language required for the comprehensive assessment and scoring of the PI *Research and gather information*. This added detail in rubric development is a necessary requirement without which the rubrics actually lose the reliability and validity needed to precisely assess specific engineering activities. This detailed rubric provides students greater clarity in realizing all aspects of this PI to attain the desired performance levels.

Now, with this improved understanding of specific PIs and their detailed rubrics, we would like to point out to our readers that it shall be ironical, if for the new proposed composite ABET

EAC SO, such as *'An ability to recognize the ongoing need to acquire new knowledge, to choose appropriate learning strategies, and to apply this knowledge'* we still resort to few simplistic and generic PIs and their rubrics to comprehensively complete its assessment.

SO: Function effectively in multidisciplinary teams **Dimension/PI**	**Unsatisfactory** **1**	**Developing** **2**	**Satisfactory** **3**	**Exemplary** **4**
Research and gather information	1. Only one method used for locating information	2 methods used for locating information	3 methods used for locating information	5 or more methods used for locating information
	2. Less than 2 professional citations	3 professional citations	4 professional citations	5 or more professional citations
	3. No engineering consultants contacted	No engineering consultants contacted	1 engineering consultant contacted	2 engineering consultants contacted
	4. No site/field visits	No site/field visits	No site/field visits	Engineering Data collected from Site/field visits
	5. Inaccurate selection and assimilation of appropriate research information	Partially correct selection and assimilation of appropriate research information	Accurate selection and partial assimilation of appropriate research information	Accurate selection and complete assimilation of appropriate research information

Figure 7.6: Analytic rubrics showing just one PI research and gather information with 5 descriptors as performance criteria for each scale in measuring ABET SO 'd'

As the discussion for assessment of several hundred student learning activities in any specialization of higher education continues and the conviction of the need for implementing a combination of a majority of specific and a minority of generic PIs deepens, we see more clearly that neither the holistic nor simplified analytic rubrics can accurately assess such complex student performances. Since the purpose of rubrics as stated earlier is validity – precise alignment with purpose of assessments and reliability – accuracy of scoring details of student performance, holistic rubrics will definitely not be applicable to accurate assessments and present major issues related to reliability, and analytic rubrics will need several PIs, specific and generic, with each PI or dimension, in fact, containing several descriptors for each scale as shown in the example of Figure 7.6.

To elucidate this point further, let's take an example of two introductory, 200-level courses from a typical Electrical Engineering program: (1) *EE_2xx: Digital Logic Design* and (2) *EE_2yy: Electromagnetic Field Theory*. An assessment for course *EE_2xx: Digital Logic Design* is related to implementing a Boolean function using specified logic gates, creating the truth table and expressing the same Boolean function in sum of minterms form. To solve problems for this assessment, students need fundamental knowledge of Boolean algebra, creating truth tables, understanding of logic gates, and knowledge of implementing digital circuits using logic gates. The other assessment for course *EE_2yy: Electromagnetic Field Theory* is related to computing the potential at various coordinates with given charge placed in free space. Problem-solving for this assessment requires fundamental knowledge of electromagnetic theory coupled with basic math skills. The problem-solving mechanisms for these various topics in the two 200-level EE courses are completely different, involving varying types of factual, conceptual, and procedural engineering knowledge.

The big question now is whether one generic set of problem-solving rubrics could accurately apply to properly assess and precisely score both of these very different engineering activities, and deliver the validity, inter- and intra-rater reliability, required by the purpose of rubrics. What would happen to the quality of assessments if we apply a generic set of PIs and rubrics to assess engineering activities from two courses, one from the senior and another from the junior levels? To expand the complexity of the problem further, how could we apply a small set of generic rubrics to problem-solving activities that relate to various learning levels of Bloom's cognitive domain? Activities could range from *applying* – pure and simple application of appropriate theory or math skills; *analyzing* – identify the problem, select appropriate theory, and apply, derive/formulate, solve, apply math skills; *evaluating* – identify, select appropriate theory, derive/formulate, solve then interpret, and evaluate the end result; *creating* – a complex combination of applying, analyzing, and evaluating from the cognitive domain targeting application of theory, identification, solving problems, conducting experimentation, designing prototype, manufacturing, evaluating; etc.

The ultimate level of complexity would be engineering activity that targets all learning levels in the cognitive, psychomotor, and affective domains of Bloom's taxonomy. Employing generic PIs and rubrics that cannot classify and assess complex engineering activity like design and then finally giving one erroneous consolidated score to represent a vast combination of skills relating to all 3 domains and several learning levels is nothing but a cocktail dessert with absolutely bad taste for CQI. Such applications render the entire set of OBE power principles void and the consequences are huge amounts of work, data collected, vague results, evaluation, feedback, CQI rendered ineffective and meaningless.

Prior to introducing the *Hybrid Rubrics*, we would like to once again reinforce the necessity of specific PIs and rubrics, with a reference to an exhaustive empirical research that reviewed 75 studies on rubrics, and summarized their benefits, with the topmost benefit coming from rubrics that are *analytic, topic-specific, and complemented with exemplars and/or rater training*:

The Hybrid Rubric

The hybrid rubric is a combination of the holistic and analytic rubrics developed to address the issues related to validity: precision, accuracy of assessment alignment with outcomes, PIs; and inter-, intra-rater reliability: detail of specificity of acceptable student performances; when dealing with assessment of complex and very specialized engineering activities. The hybrid rubric is an analytic rubric embedded with a holistic rubric to cater to the assessment of several descriptors that represent all the required major steps of specific student learning activity for each PI/dimension listed. Figure 7.7 shows an ABET SO 'e,' problem-solving, specific PI *"Simplify a given algebraic Boolean expression by applying the k-map and express in POS form"* and its hybrid rubric.

PI_5_1: SIMPLIFY A GIVEN ALGEBRAIC BOOLEAN EXPRESSION BY APPLYING THE K-MAP AND EXPRESS IN POS FORM

SCORING	UNSATISFACTORY (0-60%)	MINIMAL (60-75%)	ADEQUATE (75-90%)	EXCELLENT (90-100%)
1. 20%	1. **UNABLE/ABLE TO** Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.
2. 20%	2. **UNABLE/ABLE TO** Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.
3. 35%	3. **UNABLE TO** Apply **OR INCORRECT** K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **MOST** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **MOST** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **SOME** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and obtaining prime implicants with max coverages
4. 25%	4. **UNABLE TO** Obtain AN UNsimplified POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain AN **UNsimplified** POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain **AN ALMOST** simplified POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain simplified POS Boolean expression by ANDing the minterms from prime implicants

Figure 7.7: A specific PI and hybrid rubric for assessing ABET SO 'e' "Ability to identify, formulate, and solve engineering problems"

The hybrid rubric also contains a column to indicate the percentage of the total score allocation for each descriptor (major step of learning activity) corresponding to PI. a certain The scales implemented are obtained from Estell's FCAR E, A, M, and U performance vectors that stand for the Excellent (100–90)%, Adequate (89–75)%, Minimal (74–60)%, and Unsatisfactory (0–60)% categories, respectively. Readers can also refer to elaborate, step-by-step, instructional videos on YouTube channels for developing hybrid rubrics for the CE, EE, and ME programs.

The four power principles of a 'real' OBE are applied as guidelines for the development and implementation of specific PIs and hybrid rubrics:

1. **Clarity of Focus.** Subject specialists within a program form sub-groups to select appropriate course content, topics, learning activities, and their skills/complexity levels based on student standards for the development of specific PIs and their hybrid rubrics. The language of specific PIs and hybrid rubrics should have sufficient transparency in meaning to promote easy faculty comprehension and application, resulting in perfect implementation of scientific constructive alignment and use of the "unique assessments" philosophy, where a single assessment does not map to more than one specific PI. The language of the specific PIs and descriptors should have an approximate correspondence with student learning activities, so both students and faculty can clearly understand the various scales of performance expectations.

2. **Expanded Opportunity.** Use hybrid rubrics and their descriptors to be consistent in rating assessments. Give the student prior notice on what is expected by rehearsing examples of problems indicated in the developed hybrid rubrics. Provide clear feedback on student graded work highlighting performance issues. Use criterion-based standards and provide opportunities to improve based on some minimal required expectations. Weighted averaging should be used to scientifically score combination of assessments or performances of students. Pure averaging to conduct quantitative evaluation of outcomes assessment should be strictly avoided.

3. **High Expectations.** The Excellent scale 'E' of the hybrid rubric should clearly identify required steps for excellent performance in using a specific *major method*, say 'M_i' for performing a certain task. A *major method* would be a complex engineering activity involving several unique steps for completing a specific task. There should be only one specific hybrid rubric designed to assess one major method or technique applied to complete a particular task. Any alternative *major methods*, say 'M_1, M_2…M_n' that complete the same task, let's say 'T' and deemed necessary curricular content by the instructor, should be assessed independently with rubrics of their own. This would eradicate the possibility of producing "excellent" performing engineering graduates who have partial knowledge of necessary curricular content or lack required engineering skills.

4. **Design Down.** Develop PIs, hybrid rubrics in perfect alignment with institutional mission, PEOs, SOs and COs. As mentioned earlier in this chapter, mission statements and PEOs should be designed scientifically avoiding the use of vague and redundant language. Learning outcome and PIs information should be used for implementation of scientific constructive alignment to develop and align assessments, their teaching/learning strategies, scoring, evaluation, feedback and CQI efforts.

OA's Approach to Scientific Constructive Alignment in the Design and Use of Outcomes Assessments Is Marginal at Best

Most quality assurance and accreditation agencies do not mandate the use of unique assessments and application of scientific constructive alignment or provide guiding frameworks for design of unique assessments to achieve the critical requirements of precision in outcomes measurement. Scores of cases of accredited programs are available on the public domain which clearly display severe limitations of the validity of assessment tools and techniques employed. We generally observe that a composite curricular assessment with a consolidated score corresponding to multiple skills and student learning activities such as design, experimentation, and report writing is repeatedly mapped on various occasions of a program level evaluation of culminating student outcomes to all or most of the mentioned student activities. So, erroneously, one consolidated score is used across the board to reflect the result of various student performances for multiple learning activities.

Generally, curricular grade-giving assessments in a higher education curriculum are comprised of single or multiple questions and cover more than one performance criterion. This is elaborately discussed in an explanation on assessments: *Whys and hows of assessments*. Eberly Center for Teaching Excellence, Carnegie Mellon University CMU website, 2015.

> To achieve precision measurement of specific performance criteria related to program outcomes, and avoid inaccurate repeated mappings of the same composite assessments to multiple student skills, programs may choose to:
>
> a. develop new outcomes assessments apart from curricular assessments; and/or
>
> b. use existing curricular assessments.

In the first method, additional resources and faculty time would be required to measure the performance criteria of interest. The second method may pose limitations on the number of performance criteria measured in a given time frame and the quality of data collected depending upon the availability of streamlining electronic tools or assessments which possess maximum relative coverage of a single performance criterion. The limitations of manual systems and learning outcome information collected in a given time frame are discussed in detail by Kumaran et al. (2007) and Mead et al. (2006).

Unfortunately, the result of both methods is a comparatively small set of performance criteria finally measured in a given time frame by a program using assessments that may not have maximum relative coverage of the specified criteria. Measurement of PEOs, student learning outcomes, and performance criteria would therefore be completed in comparatively longer cycles. This minimum number of performance criteria measured with comparatively fewer assessments and obviously lesser number of raters over a given time frame would render the program evaluation term review less comprehensive and result in a deficiency in the eventual realization of its PEOs.

McGourty et al. (1998), Gannon-Slater, Ikenberry, Jankowski & Kuh (2014), and many others have conducted exhaustive research and observed that both in the United States and internationally, a minimal number of institutions have implemented comprehensive systems for learning outcomes assessment and measurement. Let us now discuss the issues related to the accreditation-driven, widely practiced methodology of employing superfluous non-curricular outcomes assessments and alternatively present intelligent design of curricular assessments embedded with necessary specific performance criteria to implement a high degree of scientific constructive alignment and required precision of outcomes measurement using state-of-the-art digital technology.

Designing and Dealing with Superfluous Non-Curricular Assessments

Since grade-giving assessments in an engineering curriculum are comprised of single or multiple questions and cover more than one performance criteria, the total score of such an assessment is generally a sum total of individual scores obtained from grading multiple performance criteria corresponding to this assessment. Thus, the assessment score does not actually reflect the grading results from a single performance criteria but rather, a complex distribution of grading results from multiple performance criteria. Therefore, the outcomes assessment data resulting from this approach is not realistic and does not reflect precise information relating to specific performance indicators or outcomes for quality improvement.

To obtain realistic data for continuous improvement purposes, one option available for faculty is to create a new set of assessments specifically for performance criteria, outcomes measurement. Several programs worldwide have chosen this approach for accreditation purposes, but since it is tedious and requires additional faculty time, resources the programs generally collect minimal information for small set of outcomes, performance indicators which are not sufficient for the implementation of a comprehensive academic improvement process. This would finally result in programs spending additional resources for maintaining independent processes for accreditation and realistic continuous improvement.

A noteworthy quote from a foreword by Stanley O. Ikenberry for NILOA, Occasional Paper #6, *Regional Accreditation and Student Learning Outcomes: Mapping the Territory*, Provezis (2010, p. 8), echoes the question whether learning outcomes assessment systems motivated by accreditation achieve realistic improvement:

> "The other major finding of our work that stood out was that chief academic officers pointed out that regional and specialized accreditation standards and expectations were the main drivers of outcome assessment initiatives on their campuses. In some respects, learning that accreditation was the main driver of assessment on most campuses is disappointing. Instead, we would have been elated if institutions themselves, faculty members and academic and administrative leaders and governing boards, driven by the desire to be the best and continuously improve, would have been in the driver's seat.
>
> Still, if accreditation is driving learning outcome assessment in American higher education, where is it taking us? What are the standards? What is the variation among regions? And how are regional accrediting groups guiding and helping institutions meet these rising expectations for outcome evidence? These and other key questions are probed in this NILOA Occasional Paper #6, Regional Accreditation, and Student Learning Outcomes: Mapping the Territory. It comes as a result of a

> year-long effort by Dr. Provezis and the generous cooperation of the seven regional accrediting commissions, all made possible by support from Lumina Foundation for Education, Carnegie Corporation, and The Teagle Foundation. The findings should be of interest to all those concerned with the future of higher education in the United States and the integrity of the systems of quality control that sustain it."

Another quote from a latest study by Gannon-Slater et al. (2014), *Institutional Assessment Practices Across Accreditation Regions*, pp. 7, NILOA with similar information: "Similar to findings reported in 2009 and the 2013 national report, regional and specialized/program accreditation bodies remain the prime drivers of assessment work at colleges and universities across all regions."

Designing Aligned Curricular Assessments for Realistic Outcomes Measurement

The intelligent design of curricular grade-giving assessments in higher education involves creating a composite assessment that consists of multiple embedded, extractable portions, where each portion is independently scored and uniquely aligned to a specific student learning activity corresponding to a specific PI, learning domain, and its learning level. Significant reduction of work is achieved by avoiding the creation of superfluous non-curricular assessments specifically for outcomes measurement through the intelligent design of curricular grade-giving assessments that apply scientific constructive alignment to multiple embedded performance indicators for realistic learning outcomes measurement. This method of development of composite assessments with independent, embedded, and extractable portions that are tightly aligned to very specific student skills is called *scientific constructive alignment*.

By applying *scientific constructive alignment*, we can intelligently design composite outcomes assessments that comprise of multiple independent portions and scores; each portion is tightly aligned to a specific skill, learning domain, and learning level. The final desired outcome of multiple student performances in complex learning activities defines the intricate combination of multiple skills, learning domains, and learning levels to be measured together in a composite assessment. While designing any assessment related to a specific course content, the concerned faculty member should consider the measurement of the most appropriate performance criteria. To apply *scientific constructive alignment*, the contribution of various performance criteria to the total score of an assessment would be defined during the assessment design.

For the initial and less critical formal assessments in a course, faculty may map the composite assessment to a certain course outcome and select performance criteria of interest to dominate the overall score of the assessment. This PI would be given nearly 70% or more share in the total score distribution, and the effect of grading results of the other performance criteria on the total score would be thus rendered negligible. This would be a secondhand option to faculty regarding certain assessments, as mentioned earlier, in which rigor and detail have to be minimized while maintaining the overall accuracy of the score of the composite assessment mapped to a specific course outcome.

Obviously, adequate digital technology would be required to store the vast amounts of information related to multiple portions, their PIs and scores in each composite assessment corresponding to several thousands of students and hundreds of courses offered at a typical higher education program. Examples of web-based software such as EvalTools® 6 with programmable digital database of several hundred specific PIs and sophisticated Outcomes Assessment System (OAS) would help streamline faculty efforts in managing the information related to assessments, outcomes and their PIs data for all students enrolled in any course of a higher education program.

For cases where it is not possible to assign a nearly 70% or more share to a certain performance criteria in an entire assessment, the Assignment Setup Module of EvalTools® 6 is used to split a question or sub-question of an assessment for achieving 70% high-relative coverage of a specific performance criteria. Appendix A indicates examples of implementation of splitting of assessments to questions, sub-questions using EvalTools® 6 Assignment Setup Module to obtain the maximum relative coverage and the measurement of a specific PI mapping to a certain CO and ABET SO. Such assessments or set of questions are said to be unique since they are just used once for measurement of a certain PI. This methodology of implementing unique assessments with high-relative coverage of PIs mapping to COs and ABET SOs would ensure realistic measurement of outcomes assessment data for comprehensive continuous improvement.

Now, let us apply scientific constructive alignment to design a sample composite assessment for experimental activity with 3 independently gradable portions, embedded PIs, and extractable results for feedback and CQI.

The multiple portions of experimental activity as decided by the subject specialists could be as follows:

1. *Cognitive-Domain, Applying-Level* activity; PI_1: Solve or formulate a practical problem by applying fundamental principles or theory. (30 points)
2. *Psychomotor-Domain, Adaptation-level* activity; PI_2: Assemble or connect apparatus, test equipment, and observe measurement readings. (20+20 points)
3. *Affective-Domain, Organizing into Values-Level* activity; PI_3: Organize and interpret the experimental results. (15+15 points)

From this example, it is clearly evident that the process of applying scientific constructive alignment for designing composite curricular assessments is perfectly congruent with the method of development of hybrid rubrics.

Figure 7.8 shows a sample of design of curricular assessments for outcomes measurement using scientific constructive alignment implemented by the Faculty of Engineering, IU. In this figure, we see each part or portion of the composite curricular assessment, *Final Project*, is designed with independent scores and tightly aligned to an embedded specific PI associated with a certain CO and overall program SO.

Faculty of Engineering Department of Mechanical Engineering	كليه الهندسة قسم الهندسة الميكانيكية

ME 213(Mechanical Engineering Drawing)

Final Project Batch IV NonReturnValve [Spring 2016-17]

	Name	Student ID	Signature
1	[redacted]		
2	[redacted]		
3			
4	[redacted]		

Part	Maximum Marks	Marks Awarded
1	10	6.25
2	15	13.5
3	5	4.25
4	10	9.5
Score	40	33.5

Part-1

CO	**CO 7** **Apply** standards in Mechanical Engineering Drawings drafted on AutoCAD
PI	**[abet_PI_11_13]** Psychomotor: Complex overt response Produce standard engineering drawings in AutoCAD complete with suitable templates, dimensions and text labels.
SO	[abet_SO_11] an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Part-2

CO	**CO 3** **Utilize** 3D modeling features in AutoCAD in detail to **Model** Components in Mechanical Engineering
PI	**[abet_PI_11_28]** Psychomotor: Adaptation Identify and utilize 3D modeling and editing tools in AUTOCAD to generate complex geometrical features
SO	[abet_SO_11] an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Part-3

CO	**CO 4** **Draw** sectional drawings in 2D environment and **Extract** sections from 3D models in AutoCAD
PI	**[abet_PI_11_14]** Psychomotor: Complex overt response Draw the sectional views of the three dimensional model in AUTOCAD
SO	[abet_SO_11] an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Part-4

CO	**CO 6** **Draw** and **Explain** Assembly Drawings of Mechanical Engineering Systems based on detailed drawings of mechanical elements
PI	**[abet_PI_1_22]** Psychomotor: Complex overt response Model ME systems/sub-systems by producing assembly drawings with exploded views for various mechanical engineering components using AUTOCAD
SO	[abet_SO_1] an ability to apply knowledge of mathematics, science, and engineering.

Figure 7.8: Faculty of Engineering, sample of assessment design implementing scientific constructive alignment

OA Doesn't Provide Guiding Frameworks for Developing Outcomes That Reflect Appropriate Developmental Levels of Holistic Curriculum Delivery

The International Engineering Alliance (IEA) confirms the necessity of measurement of graduate attributes and professional competencies for qualifying graduates and practicing engineers, which is expressed clearly in statements extracted from publicly available documentation on their website:

> "Graduate attributes form a set of individually assessable outcomes that are the components indicative of the graduate's potential to acquire competence to practise at the appropriate level. The graduate attributes are exemplars of the attributes expected of graduate from an accredited programme. Graduate attributes are clear, succinct statements of the expected capability, qualified if necessary by a range indication appropriate to the type of programme. The graduate attributes are intended to assist Signatories and Provisional Members to develop outcomes-based accreditation criteria for use by their respective jurisdictions. Also, the graduate attributes guide bodies developing their accreditation systems with a view to seeking signatory status. A professionally or occupationally competent person has the attributes necessary to perform the activities within the profession or occupation to the standards expected in independent employment or practice. The professional competency profiles for each professional category record the elements of competency necessary for competent performance that the professional is expected to be able to demonstrate in a holistic way at the stage of attaining registration."

Tables 1 and 2 in Appendix B show knowledge and problem-solving profiles listed by the IEA for practicing engineer, engineering technologist, and technician detailing types of engineering knowledge and a range of problem-solving activities. The profiles use generic language, but nonetheless indicate a very complex process for assessment of these attributes in qualifying graduates.

The Washington Accord engineering knowledge profiles contain several graduate attributes as summarized below:

1. WK1: Knowledge of natural sciences
2. WK2: Knowledge of conceptual mathematics, statistics, computer and information sciences necessary for analysis and modeling
3. WK3: Knowledge of systematic theory-based formulation of engineering fundamentals
4. WK4: Knowledge of theoretical frameworks and bodies of knowledge for engineering practice
5. WK5: Knowledge that supports engineering design

6. WK6: Knowledge of professional responsibility in terms of safety and engineering ethics
7. WK7: Knowledge of impact of engineering activity to environmental, societal, safety sustainability, and economic aspects
8. WK8: Knowledge of engagement with select research literature

The range of problem-solving profiles (P1−P7) for the practicing engineer, engineering technologist, and technician also lists multiple graduate attributes based on competencies required for various types of problems such as depth of knowledge required, range of conflicting requirements, depth of analysis, familiarity of issues, extent of applicable codes, extent of stakeholder involvement, interdependence, consequences, and judgment. Problem-solving and design for various engineering specializations or even course content is very specific process and can vary drastically and be heavily dependent upon content-specific, factual, conceptual, and procedural knowledge. McCade has also echoed a great amount of detail on the subject of problem-solving being a very comprehensive engineering activity, which comprises of several sub-activities not limited to design, experimentation, analysis, evaluation, etc.

The IEA requirements for engineering knowledge and practice profiles as referred to above are categorized based on various levels and types of complexity and are very detailed but there is no mandate prescribed or framework provided to the signatories of these accords for the development and classification of outcomes according to appropriate domains of learning and their learning levels for a given specialization to implement an essential OBE concept called *Bloom's Taxonomic Learning, TL*.

Program, course-level student outcomes and their PIs are not developed and classified according to appropriate learning levels for a given specialization and therefore do not implement the principle of sequential learning as postulated by *TL*. Unfortunately, the lack of mandate or frameworks coupled with the rampant tendency of programs and institutions to barely fulfill minimal accreditation criteria have created throughout the world OBE systems which are totally devoid of the *TL* concept.

As suggested in an earlier section of this chapter, FCAR methodology with supporting digital technology and a database of outcomes and classified specific PIs is a viable solution to practically implement TL in the curriculum delivery process. Specific PIs can be developed for various courses, classified as per appropriate domains and their learning levels and implemented in a typical higher education curriculum delivery process using world class best assessment practices and streamlining digital automation technology to establish sequential Taxonomic Learning and eventually achieve the much required graduate attributes related to knowledge and problem-solving profiles similar to those listed by the IEA.

OA Doesn't Apply OBE's Design Down Principle to Curriculum Organization and Instructional Delivery

In Chapter 2, we emphasized that culminating outcomes define what an education system wants all students to be able to do when their official learning experiences are completed. In fully developed OBE systems, the term 'culminating' is synonymous with 'exit outcomes.' But in less developed systems, culminating might apply to program outcomes and course outcomes. Enabling outcomes are the key building blocks on which those culminating outcomes depend. They are truly essential to students' ultimate performance success. Discrete outcomes, however, are curriculum details that are 'nice to know' but are not essential to a student's culminating outcomes.

Therefore, in the OBE systems, which we refer to in this chapter, SOs are the culminating outcomes and COs are the enabling outcomes or the fulcrum of the curriculum delivery process that drive specialized engineering learning activity.

Many accredited engineering programs' websites display their course syllabi and content on the Internet. Random examination of several syllabi and COs from world famous ABET accredited engineering programs revealed a serious issue with the language used for writing outcomes. An example from a world-famous EE program's online course information for Electrical and Electronic Circuits, EE100 shows several COs using *'understand,'* such as *'Understand operation of diodes and role as rectifiers'* and *'Understand the electrical properties of inductors and capacitors and the concept of mutual inductance,'* etc. Strangely, the following statements are also listed as COs: *'Several homework assignments delving on core concepts and reinforcing analytical skills learned in class'* and *'Opportunities to interact weekly with the instructor and the teaching assistant(s) during regular office hours and discussion sections in order to further the students' learning experience and the students' interest in the material.'*

Verbs which are not demonstrational or operational, such as 'familiarize,' 'understand,' 'gain knowledge,' 'demonstrate,' etc., coupled with nouns such as "awareness," "ability," or "capacity," are commonly found in the language used for writing outcomes. This incorrect language stems from the fact that most programs utilize generic PIs and their rubrics to fulfill minimum requirements of accreditation, without proper implementation of scientific constructive alignment, resulting in lack of precision and validity of assessments. The outcomes data collected is vague without utility for effective CQI and student improvement.

Recently, since almost a decade, the higher education community has just begun to realize the critical necessity of utilizing specific PIs in teaching, learning, and assessment. Today, many popular engineering and science textbook publishing companies, such as Wiley, have new online research features, WileyPLUS, for tracking teaching and learning activity. For example, a world-famous mother book on physics, which most engineers today grew up reading, *Fundamentals of Physics*, the *Extended 10th Edition*, by David Halliday, Robert Resnick, and Jearl Walker now includes chapters that are restructured into modules based on a primary concept. Each module begins with a big list of learning outcomes. For instance, a single chapter on Coulomb's law starts with 21 learning outcomes, written with such specific language, that would qualify them as specific PIs. These special modules are available for both online and text versions.

The Faculty of Engineering, Islamic University has implemented a format as shown in Figure 7.9 for writing COs which is primarily based on the use of specific PIs, our much-referenced past work, some standards mentioned by Adelman, and many years of experience in writing measurable outcomes for CQI. Formats containing several rules were formulated for the development of the COs and their corresponding specific PIs to implement scientific constructive alignment and achieve precision measurement with the necessary reliability and validity of assessments.

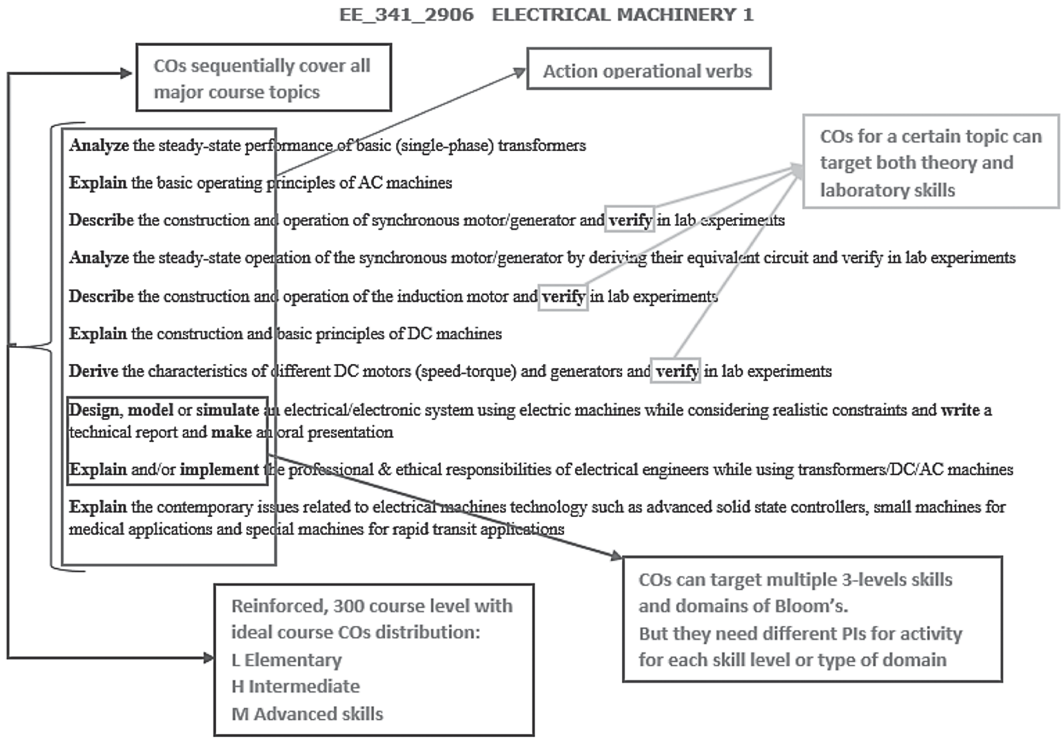


Figure 7.9: Faculty of Engineering format for writing measurable COs covering Bloom's three domains and 3-level skills

The main points of the format in writing measurable COs:

1. Use active, operational verbs to demonstrate the target learning activity that has to be assessed.
2. The COs can target multiple activities covering 3 domains of Bloom's and the 3-level skills: elementary, intermediate, and advanced skills. But each activity would have to be assessed by corresponding PI. Figure 7.9 shows a reinforced level course − COs with *Ideal Learning Distribution* (Figure 8.4, Chapter 8): low elementary, high intermediate, and medium proportions of advanced skills.
3. The COs should sequentially cover all major course topics.

4. The COs for a specific topic should measure both theory and experimental laboratory skills to ensure comprehensive learning related to the topic.
5. Write moderately generic COs with context of several specific PIs that will measure various learning activities mentioned in the COs. As shown in Figure 7.9, COs target both theoretical cognitive and psychomotor skills in lab. So, different specific PIs are required to independently assess the cognitive and psychomotor skills.

The main points of the format in writing measurable specific PIs:

1. The PIs should be approximately aligned to action verb and subject content in COs.
2. The PIs should be at a similar skills level as the corresponding activity in the CO.
3. The PIs should align with the complexity and methods used in assessments planned to measure corresponding learning activities mentioned in the CO.
4. The PIs should be more specific than COs and indicate names of techniques, standards, theorems, technology, methodology, etc.
5. The PIs should provide major steps to analyzing, solving, evaluating, classifying, etc. so that they can be utilized to develop hybrid rubrics.
6. Several PIs should be used to assess multiple learning activities related to multiple domains and 3-level skills.

Appendix C shows an example of a typical exercise the Office of Quality and Accreditation would perform with faculty assigned to teach a new course. Generally, this intensive exercise would take 3 to 6 hours per course to develop measurable COs and their specific PIs that are aligned with teaching, learning strategies, assessments, feedback, and CQI activities. The time for this exercise would depend on the type of teaching, learning strategies, and assessments used in the course. A course that offers lecture and laboratory sessions and involves a project or term paper would require maximum time to complete.

We can see in this section, the authentic OBE power principle, design down, applied perfectly to completely align the course or curriculum delivery process to the ABET SOs, COs, and their specific PIs. The widely accepted golden rules of design down process as proposed by us, first, require faculty to start at the end of a set of significant learning experiences or the culminating outcomes, and determine which critical learning components and building blocks of learning (enabling outcomes) need to be established so that students can successfully arrive there. The term ‘mapping back’ is often used to describe the first golden rule. The second rule states that faculty must be willing to replace or eliminate parts of their existing programs that are not true enabling outcomes.

In the given example in Appendix C, we show for the course, EE 421, Wireless and Mobile Communication, the original COs and PIs developed by the faculty member with issues related to language of COs highlighted in yellow.

At this point, faculty members are reinforced with the goal of achieving holistic education processes by employing teaching-learning strategies that involve coverage of all the 3 Bloom's domains using outcomes and PIs that correspond to an ideal learning distribution of 3-level skills to implement Taxonomic Learning with valid aligned assessments to accurately measure this learning. Any teaching which would not be followed by assessment would be considered incomplete and peripheral. A list of inputs is then prepared with details of ABET SOs to be covered, teaching and learning strategies involved, major topics to be covered, text and references, and any assessment samples.

The original COs would be reviewed sequentially, one by one, during intensive interactive discussions with the concerned faculty for corrections in language and specific content related to coverage of learning activities related to the major topics being covered. The language of COs would be more generic in description than the specific PIs. As mentioned earlier, the format for PIs development would be followed to give them the specificity required to facilitate clarity of expectations of student performance and necessary detail for assessment.

In the case of this course, depending on the learning activities related to a certain topic, the COs could cover multiple learning activities corresponding to various levels of the Bloom's cognitive domain: remember, comprehend, apply, analyze, evaluate, or create using various action operational verbs like explain, solve, analyze, etc. Major topics in each chapter would be reviewed for selection of appropriate learning activities. Selection of required techniques and methods from a generally vast list would be made based on priority. The level of complexity selected for planned assessment of problem-solving components related to topics would strongly consider current engineering requirements blended with the general standards of benchmarked student performances. Peripheral content would be removed. Several PIs would be developed targeting the select learning activities mentioned in a CO.

By applying the above-mentioned format in Appendix C, the original CO_1: *'Understand evolution of wireless communication systems and also **understand** and **compare** existing common mobile radio systems'* was modified to *"**Define** basic terms used for wireless communication systems, **elaborate** on their evolution, and **compare** existing common mobile communication systems."* The modified CO now consists of 3 major learning activities related to defining basic terms: cognitive understanding, SO 'a'; elaborating evolution of wireless communication systems: affective organizing values into priorities, SO 'h'; and comparing given existing mobile communication systems: cognitive evaluating, SO 'h,' where SO 'a' is *'Applying knowledge of engineering, math, and science'* and SO 'h' is *'Studying the impact of engineering solutions in global, societal, economic, and environmental context.'*

Three specific PIs were developed to precisely measure CO_1:

- PI_SO_1: Cognitive understanding – *'Define basic terms used to describe elements of wireless communication systems such as types of stations, types of radio transmission systems and devices, types of mobile communication, etc.'*; corresponds to SO 'a'

- PI_SO_8: Affective organizing values into priorities – *'Elaborate on the evolution of wireless communication systems, common paging systems, cordless, cellular, and personal communication standards used in North America, Europe, and Japan, technological changes, impact in a global, economic, environmental and societal context'*; corresponds to SO 'h'
- PI_SO_8: Cognitive evaluating – *'Compare the types of services and functionality, level of infrastructure, hardware cost, carrier frequency, and complexity required for the subscriber segment and base station segment of given mobile communication systems'*; corresponds to SO 'h'

These specific PIs related to the course topic *Introduction to Wireless Communication Systems* provide clarity of focus for faculty teaching and course delivery, expected student performances, and necessary detail for constructing valid assessments. Appendix C provides details of all the 10 COs with their specific PIs and an additional CO added to measure the report-writing skills for the term paper.

The benefit of using this format for the development of COs and their specific PIs was clearly evident in the course EE_452, Electrical Power Transmission and Distribution offered in term 371 at the Faculty of Engineering, IU, in which a staggering 40 assessments, 19 specific PIs corresponding to learning activities, and 8 ABET SOs were all comprehensively measured in one course. The 3-level skills were measured in multiple learning domains. Learning activities measured included applying knowledge, problem-solving, experimentation, design, teamwork (team contract, team roles), oral communication, report writing, lifelong learning (literature survey, assimilation of research, citing references), study of impact of engineering solutions, use of techniques, skills, and tools for engineering practices, etc. The implementation of the best assessment practices that support automation and streamlining technology made this rigorous course evaluation process a manageable faculty affair.

This exhaustive *design down* exercise, spanning four years, was an eye opener for the authors of this book. Almost 80% of course and curriculum delivery process was impacted at the Faculty of Engineering with faculty members re-evaluating course topics, restructuring course content, changing topics coverage timelines, re-designing assessments, and even considering change of textbooks. The true spirit and essence of OBE was realized with the implementation of specific PIs in the CO development process. Scientific constructive alignment, literally, drove all phases of the course delivery process.

We summarize this phenomenal experience by elaborating on the profound effects of *design down* on curriculum delivery mentioned in earlier chapters. As the body of knowledge grows rapidly and the demands of Information Age increase, prudent and insightful curriculum choices become ever more difficult. Basing those choices on a compelling framework of significant outcomes and what will directly help students attain them is preferable to having teachers and students cover more and more material at an increasingly superficial level, with no assurance of a culminating performance ability being the result. Our OBE work succinctly states that the *design down* principle gives education systems a rigorous way to make systematic and practical what has become increasingly difficult curriculum decisions. It compels them to examine what is truly essential for their students to accomplish in the limited amount of time a school year or a student's schooling career affords.

Chapter

8

Moving Beyond Outcomes Accreditation: Student-Centered Continuous Quality Improvement

Wajid Hussain

This chapter presents several limitations of outcomes assessment methodology and evaluation processes commonly employed in higher education institutions and their programs. We elaborate on some practical solutions using best assessment practices and state of the art streamlining technology to implement 'real' OBE and its realistic student-centered Continual Quality Improvement (CQI) processes. In the following sections of this chapter, deficient outcomes assessment methodology and consequent 'quality improvement' practices that are in stark contrast with the principles of OBE and students' CQI are highlighted. It is generally observed that certain samples of student performances, which are a small subset of the total enrolled population of students, are utilized for the evaluation of programs. In most cases, the outcomes data collected is composed of multiple types of skills and aggregated together for the program evaluations using pure averaging. The outcomes assessments are generally summative in nature, not providing real-time, specific, student performance information for on-time remedial action. The quality cycles are mostly deficient since they employ corrective actions much after the student cohorts exit the programs' education process. Finally, we conclude this chapter by elaborating on a very serious deficiency related to prevalent academic advising systems in higher education that claim to implement OBE but totally lack comprehensive outcomes information for every enrolled student. Academic advising is not based on outcomes performance data since this information is severely insufficient due to outcomes data collected for only a small sample of students and inaccurate being nonspecific resulting from measurement of broad outcomes and their generic performance indicators.

OA's Continuous Quality Improvement Criteria Are Institutional or Program-Centered, NOT Student Performance-Centered

In their effort to establish universal and practical accreditation procedures, quality assurance agencies across the globe have drifted toward an institutional- or program-centered version of the outcomes-based educational model. This approach is directed at evaluating the performance of the program or institution based on select data points versus actually assessing the performance or skills of each student. In fact, the performance of any institution or program cannot be sufficiently evaluated based on limited samples of student outcomes data collected at various phases of the education process either by random selection or from a culminating phase of student education. As a result of this approach, many accreditation agencies directly or indirectly propose selecting some courses at the mastery level with a small sample of students, and label this as scientifically justified approach called heuristics for assessment and program evaluation.

This program- or institution-centered model focuses ONLY on graduating students as declared in the typical introduction to outcomes statements of some world-famous accreditation agencies and clearly mention: *"At the time of graduation, students will be able to…."* This approach requires observing the needed skills only in graduating students, thus resulting in automatic dumping of failing students from the assessment data pool. Ironically, the failing students should have been the focus of outcomes data collection, evaluation, feedback, and remedial corrective action.

This model proposes establishing some key performance indicators which are focused on assessing and monitoring institutional or program-level performance and do not represent the actual student performances. Student performances are related to hundreds of learning activities in a typical undergraduate or graduate program curriculum. Intentionally, the key indicators are set to measure 'program or institutional' performances in current accreditation models. They are inaccurate, in total contrast with authentic OBE, and cannot possibly relate to the specific learning activities of students in various phases of their education therefore presenting a serious problem for formative approaches to learning and CQI.

We have already referenced NILOA's whistle blowing work in Chapter 7 on the widening gap between CQI and accreditation activity in the United States with the reason for outcomes assessment being primarily accreditation. Since the only outcomes assessment efforts, a majority of institutions or programs process, are the ones emphasized by accreditation agencies, program- or institution-centered models severely compromise the quality, level of rigor, and detail required for accurate measurement of outcomes for the success of ALL learners.

OA's Prevalent Assessment Methods Don't Allow for Accurate Outcome-Based CQI

Some quality assurance agencies like ABET present the alignment in the design down process flow chart by mapping Program Educational Objectives (PEOs) to Student Outcomes (SOs) and then to Performance Indicators (PIs). Figure 8.1 shows a very simplistic mapping of PEOs to SOs and then to PIs, the language used in this chart is presented by ABET in their training materials. We see affective domain activities, like teamwork, are shown with their generic PIs in most ABET assessment training examples. Generic PIs which can be applied across several courses can be placed right below SOs in this process flow chart. But, a critical thing to note is that all PIs, whether specific or generic, are measured using student course work.

In the Gloria Roger's (GR) assessment model, outcomes assessment data is measured for the mastery level courses by independent raters, in order to streamline the documentation and effort needed for an effective program evaluation. This approach presents a major deficiency for CQI in a student-centered OBE model because performance information collected at just the mastery level is at the final phase of a typical quality cycle, and is too late for implementation of remedial efforts. Instead, student outcomes and performance criteria, progressing from the elementary to advanced levels, should be measured at the course level, for all courses spanning the entire curriculum.

As mentioned earlier, the independent raters mechanism takes the outcomes evaluation process out of the hands of course faculty, who are in direct contact with students, and can apply remediation efforts, thus severely impeding CQI. This model, for practical purposes and related to implementation of manual processes, supports very selective sampling of students to gauge overall program performances.

It is generally observed that assessment training materials for most quality assurance and accreditation agencies instruct programs to not measure every student's performance in every course, but rather focus on selective sampling, to measure program effectiveness.

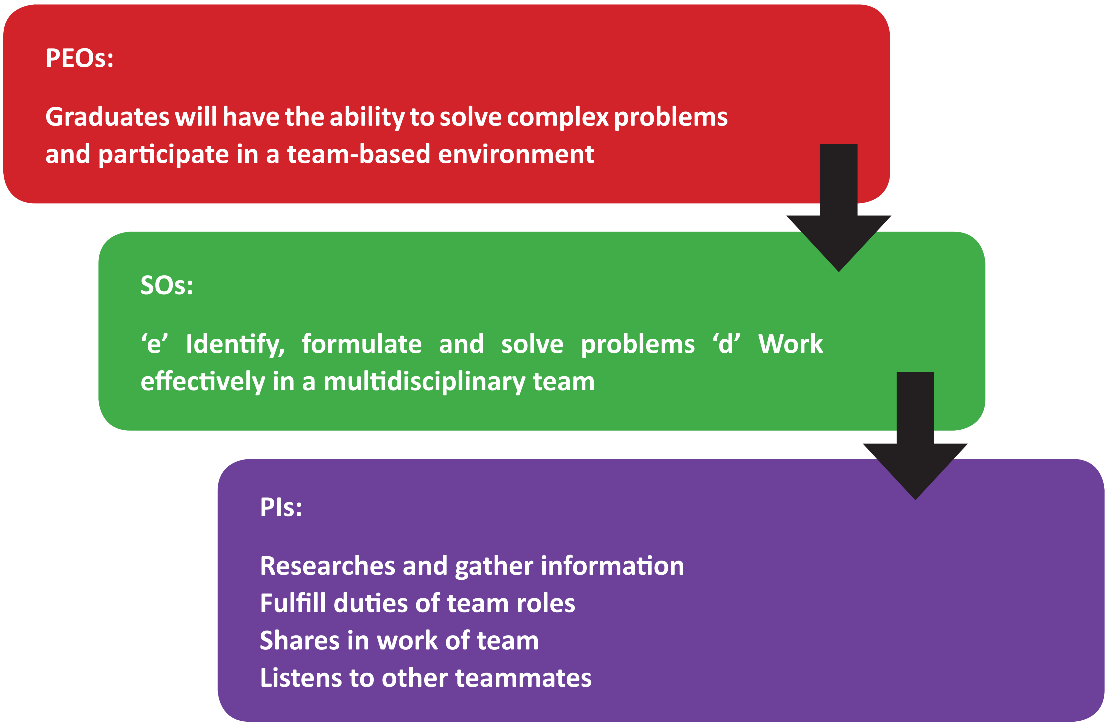


Figure 8.1: ABET Example Assessment Process Flow Chart PEOs > SOs > PIs

Insufficient Data and Extremely Lengthy Assessment Cycles Don't Result in CQI

It is established from popular research that due to accreditation being the prime driver for outcomes assessment, many programs in the United States and worldwide resort to fulfillment of the bare minimum accreditation requirements. This rampant culture of fulfillment of the bare minimum accreditation requirements embeds in programs the practice of measuring outcomes just for accreditation processes. This directive of quality assurance and accreditation agencies to programs not to collect outcomes information for every student in every course hammers the nail into the coffin of the OBE philosophy, which is centered around the premise that *"all students can learn and succeed."* If *"all students can learn and succeed"* in an 'OBE' education system and *'OBE' means clearly focusing and organizing everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences,* then we have a severe paradox created, with a very small set of students selected for outcomes assessment, feedback, and CQI.

Students' success is based on outcomes achievement measured by assessment, qualified by evaluation, and improved by feedback and CQI efforts. The big question, then, is: Can students achieve those culminating and enabling outcomes without even knowing how they performed, when in fact they were never even assessed? It is obvious, from popular assessment training materials, that assessment models such as GR propose a program-centered approach and not an authentic OBE student-centered holistic system.

The GR model's assessment process is also very selective for the program-level evaluation of ABET SOs. Figure 8.2 below shows a 3-year cycle for data collection process for 6 affective domain ABET SOs. With 3-year cycle rates of data collection and comprehensive evaluation of 6 affective domain ABET SOs as shown in Figure 8.2 below, we can estimate the assessment and evaluation of 11 EAC SOs can extend to six years at least, and for some programs, and new Computing Accreditation Commission (CAC) criteria, which have up to five additional SOs for assessing program criteria, the time frame for comprehensive evaluation can perhaps easily stretch to more than a decade.

Learning Outcomes (with PIs)	YR1	YR2	YR3	YR4	YR5	YR6
Recognize ethical and professional responsibility	•			•		
Communicate effectively in oral, written, graphical, and visual forms		•			•	
Work effectively in teams			•			•
Explain contemporary engineering issues	•			•		
Explain the impact of engineering solutions		•			•	
Exhibit lifelong learning			•			•

Figure 8.2: ABET assessment timeline sample showing 6 SOs with data collection cycle of 3 years, measures only two outcomes each year

We know that too much data collection is a disastrous process, but is the GR assessment model data collection process sufficient for evaluating specialized skills for state of the art engineering today, implementing effective CQI, and fulfilling the standards of authentic OBE? The status of CQI for specialized engineering education today is similar to medical diagnosis, where technology, precise methodology, and detailed testing are the only recourse to arrive at correct treatment methods to prevent misdiagnosis and fatalities.

Another critical thing to note is that any annual data collection event of assessing 2 SOs in the GR manual model usually involves measuring just a handful of data points or generic PIs information for a very small sample of students and covering a few mastery level courses. If we introduce specific PIs for assessment into the manual GR model, then the time required for program evaluation will expand exponentially. If all students in every course have to be assessed, as a mandatory and fundamental requirement for all students to succeed and learn in an authentic OBE system, then we can easily conclude that the manual GR assessment model, which proposes independent raters, will not be able to fulfill the basic requirements for CQI in OBE.

Delayed Corrective Actions Result in Severely Deficient CQI and Do Not Support Formative Assessments

Figure 8.3 below shows the methodology for program assessment and evaluation activity as observed in ABET training materials. Data is collected for ethics ABET SO 'f' in the year 1, but the evaluation, reporting, and actions for CQI take place much later in the year 2, after a full academic year. We observe the same, for contemporary issues ABET SO 'j', data is collected in the year 2, but the evaluation, reporting, and actions for CQI take place much later in the year 3, after a full academic year.

Activity	YR1						YR2						YR3					
	ETHICS	COMMUNICATION	TEAMWORK	CONTEMPORARY ISSUES	ENGINEERING SOLUTIONS	LIFELONG LEARNING	ETHICS	COMMUNICATION	TEAMWORK	CONTEMPORARY ISSUES	ENGINEERING SOLUTIONS	LIFELONG LEARNING	ETHICS	COMMUNICATION	TEAMWORK	CONTEMPORARY ISSUES	ENGINEERING SOLUTIONS	LIFELONG LEARNING
Review performance criteria			•			•	•			•				•			•	
Align teaching strategy to performance criteria		•			•				•			•	•			•		
Check alignment and identify areas for data collection		•			•				•			•	•			•		
Review, revise and develop assessment methods corresponding to outcomes		•			•				•			•	•			•		
Collection and analysis of outcomes data	•			•				•			•				•			•
Evaluate outcomes assessment data			•			•	•			•				•			•	
Report observations			•			•	•			•				•			•	
Corrective action			•			•	•			•				•			•	

Figure 8.3: ABET 6 SOs 3-year cycle of program assessment and evaluation activity

So, with the mentioned rates of evaluation process completion, 11 EAC SOs, would be comprehensively covered every six years, and the actions generated for CQI for any outcome would never target the small sample of students assessed in courses for real-time improvement, but actually target the program level activities, a full academic year later.

CQI and *corrective action* items form the core of the entire assessment and evaluation process. *Corrective action* ideally means implementing action items based on failing PIs, for real-time course improvements related to teaching and learning strategies, assessment methods, and PIs review. Ironically, as shown in Figure 8.3, teaching and learning strategy improvements only happen two years after data collection for a specific SO.

Real-time feedback from formative assessments actually becomes a superfluous process, not tied into the model, and a realm faculty does not want to deal with. This quality cycle thus renders the entire CQI process unfit for the development of required engineering skills in all students, using on-time remedial actions.

Where Are the Course Outcomes?

Gloria Rogers does mention that PIs should be measured in course work but their training materials do not indicate COs in the process flow charts. Another reason for the COs not appearing above PIs in the process flow chart is that the GR traditional rubrics assessment model is implemented with independent raters who typically assess student work after courses are completed, to measure the PIs and SOs data. This process flow model has thus mostly proposed to programs, the GR assessment model, generic PIs, and an independent raters system of scoring. For authentic OBE, students in the course are the focus of the faculty and so, faculty members teaching the course must be directly involved in the outcomes assessment process. They should apply constructive alignment based on outcomes, use formative and summative assessments, conduct evaluations, choose the best teaching and learning strategies for improved performances, and provide real-time feedback to students for effective CQI.

The Problem with Independent Raters

Independent raters definitely do not interact with students, cannot understand the intricacies of the teacher-student relationship, and do not support formative assessments for CQI. The argument, in favor of independent raters, is to have unbiased scoring of assessments. But, the important thing to note, as per our earlier discussions and referred research, was that generic rubrics have the least reliability, and therefore, keep the door open to biased scorings and human factors. On the other hand, specific PIs and hybrid rubrics present very high reliability and when coupled with objective evidence to verify proper application of these specific hybrid rubrics, it becomes almost impossible for biased scoring to happen. Finally, independent-rater scoring is an additional effort, beyond curricular scoring, and is a manual process that can never be automated. Dissecting curricular grades to extract outcomes information is a totally automatable process, and we can effectively leave scoring in faculty hands while not doubling the efforts or required resources for collecting outcomes data. Therefore, assessment models, supporting generic rubrics, and independent rating systems are in total conflict with authentic, student-centered, OBE methodology and do not facilitate implementation of the four authentic OBE power principles of *clarity of focus, expanded opportunity, high expectations, and design down*.

Holistic Curriculum Delivery and the Ideal Outcomes Assessment Model

The learning outcomes data measured by most higher education institutions are rarely classified into all three learning domains of the revised Bloom's taxonomy and their corresponding categories of the levels of learning. Generally, institutions classify courses of a program curriculum into three levels: introductory, reinforced, and mastery, with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for an effective program evaluation. This approach presents a major deficiency for CQI in a student-centered OBE model because performance information collected at just the mastery level is at the final phase of a typical quality cycle and is too late for implementation of remedial efforts.

Instead, student outcomes and performance criteria progressing from the elementary to advanced levels should be measured at the course level for all courses spanning the entire curriculum. A holistic approach for a CQI model would require a systematic measurement of PIs in all three of Bloom's domains of learning and their corresponding categories of learning levels for all course levels of a program's curriculum. Figure 8.4 shows the design flow for the creation of holistic learning outcomes and their performance indicators for all courses corresponding to introductory, reinforced, and mastery levels spanning the curriculum.

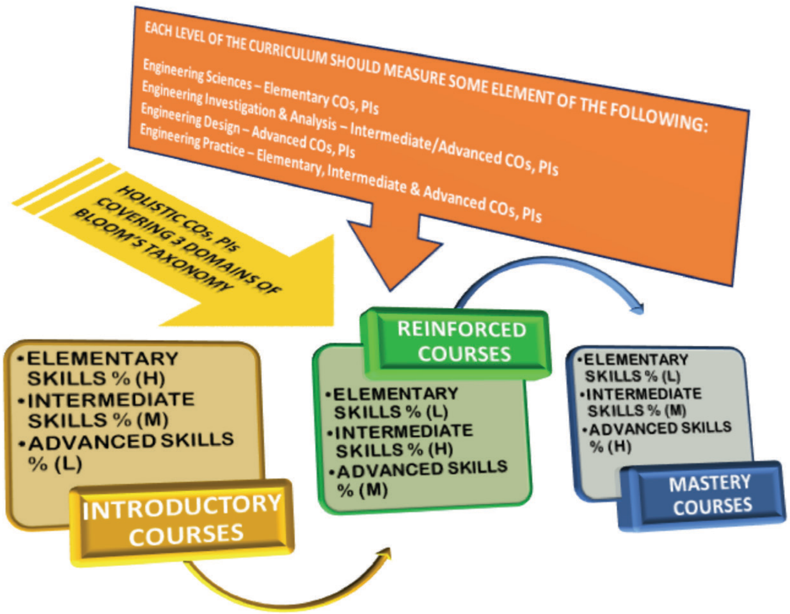


Figure 8.4. Design flow for the creation of advanced, intermediate, and elementary COs, PIs covering three domains of Bloom's taxonomy and spanning courses in different phases of the curriculum.

As stated in several research papers, PIs should be specific in order to collect precise learning outcomes information related to various course topics and phases of a curriculum, while addressing multiple levels of proficiency of a measured skill. Ideally, all courses should measure the elementary, intermediate, and advanced level skills with their COs, specific PIs, and associated assessments. However, introductory-level courses should measure a greater proportion of the elementary-level skills with their COs, PIs, and assessments. On the other hand, mastery-level courses should measure more of the advanced, but fewer intermediate and elementary-level skills. Figure 8.4 indicates this desired proportion of the elementary, intermediate, and advanced skills in the various course levels using abbreviations [H]: High, Medium: [M], and [L]: Low.

Any specialization among the vast number of disciplines in higher education has total liberty to appropriately select or propose suitable learning models consisting of different learning domains with multiple learning levels in each domain. As discussed in the section on learning domains categories in Chapter 7, Bloom's three domains are very generic and can be utilized by any specialization to achieve high level of accuracy in measurement of outcomes. However, the learning levels in each of the three learning domains can be specifically modified to suit any specialization. We have considered learning levels proposed by Anderson and Krathwohl (2001) for the *cognitive*; Krathwohl, Bloom, and Masia (1973) for the *affective*; and Simpson (1972) for the *psychomotor* domain. We studied past research which grouped Bloom's learning levels in each domain based on their relation to the various teaching and learning strategies. With some adjustments, a new *Three-Level Skills Grouping Methodology,* as shown in Figure 8.5, was developed for each learning domain with a focus on grouping activities which are closely associated to a similar degree of skills complexity.

Skills Level	Cognitive Domain (Bloom, 1856; Anderson & Krathwohl, 2001)	Affective Domain (Krathwohl, Bloom & Masia, 1973	Psychomotor Domain (Simpson, 1972)
Elementary	1. Knowledge 2. Comprehension	1. Receiving phenomena 2. Responding to phenomena	1. Perception 2. Set 3. Guided response
Intermediate	3. Application 4. Analysis	3. Valuing	4. Mechanism 5. Complex overt response
Advanced	5. Evaluation 6. Creation	4. Organizing values into problems 5. Internalizing	6. Adaptation 7. Origination

Figure 8.5: 3-Level Skills Grouping Methodology of Bloom's Revised Taxonomy

Figure 8.6 indicates an ideal *learning level distribution model* for introductory- and mastery-level courses represented by red- and blue-shaded areas, respectively. Sample of demonstrable action verbs are listed for the design and alignment of COs, PIs, and associated assessments in the elementary, intermediate, and advanced skills levels. The design of COs and their PIs should therefore be meticulously completed by using appropriate demonstrable action verbs and subject content, thus rendering the COs, their associated PIs, and assessments at a specific skill level—elementary, intermediate, or advanced.

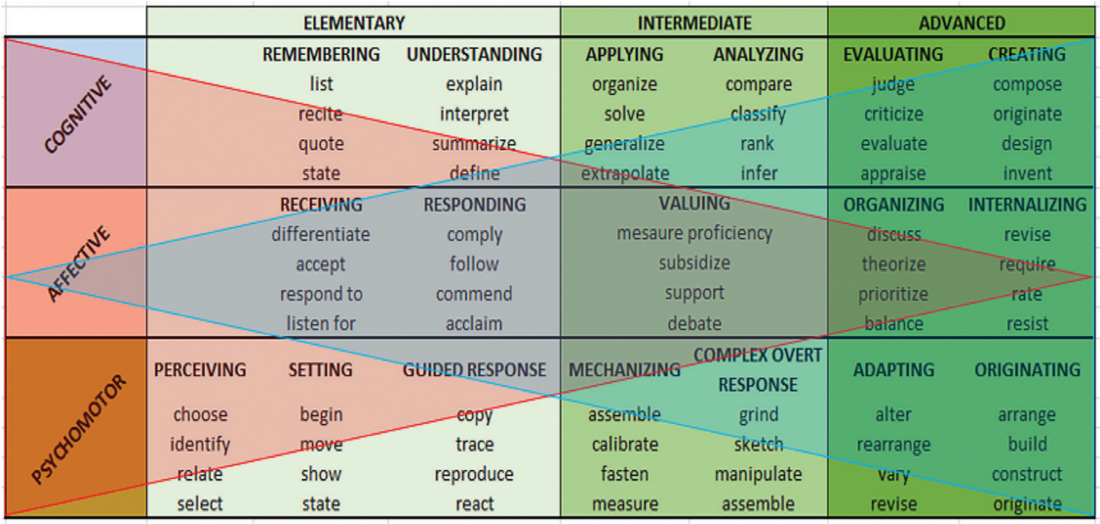


Figure 8.6. An ideal learning level distribution scenario for COs, PIs, and associated assessments for introductory-level (indicated by shaded red triangle looking L to R) to mastery-level (indicated by a shaded blue triangle looking R to L) courses.

Figure 8.7 shows an example from a civil engineering course, Faculty of Engineering, Islamic University in which the *Three-Level Skills Grouping Methodology* is implemented in the design of COs, their associated PIs, and tightly aligned with assessments to a specific skill level. In this example, CO_2: *Describe the composition of soil and solve volume-mass relationship equations for soils*; and its associated specific PI_5_34: *Determine the physical properties of soil using given parameters*; measured by assessment Mid Term Q9 are of similar complexity and at the same level of learning. The corresponding category of learning is *intermediate-cognitive-applying*. Therefore, COs would be measured by PIs and assessments strictly following the *Three-Level Skills Grouping Methodology*.

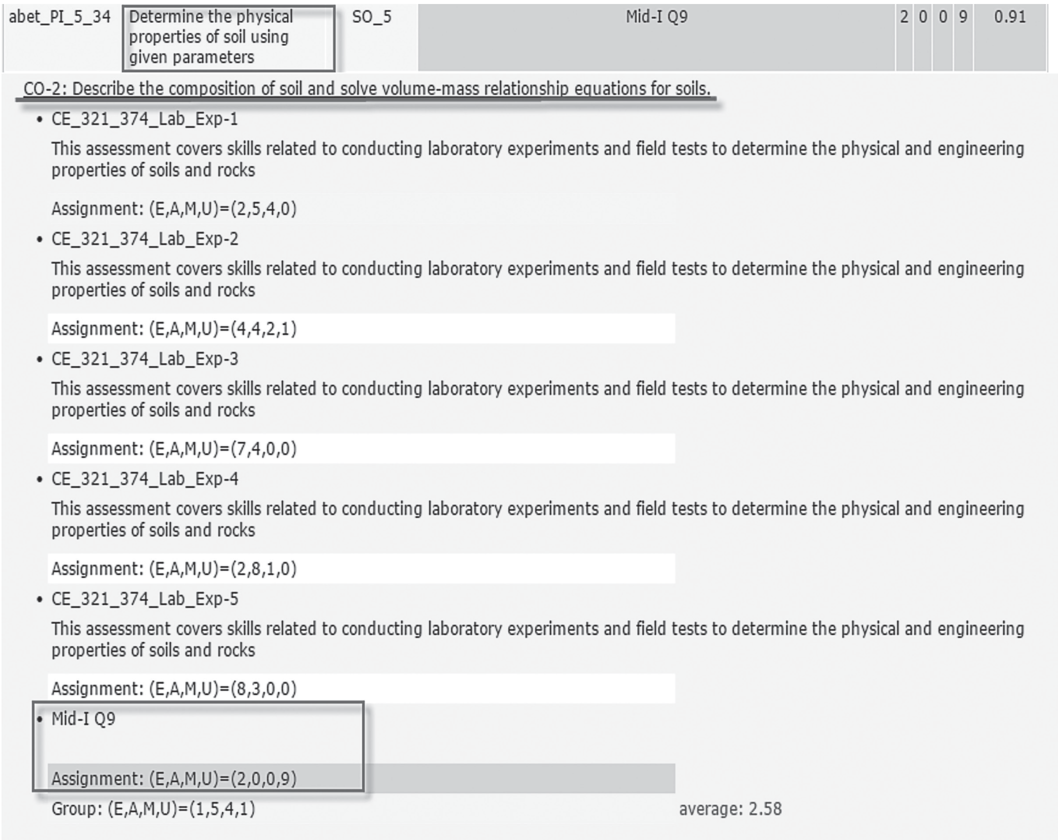


Figure 8.7. Example of a civil engineering course showing CO_2, PI_5_34, and assessment Mid Term Q9 assigned to *intermediate-cognitive-applying* skill level based on the *Three-Level Skills Grouping Methodology*.

The measurement of outcomes and PIs that are designed following such an ideal distribution will result in the development of a comprehensive database of learning outcome information, which will facilitate a thorough analysis of each phase of the learning process, and a comparatively easier mechanism for early detection of the root cause of student performance failures at any stage of a student's education.

FCAR, EAMU Performance Vector Methodology and Web-Based Software EvalTools® 6

A limited number of advanced technological solutions are available that facilitate best assessment practices to implement the principles of authentic OBE and CQI for all enrolled students. EvalTools® 6 is suggested as the platform for outcomes assessment instead of Blackboard® since it is the only tool that employs John Estell's Faculty Course Assessment Report (FCAR) and *EAMU performance vector methodology* with scales Excellent: 90–100%; Adequate: 75–90%; Minimal: 60–75%; and Unsatisfactory: < 60%. The FCAR uses the performance vector, conceptually based on a performance assessment scoring rubric developed by Miller and Olds, to categorize aggregate student performance. The performance vector methodology, when automated using appropriate digital technology, can support collection of assessment information for all enrolled students, even if numbering in the thousands. Figure 8.8 shows the performance criteria and heuristics for the performance vector called EAMU.

The web-based software EvalTools® 6 FCAR module provides summative/formative options and consists of the following components: course description, COs indirect assessment, grade distribution, course reflections, old action items, and new action items; COs direct assessment; PIs assessment; student outcomes assessment; assignment list; and learning domains and skills levels assessment distribution.

1. Specification of EAMU performance indicator levels:

This set of EAMU performance criteria apply to key assignments that were selected as objective evidences for meeting course outcomes. The setting here applies to all courses as a basic point of reference. However, individual instructors can alter the indicator levels appropriately applied to their own courses as desired.

Category	General Description	Letter Grade	Nominal Indicator Level
Excellent	Student applies knowledge with virtually no conceptual or procedural errors	E	90.0% - 100%
Adequate	Student applies knowledge with no significant conceptual errors and only minor procedural errors	A	75.0% - 90.0%
Minimal	Student applies knowledge with occasional conceptual errors and only minor procedural errors	M	60.0% - 75.0%
Unsatisfactory	Student makes significant conceptual and/or procedural errors when applying knowledge	U	0.0% - 60.0%

2. Heuristic rules for performance vector tables (PVT):

This set of rules applies to the performance vector tables that are formed by compiling all the key assignments' EAMU results together. The rationalization behind this classification is to streamline the assessment and evaluation processes by focusing on those areas that are out of the ordinary. Based on the color coded flags, the potentail problem areas will be flagged. This set of settign applies to all courses in the program.

Category	General Description	Scale (out of 5)	Maximum Percentage
Red Flag	Any performance vector with an average below the defined scale and a level of unsatisfactory performance that exceeds defined percentage in the U column	below 3.3	and >10%
Yellow Flag	Any performance vector with an average below the defined scale or a level of unsatisfactory performance (U) that exceeds the defined percentage, but not both	below 3.3	or >10%
Green Flag	Any performance vector with an average that is at least greater than the defined scale and no indication of unsatisfactory performance (U)	>= 4.6	
No Flag	Any performance vector that does not fall into one of the above categories		

Figure 8.8. Performance Criteria: EAMU PI Levels and Heuristic Rules for Performance Vector Tables (PVT)

Details of implementation of the FCAR methodology using supporting automation software and realized benefits related to course, student, program evaluations, feedback, and realistic CQI efforts are not within the scope of this book and, therefore, readers who are interested in specific details are referred to past extensive research work on this subject Wajid Hussain et al. (2016, 2017). We will, however, compare FCAR + automation technology to commonly existing evaluation methodology and their manual CQI processes to highlight some key advantages and features that support implementation of authentic OBE and successful learning for all students.

A comparative study of automation software as shown in Figure 8.9 highlights the overwhelming advantage of using the assignment setup module of the web-based software EvalTools® 6 which facilitates the dissection and extraction of parts of curricular scores from existing composite assessments for measurement of specific outcomes and therefore achieving a high level of automation of the data collection process.

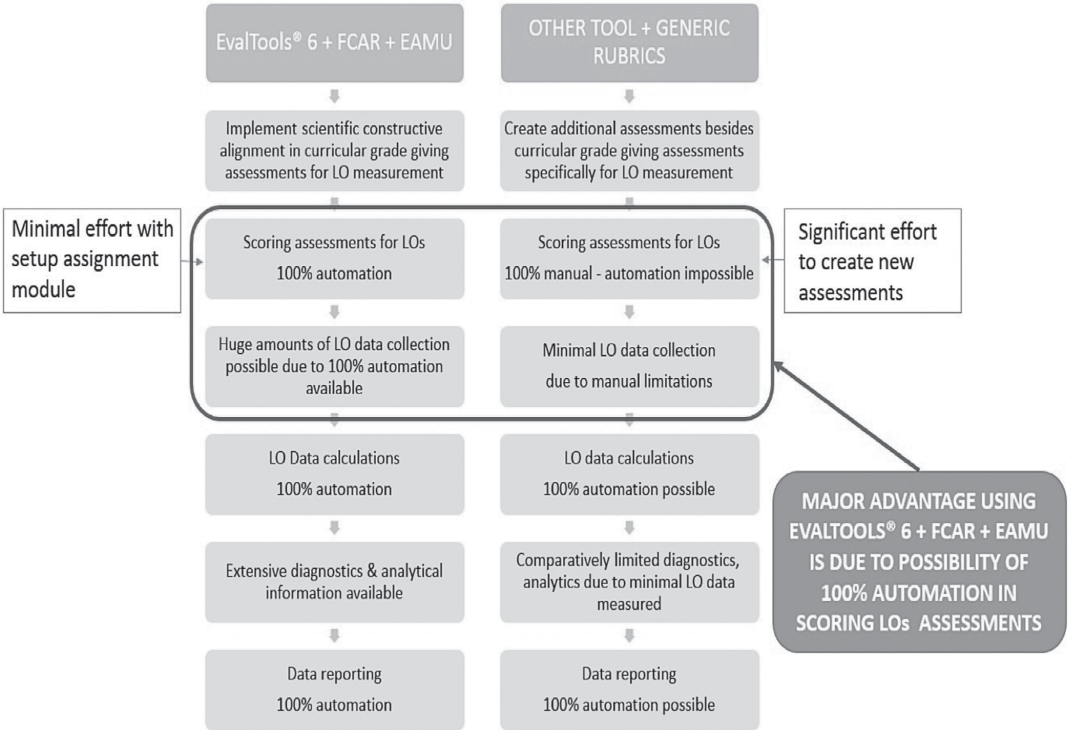


Figure 8.9. Comparative Study of the Advantages of Automation Achieved with EvalTools® 6 Versus Other Tools with Generic Rubrics Used for Learning Outcomes (LOs) Measurements

Figure 8.10 shows a process flow chart for a FCAR + specific PIs classified per Bloom's three domains and three-level skills assessment model. The important point to note in this model is that course faculty are involved in most CQI processes whether at the course or program level.

Course faculty are directly involved in the teaching and learning process and interact closely with all the enrolled students. An ideal CQI cycle would therefore include the course faculty in most levels of its overall process, to generate and execute action items that can directly target real-time improvement in student performances for ongoing courses. Models that involve program faculty or assessment teams that are not directly involved with the students enrolled in courses will definitely not support real-time CQI which is an essential element of an authentic OBE system.

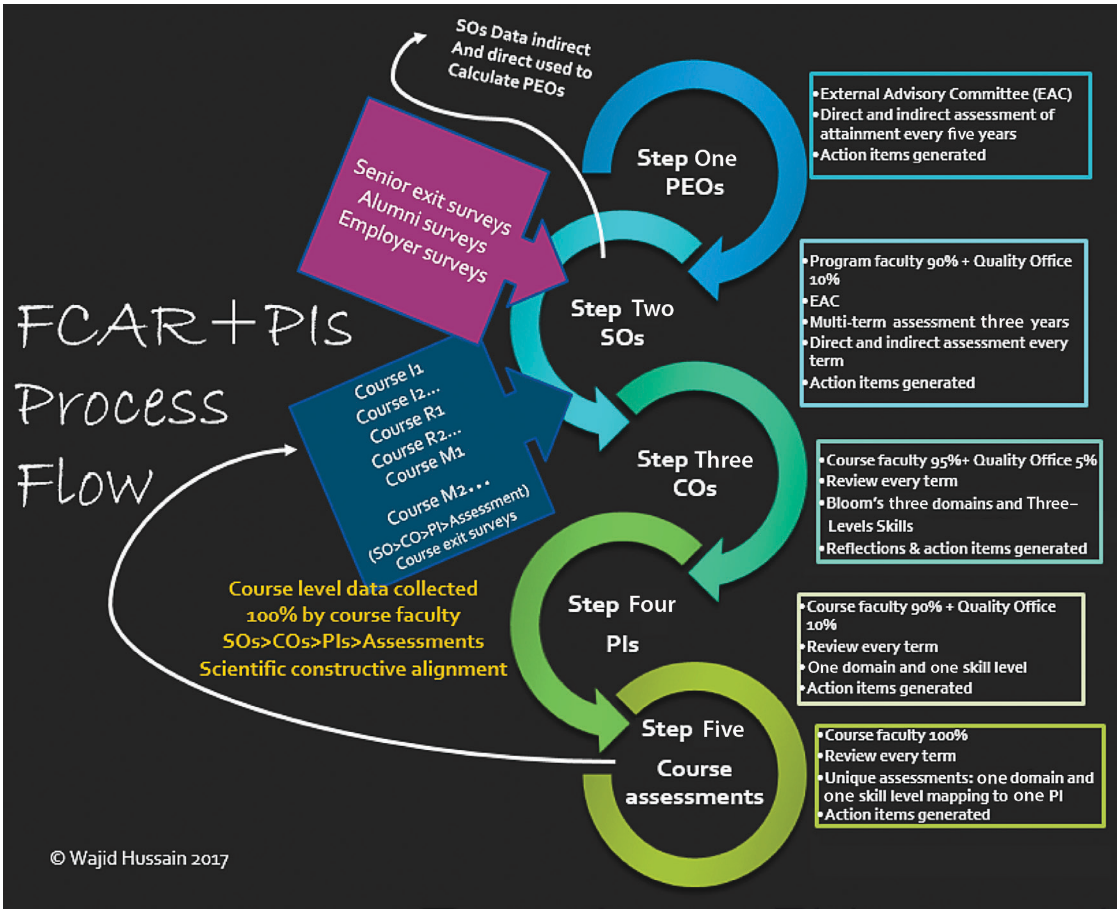


Figure 8.10. FCAR + Specific PIs Assessment Model Process Flow Indicating Course Faculty Involvement in Almost All Phases of CQI Cycle

Summary of Comparison of the GR and FCAR+ Specific PIs Assessment Models

In order to develop a comprehensive understanding, let us review some of the salient points of comparison of the GR model and FCAR + specific PIs methodology coupled with technology for automation. Attainment of PEOs is no longer a requirement of ABET and is therefore not included in the GR assessment model. The External Advisory Committee (EAC) just reviews the PEOs to verify their alignment with the mission of the program and institution. The FCAR + specific PIs model, on the other hand, fully automates the PEOs attainment evaluation process. It employs a scientific weighting formula for the calculation of PEOs values applied to aggregate various types of direct and indirect assessments ABET SOs data collected electronically over a multi-term period for any program. Direct assessments would cover course work on campus as well as practical work on the field. Indirect assessments would be the employer, alumni, senior exit, and course-exit surveys. These values provide a reliable performance indicators scheme for the EAC committee to thoroughly review attainment of the PEOs.

In a typical GR model, a complete evaluation cycle for 11 EAC SOs and 30 PIs would take a program six years with, let's say, 2 SOs and 5 PIs assessed per year. In the FCAR model, it is possible to assess all 11 SOs in a single term, and for a comprehensive multi-term review in three years, several hundred PIs would be measured for all SOs and 30–100 PIs can be assessed for a single SO.

Creation of additional SOs for assessment and evaluation of necessary student skills for specific specializations is a huge unavoidable effort for those using the GR model since it does not utilize specific PIs. Additional SOs are not required in the FCAR + specific PIs model, thereby earning significant savings on additional workload otherwise necessary for their assessment, collection, evaluation, reporting, feedback, and CQI activities.

The GR model does not involve review of COs, and outcomes data collection, analysis, evaluations, reporting, and generation of action items are all done manually. In the FCAR + specific PIs model, all assessment activities conducted by faculty are at the course level and during course delivery. So, the COs are computed by weighted average of the corresponding PIs and assessments. Data collection, analysis, evaluation, reporting, and generation of action items are all done electronically by using appropriate web-based software such as EvalTools 6®.

As explained earlier, root cause failure analysis is a much quicker process with the FCAR + specific PIs model than in the GR model. Also, the Continuous Improvement Management System (CIMS) module supports streamlined CQI activity by providing electronic integration of outcomes information with committee meetings, action item generation, prioritization, transfer, and follow-up to closure.

The GR model's manual process, with its many limitations, supports very selective sampling of students, courses, and assessments using generic PIs and rubrics for program-level evaluations. An individual student's SOs or PIs data for academic advising is practically impossible to measure using manual processes, especially for campuses where thousands of students are enrolled. The FCAR + specific PIs model with automation fully supports assessment of all students, in all courses, and multiple skills levels, using specific PIs classified per Bloom's three-domains. So, this system collects outcomes data for both program and student evaluations as discussed earlier and provides an academic advising module which integrates with the SOs, PIs, and assessment data for every single student.

OA Is Bogged Down in Cumbersome Manual Processes of Outcomes Data Collection, Analysis, Evaluation, and Feedback

One of the primary reasons outcomes information is not utilized for CQI is that the information collected is insufficient to make improvement decisions due to impractical manual processes that are either too exhaustive to complete for timely measurement and reporting, or too minimal for basic fulfillment of accreditation requirements. Massive amounts of outcomes data collected from various stages of curriculum delivery are a critical requirement for informed improvement decisions. Therefore, manual assessment, documentation, and reporting systems are major factors that exacerbate the implementation of streamlining activities which are necessary to integrate improvement efforts of several stakeholders in an academic CQI process.

Citing an impressionable quotation from a particular research as a strong argument in favor of automation of outcomes assessment, "While outcomes assessment offers great promises for improving student learning, existing processes for integrating learning outcomes, collecting resulting data, and analyzing student performance are limited. They are typically labor intensive, paper-based, and often exclusively driven by accreditation visits or other ad-hoc considerations. At the program level, however, the main problem is usually related to compiling the enormous amount of heterogeneous data collected from different course assessment exercises and using different assessment instruments (e.g., survey results, exit interviews, etc.). This federation of assessment data across program courses needs to be further converted to useful information that accurately reflects the achievement levels of student outcomes to facilitate curricular decisions. Failing to do so may affect the correctness of the assessment results and could lead to ineffective or even wrong remedial actions. Therefore, there is currently a clear need for automating the assessment workflows in higher education institutions. An assessment management system could effectively streamline the collection and analysis of assessment data."

The University of Alberta, Edmonton, Canada, a practical example which confirms the above, it is estimated that the preparation for the last CEAB accreditation review of their nine engineering programs had cost them over $1 M and required the collection of more than a ton of documents, and 16,000 man/hours of preparation time.

Faculty Compliance

Faculty compliance for outcomes assessment has been quoted by many as a major issue in achieving realistic CQI. Majority of the faculty members are not keen to get involved in the assessment process, mostly because they are not familiar with the assessment process and/or the methods used, so there exists a dire need to explore avenues by which faculty can be engaged actively in the assessment process at the course and program levels. Myriad complexities related to improper tools that do not integrate multiple processes for direct/indirect outcomes assessments at course and program levels for the identification of failures, remedial actions, and CQI are identified as the root cause for the lack of faculty involvement.

A paper free web-based digital system, with friendly user interface encouraging faculty participation while integrating multiple outcomes assessment processes, world class best practices for skills measurement, information processing, and communication for remedial efforts, and CQI is therefore highly desired. The recent global trends highlighting a shift toward OBE coupled with established arguments in favor of automation presented in research literature summarize the fact that automation of outcomes assessment using state-of-the-art digital technology is essential for CQI in education.

OA's Approach to Student Academic Advising Is Not Based on Outcomes Data

National Academic Advising Association (NACADA) guidelines for academic advising state that each institution must develop its own set of student learning outcomes and the methods to assess them. The first outcome listed is *"students will craft a coherent educational plan* *based on assessment of abilities, aspirations, interests, and values."* NACADA also states that student learning outcomes for academic advising are *"an articulation of the knowledge and skills expected of students as well as the values they should appreciate as a result of their involvement in the academic advising experience."* These learning outcomes answer the question "What do we want students to learn as a result of participating in academic advising?" Assessment of student learning should be a part of every advising program. ABET criterion 1 for accreditation specifically states "Student performance must be evaluated. Student progress must be monitored to foster success in attaining student outcomes, thereby enabling graduates to attain program educational objectives. Students must be advised regarding curriculum and career matters." So individual student skills data or results would be both fundamental requirement and pivotal base for the entire academic advising process to initiate and continue successfully. In fact, the ongoing and continual assessment of individual student skills would actually be the litmus test for a successful academic advising process.

However, a critical point to note is that we have not found any tangible data or research suggesting any existing student advising models or systems that are based on skills or SOs data collected for individual students. Quality assurance agencies mention the importance of improving performance in SOs using academic advising, but ironically do not list assessment of individual student skills as a requirement for accreditation. The reason for this is obviously the staggering amount of work and resource requirements that would be imposed on programs or institutions related to the manual assessment, collection, and reporting of outcomes data for every single student, especially when thousands are enrolled in a single program.

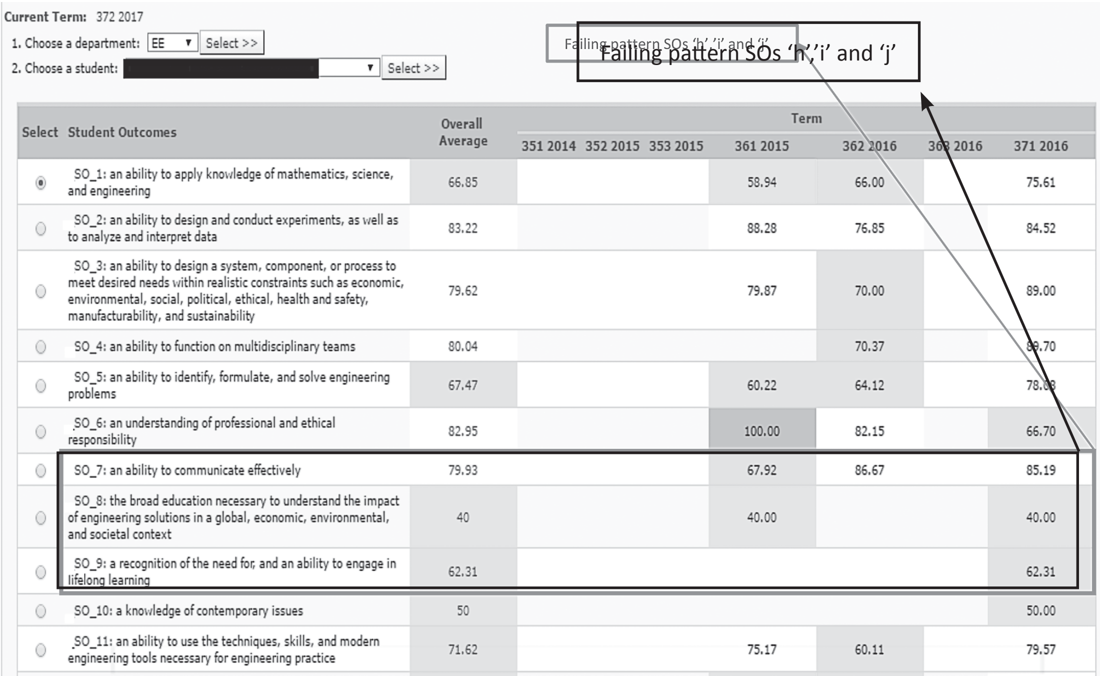
We have clearly stated that the keys to establishing an OBE system are:

1. developing a clear set of learning outcomes around which all of the system's components can be focused; and
2. establishing the conditions and opportunities within the system that enable and encourage all students to achieve those essential outcomes.

Cautiously, we can say that most academic advising today is not based on an accurate and realistic set of SOs data which provide qualitative and quantitative analysis of every student's skills but rather on summative transcript scores and abstract derivations of student-advisor communications.

The Faculty of Engineering at the Islamic University has implemented a student advising system employing the FCAR + specific PIs classified per Bloom's domains and three-level skills grouping methodology and using a web-based software EvalTools 6®. A YouTube video also presents some details of the features of this module and how individual student skills data is collected by using specific PIs, course assessments, and integrated by faculty into academic advising. At the Faculty of Engineering, both program and students' performance evaluations are based on considering their respective measured ABET SOs and associated PIs as a relevant indicator scheme.

Figure 8.11 illustrates a list of ABET SOs calculated from PIs measurements for a typical student evaluation. The student skills SOs data is realistic and corresponds closely with actual student performances since 15 essential elements of the assessment model have been implemented to ensure outcomes data is as accurate as possible.



Current Term: 372 2017

1. Choose a department: EE Select >>

2. Choose a student: [redacted] Select >>

Failing pattern SOs 'h','i' and 'j'

Select	Student Outcomes	Overall Average	Term 351 2014	352 2015	353 2015	361 2015	362 2016	363 2016	371 2016
◉	SO_1: an ability to apply knowledge of mathematics, science, and engineering	66.85				58.94	66.00		75.61
○	SO_2: an ability to design and conduct experiments, as well as to analyze and interpret data	83.22				88.28	76.85		84.52
○	SO_3: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	79.62				79.87	70.00		89.00
○	SO_4: an ability to function on multidisciplinary teams	80.04					70.37		89.70
○	SO_5: an ability to identify, formulate, and solve engineering problems	67.47				60.22	64.12		78.08
○	SO_6: an understanding of professional and ethical responsibility	82.95				100.00	82.15		66.70
○	SO_7: an ability to communicate effectively	79.93				67.92	86.67		85.19
○	SO_8: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	40				40.00			40.00
○	SO_9: a recognition of the need for, and an ability to engage in lifelong learning	62.31							62.31
○	SO_10: a knowledge of contemporary issues	50							50.00
○	SO_11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	71.62				75.17	60.11		79.57

Figure 8.11: EE program above average student showing pattern of weakness in skills related to SOs 'h,' 'i,' and 'j' lifelong learning, study of impact of engineering solutions and contemporary issues

Figure 8.12 indicates some aspects of the assessment model which directly contribute to the high level of accuracy required for the aggregation of SOs and PIs data to be used for academic advising. The outcomes information is computed by the application of weighting factors based on the *three-level skills methodology* for the scientific aggregation of multiple skills measured using various types of assessments and multiple raters in several courses over a period of multiple terms.

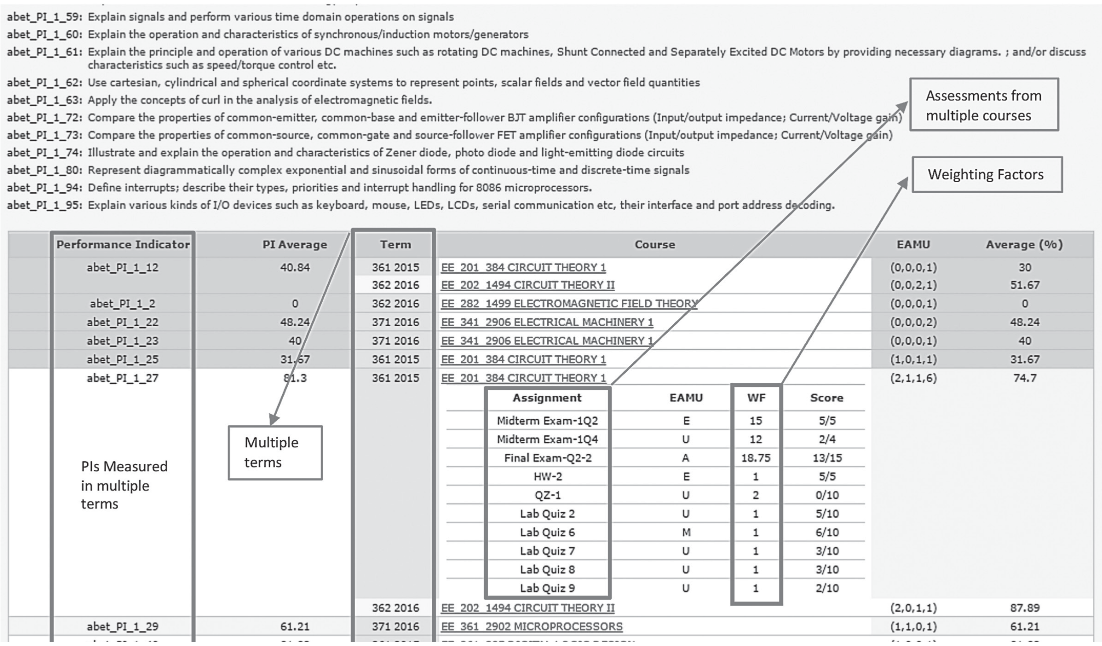


Figure 8.12: SO_1, ‘a’, individual student’s skills data measured by multiple raters using several PIs in multiple courses, types of assessments, terms, and applying weighting factors WF

Academically, well-performing students as defined based on transcript grades may have failing or underperforming skills. Figure 8.11 shows an Electrical Engineering program, well-performing, above-average student showing pattern of failures related to ABET SOs ‘h,’ ‘i,’ and ‘j’, corresponding to the study of impact of engineering solutions, lifelong learning, and contemporary issues, respectively.

A very important point to note is that this information is not available from the transcript grades. This pattern refers to failure in research activity, especially related to comprehension based on self-motivated study of issues related to engineering solutions and the capability to compare and elaborate the difference in benefits and limitations of various existing engineering systems. Therefore, advising systems need access to the individual student skills data to identify areas of weakness in otherwise “successful” students to better prepare them for the challenges of leading career roles.

By a detailed examination of academically weak students’ performances, it is also possible to identify areas of strength in learning which are based on the students’ natural affinity to and interest in certain topics. In Figure 8.13, highlighted in green color are certain areas of comparatively better patterns of learning in a typical underperforming EE student. We observe that PI_1_12: *“Employ basic electrical power formulations and quantities, such as complex vectors, delta star transformation, network flow matrices (network topology and incidence matrices), and symmetrical components”; PI_1_41: “Convert a given number from one system to an equivalent number in another system”; and PI_1_45: “Explain basic semiconductors theory concepts such as applied electrical field, junction capacitance, drift/diffusion currents, semiconductor conductivity, doping, electron, hole concentrations, N-type,* *P-type semiconductors”*; show better performance and are at a stark contrast versus majority of the other PIs measured for these two terms.

<table>
<tr><th>Performance Indicator</th><th>PI Average</th><th>Term</th><th>Course</th><th>EAMU</th><th>Average (%)</th></tr>
<tr><td>abet_PI_1_11</td><td>61.44</td><td>352 2015</td><td>EE 212 745 ELECTRONICS 1</td><td>(2,2,1,4)</td><td>61.44</td></tr>
<tr><td>abet_PI_1_12</td><td>100</td><td>352 2015</td><td>EE 202 744 CIRCUIT THEORY II</td><td>(2,0,0,0)</td><td>100</td></tr>
<tr><td>abet_PI_1_26</td><td>38.17</td><td>352 2015</td><td>EE 212 745 ELECTRONICS 1</td><td>(0,0,1,3)</td><td>38.17</td></tr>
<tr><td rowspan="2">abet_PI_1_27</td><td rowspan="2">50.75</td><td>352 2015</td><td>EE 202 744 CIRCUIT THEORY II</td><td>(2,0,0,1)</td><td>51.49</td></tr>
<tr><td>351 2014</td><td>EE 201 1581 CIRCUIT THEORY I<table>
<tr><th>Assignment</th><th>EAMU</th><th>WF</th><th>Score</th></tr>
<tr><td>HW-2</td><td>A</td><td>2</td><td>85/100</td></tr>
<tr><td>QZ-2</td><td>E</td><td>1.25</td><td>100/100</td></tr>
<tr><td>Mid Term-II PART III Q40</td><td>U</td><td>0.9</td><td>0/6</td></tr>
<tr><td>MID_TERM_1 Part V Q42</td><td>U</td><td>0.75</td><td>0/5</td></tr>
<tr><td>Final Exam Part IV Q45</td><td>U</td><td>1</td><td>0/3</td></tr>
</table></td><td>(1,1,0,3)</td><td>50</td></tr>
<tr><td>abet_PI_1_40</td><td>15</td><td>351 2014</td><td>EE 261 1584 DIGITAL LOGIC DESIGN</td><td>(0,1,0,1)</td><td>15</td></tr>
<tr><td>abet_PI_1_41</td><td>90</td><td>351 2014</td><td>EE 261 1584 DIGITAL LOGIC DESIGN</td><td>(1,0,0,0)</td><td>90</td></tr>
<tr><td>abet_PI_1_42</td><td>40</td><td>351 2014</td><td>EE 261 1584 DIGITAL LOGIC DESIGN</td><td>(0,0,0,1)</td><td>40</td></tr>
<tr><td>abet_PI_1_43</td><td>87.69</td><td>351 2014</td><td>EE 201 1581 CIRCUIT THEORY I</td><td>(1,1,0,0)</td><td>87.69</td></tr>
<tr><td>abet_PI_1_44</td><td>88.86</td><td>351 2014</td><td>EE 201 1581 CIRCUIT THEORY I</td><td>(4,2,1,0)</td><td>88.86</td></tr>
<tr><td>abet_PI_1_45</td><td>90.69</td><td>352 2015</td><td>EE 212 745 ELECTRONICS 1</td><td>(2,0,1,0)</td><td>90.69</td></tr>
<tr><td>abet_PI_1_46</td><td>8.79</td><td>352 2015</td><td>EE 282 743 ELECTROMAGNETIC FIELD THEORY</td><td>(1,0,0,2)</td><td>8.79</td></tr>
<tr><td>abet_PI_1_47</td><td>13.33</td><td>352 2015</td><td>EE 282 743 ELECTROMAGNETIC FIELD THEORY</td><td>(0,0,0,2)</td><td>13.33</td></tr>
<tr><td>abet_PI_1_48</td><td>0</td><td>352 2015</td><td>EE 282 743 ELECTROMAGNETIC FIELD THEORY</td><td>(0,0,0,1)</td><td>0</td></tr>
<tr><td>abet_PI_1_49</td><td>0</td><td>352 2015</td><td>EE 282 743 ELECTROMAGNETIC FIELD THEORY</td><td>(0,0,0,1)</td><td>0</td></tr>
</table>

Figure 8.13 Patterns of comparatively better learning in specific-related skills observed from a two-term student evaluation report for a typical underperforming EE student

One significant observation is that these three PIs measure elementary math skills and concepts and also cover relatively easier topics such as Boolean algebra. The other PIs dealing with topics such as operating principles of various kinds of electronic devices and components, Application of Gauss’s Law, Maxwell’s equations, etc. require slightly advanced learning of several engineering concepts and understanding of differential, integral calculus.

This information strongly suggests that students have initiated learning with the required level of interest but at later stages of the course, they may need other mechanisms of course delivery such as active learning for retention of focus and enhanced interest. Student advising based on this information helps faculty to identify potential areas of strength or weakness in student performance through the observation of patterns of relatively high or low scores for certain ABET SOs and their corresponding PIs.

Most academic or career-related failures result from an improper selection of the field of study or industrial career due to delay or lack of availability of the necessary decision-making student learning outcome information in a deficient education system. With the availability of such analytical tools and comprehensive diagnostics, early identification of weakness and prompt remediation efforts are quite possible. On the other hand, early recognition of strong skills in specific subjects based on well-observed patterns followed by professional academic guidance leading to proper selection of an area of specialization in education, research for enhanced learning, or in future industry-related prospects will produce outstanding performers in their respective fields who will shape the future of the world.

OA Evaluates Outcomes Performance with 'Pure' Averaging

Almost all quality assurance and accreditation agencies propose numeric score-based assessment models for program level outcomes evaluation. Generally, evaluation of a program-level culminating outcome is performed by comparing target values to a quantitative numeric score which is a summative representation of an outcome and is computed by pure averaging the results of multiple individual assessments corresponding to a wide range of student learning activities. We mention this *"Number Game"* in Chapter 2 and also state that *"You can average scores but you cannot average outcomes."* There are three essential requirements which pure averaging cannot fulfill while aggregating different types of outcomes together, thus rendering the final result invalid:

1. The outcomes measured for a specific set of learning activities should be defined as preliminary or final student performances clearly indicating the level of maturity of learning.
2. The outcomes measured in the mastery level courses should take precedence over the introductory and reinforced level courses of a curriculum.
3. All measured outcomes should be accurately classified based on the type of learning domain and level of complexity of skills. Appropriate weights that give precedence to higher-order skills over lower-order skills should then be applied during aggregation.

Assessments conducted at the conclusive phase of a curriculum delivery process and post-sufficient feedback provided for improvements in performance should get precedence over preliminary measurements. This is vital for the implementation of the OBE power principle Expanded Opportunity. Outcomes measured in a mastery level course correspond to the most advanced skills in a curriculum and therefore should have a greater effect on the overall program level evaluation. Furthermore, outcomes are classified into various types of domains and learning levels. For instance, if a program implements the Bloom's learning model, then it considers three learning domains, namely, cognitive with six learning levels, affective with five, and psychomotor with seven. So, pure averaging skills of different complexity such as design skills with comprehension or even mixing domains for averaging to evaluate a specific culminating outcome is like putting apples, oranges, along with red chili peppers in the same fruit salad for accreditation.

In the coming passages, we propose to accreditation agencies and institutions some schemes for weighted averaging the scores of various types of skills and assessments to obtain realistic computations of program level evaluations of culminating outcomes. A digital database of specific PIs classified according to appropriate learning domains and their learning levels can definitely support application of scientifically calculated weights to ensure accuracy of weighted averaging computations. Specific PIs and their hybrid rubrics discussed earlier in this chapter will provide the necessary validity and reliability to assessment scoring.

Weighting Factors for Various Assessments and Skill Types

Realistic learning outcomes measurements are achieved by assigning weights to different assessments according to a combination of their course grading policy and type.

The first rationale in order of priority is the type of assessments so that higher weight is assigned to laboratory/design-related assessments compared to purely theoretical assessments, because laboratory/design work covers all three domains of Bloom's taxonomy. Similarly, final exams are higher weightage than quizzes since the final exam is more comprehensive and well-designed assessment. Students are generally more prepared for a final exam as many of their skills reach a higher level of maturity and proficiency by that time.

The second rationale in priority is to account for the percentage contribution of the given assessment which is derived from the course grading scale. Figure 8.14 shows the four-course formats developed by the Faculty of Engineering to calculate the weighting factors for the different types of assessments.

Figure 8.15 shows a realistic final group weighted average EAMU value computed for CO_5 by applying appropriate weights based on course grading scale and assessment type assigned to Quiz-5, 3% and Final Exam: Q2, 24%. The Final Exam: Q2 score has greater control of the final computed group weighted average value. The final group EAMU reflects the priority of the Final Exam Q2 over Quiz-5.

DIFFERENT COURSE ASSESSMENTS FORMATS:

1. **COURSES WITH NO LABS + NO PROJECT/TERM PAPER**

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	40%	8
MID TERM EXAM - 1	25%	5
MID TERM EXAM - 2	25%	5
QUIZ	5%	1
HW	5%	1
TOTAL	100%	-

2. **COURSES WITH NO LABS + PROJECT/TERM PAPER**

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	30%	6
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
PROJECT/TERM PAPER	30%	6
TOTAL	100%	-

3. **COURSES WITH LABS + NO PROJECT/TERM PAPER**

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	25%	5
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
LAB EXAMS	30%	6
LAB REPORTS	5%	1
TOTAL	100%	-

4. **COURSES WITH LABS + PROJECT/TERM PAPER**

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	25%	5
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
LAB EXAMS	15%	3
LAB REPORTS	5%	1
PROJECT/TERM PAPER	15%	3
TOTAL	100%	-

Figure 8.14: Four-course formats developed by the Faculty of Engineering, IU to calculate the multiplication factor for estimating the weights for different assessments

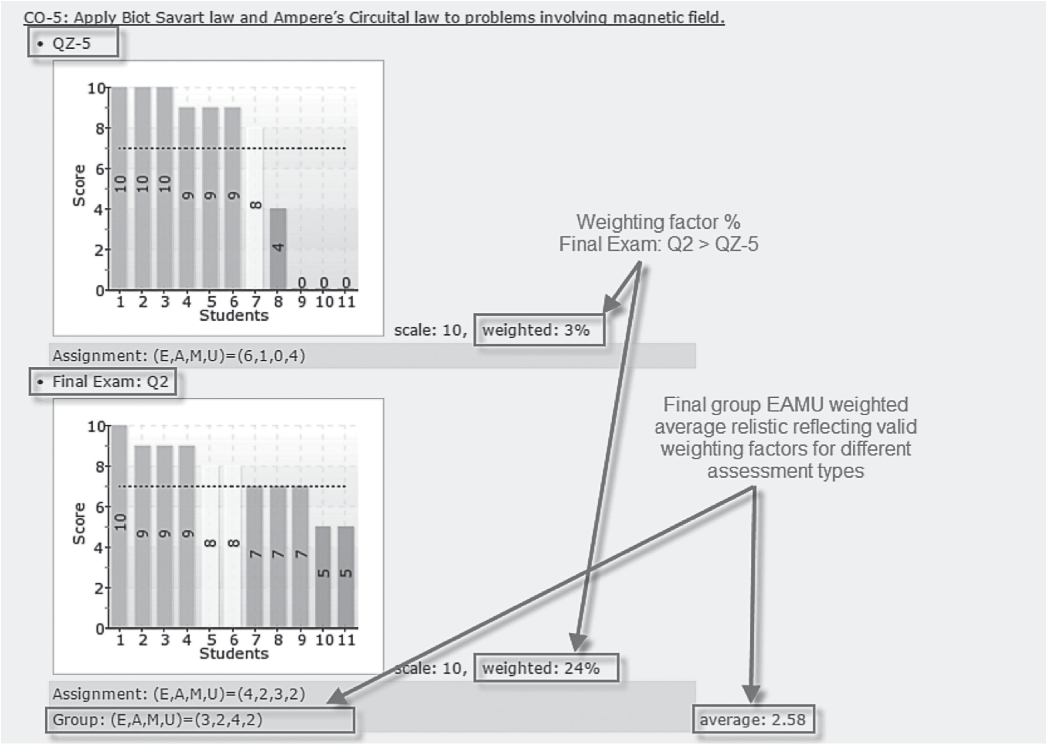
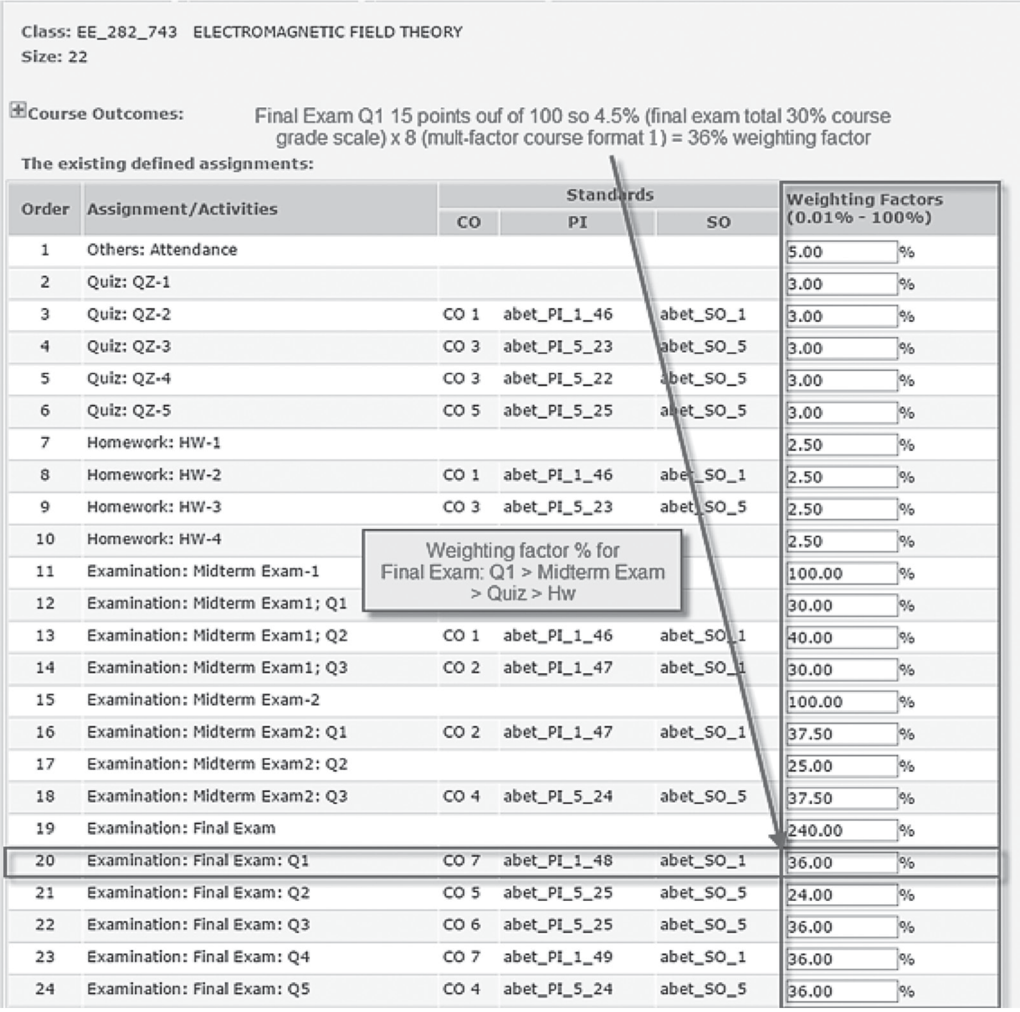


Figure 8.15: Realistic final group EAMU weighted average due to application of accurate weighting factors % applied to different assessments

The details for obtaining the weighting factor for Final Exam Q1 are shown in Figure 8.16. The total score for the Final Exam is 100 points and Q1 is for 15 points. Final Exam accounts for 30% of the total course grading scale. Then, the Final Exam Q1 will therefore account for 15% of the 30% course grading scale which is 4.5%. The course EE_282, ELECTROMAGNETIC FIELD THEORY, does not offer labs and does not involve a project or term paper, so it classifies as a course of format type 1, as listed in the weighting factors table in the Figure 8.14. We can see that the multiplication factor for assessment of type Final Exam, is listed as 8 for course format 1. Now, we obtain the weighting factor for Final Exam Q1 by multiplying the course grading scale 4.5% by the multiplication factor 8 to get 36%.

We also see that the Final Exam questions are therefore assigned weighting factors which are generally greater than those assigned for Midterms, Quiz, or Homework corresponding to the rationale of weighting factors discussed earlier.


Class: EE_282_743 ELECTROMAGNETIC FIELD THEORY
Size: 22

Course Outcomes:

The existing defined assignments:

Order	Assignment/Activities	Standards CO	PI	SO	Weighting Factors (0.01% - 100%)
1	Others: Attendance				5.00 %
2	Quiz: QZ-1				3.00 %
3	Quiz: QZ-2	CO 1	abet_PI_1_46	abet_SO_1	3.00 %
4	Quiz: QZ-3	CO 3	abet_PI_5_23	abet_SO_5	3.00 %
5	Quiz: QZ-4	CO 3	abet_PI_5_22	abet_SO_5	3.00 %
6	Quiz: QZ-5	CO 5	abet_PI_5_25	abet_SO_5	3.00 %
7	Homework: HW-1				2.50 %
8	Homework: HW-2	CO 1	abet_PI_1_46	abet_SO_1	2.50 %
9	Homework: HW-3	CO 3	abet_PI_5_23	abet_SO_5	2.50 %
10	Homework: HW-4				2.50 %
11	Examination: Midterm Exam-1				100.00 %
12	Examination: Midterm Exam1; Q1				30.00 %
13	Examination: Midterm Exam1; Q2	CO 1	abet_PI_1_46	abet_SO_1	40.00 %
14	Examination: Midterm Exam1; Q3	CO 2	abet_PI_1_47	abet_SO_1	30.00 %
15	Examination: Midterm Exam-2				100.00 %
16	Examination: Midterm Exam2: Q1	CO 2	abet_PI_1_47	abet_SO_1	37.50 %
17	Examination: Midterm Exam2: Q2				25.00 %
18	Examination: Midterm Exam2: Q3	CO 4	abet_PI_5_24	abet_SO_5	37.50 %
19	Examination: Final Exam				240.00 %
20	Examination: Final Exam: Q1	CO 7	abet_PI_1_48	abet_SO_1	36.00 %
21	Examination: Final Exam: Q2	CO 5	abet_PI_5_25	abet_SO_5	24.00 %
22	Examination: Final Exam: Q3	CO 6	abet_PI_5_25	abet_SO_5	36.00 %
23	Examination: Final Exam: Q4	CO 7	abet_PI_1_49	abet_SO_1	36.00 %
24	Examination: Final Exam: Q5	CO 4	abet_PI_5_24	abet_SO_5	36.00 %

Figure 8.16: Weighting factor calculation example for Final Exam: Q1 by product of course grading scale and multiplication factor applied using course format no. 2

Hierarchy-Frequency Weighting-Factors Scheme for Multiple Learning and Course Levels

Figure 8.4 indicates the desired design flow for COs and PIs and ideal skills levels coverages for each course level. Assessments in courses whether introductory, reinforced, or mastery level use specific PIs to measure skills corresponding to multiple domains of learning and their learning levels. Figure 8.5 shows the *three-level skills grouping methodology*, which is applied to specific or generic PIs classified as per Bloom's three domains and their learning levels to categorize them into the elementary, intermediate, and advanced skills levels. Single and multi-term program level evaluations use computed 11 EAC ABET SOs values as a good indicator scheme. As mentioned earlier, to obtain valid outcomes results, we cannot compute a program SO by aggregating several student performances that correspond to varying skills levels and collected in multiple course levels. These SOs values should in fact be computed by applying appropriate weighting factors using a weighted averaging approach such as the *Hierarchy-Frequency Weighting-Factor Scheme* to the scores of the three-level skills PIs measured in various courses of introductory, reinforced, and mastery levels.

The philosophy behind the implementation of this *Hierarchy-Frequency Weighting-Factor Scheme* for program learning domains evaluations is to consider a combination of two critical factors:

a. To implement a hierarchy of skills by giving prevalence to those assessments that measure skills of the highest order over others. For example, mastery-advanced level PIs will have a higher prevalence than those for the intermediate-advanced level

b. To consider the counts of assessments implemented in a certain learning level due to the fact that outcomes assessment is directly equivalent to learning

Our ASEE paper provides interested readers complete technical details on the implementation of program or student evaluations by employing the *Hierarchy-Frequency Weighting-Factor Scheme* to aggregate varying skills levels of student performances collected in the mastery, reinforced, and introductory courses.

OA Does Not Strictly Ensure That Outcomes Drive and Regulate CQI Efforts

As discussed in the earlier sections of this chapter and echoing the concerns of NILOA's massive work on outcomes assessment and accreditation, CQI activities and outcomes assessment in the United States are unfortunately independent activities with minimal link to each other. Accreditation, being the prime driver for CQI and not vice versa, is clearly indicated by established research as the main reason for this deficient trend. Institutions or programs that race to fulfill minimal requirements of accreditation perform a ritualistic assessment of outcomes. This assessment process, in most cases, fails to fulfill the principles of 'Real' OBE and does not result in efficient CQI. The outcomes data collected is insufficient and cannot be used to accurately diagnose student weakness in learning for on-time remedial actions.

Therefore, institutions or programs generally adopt a complicated reverse engineering process to produce missing pieces of the puzzle to patch up the obvious gap that exists between outcomes assessment failures and program-generated corrective actions. They identify major improvement changes made in curriculum, teaching- or resource-based requirements, and then artificially link these to some arbitrary or created outcomes failures to fulfill the mandatory accreditation requirement for *closing the loop* in CQI. So, in preparing self-study reports, appropriate corrective actions implemented by a program over a period of time are first identified and then mapped to either closely matching outcomes failures or in some worst cases, fabricated ones to establish the missing link between outcomes information and CQI for the stringent fulfillment of accreditation criteria. We have actually also seen firsthand that some institutions fabricate meeting minutes and action items to develop proofs for linking outcomes failures to corrective actions in a desperate effort to establish the *genuineness and legitimacy* of this reverse engineering process. In reality, an efficient CQI process that thoroughly operates and continually thrives on outcomes assessment information does not actually exist.

OBE requires all components and processes of an educational model to be totally based on outcomes. CQI is the heart and soul of continued success in student learning and should be very heavily integrated with outcomes assessment in every phase of curriculum delivery. In an authentic OBE process, accurate outcomes assessment information is followed by evaluation, feedback, and on-time remedial actions. Outcomes information is the primary source from which all corrective actions and CQI efforts originate. On the other hand, because of the many factors presented in the earlier sections of this chapter, majority of institutions or programs, on an international scale, fail to establish efficient CQI efforts which are truly based on outcomes information. Accreditation agencies for multiple reasons fail to report or identify these uncanny methods that endeavor to artificially bridge the gaping mismatch between outcomes assessment and CQI activities. Additional efforts, resources, and investigative methods need to be deployed by evaluators to regulate such malpractice which severely distort principles and practice of OBE and thus do not produce the right environment for all students to succeed in learning.

Digital technology can definitely ease up the process of validating authentic CQI activities that stem from actual cases of outcomes assessment and performance failures. Continuous Improvement Management Systems (CIMS) can integrate student performance failures in courses and link them to actual program evaluations, committee meetings, minutes, and action items. Several features that streamline and facilitate the validation of authentic CQI activity could be easily accessible by using the appropriate digital technology:

1. Digital date and time stamps for all CQI activity
2. Digitally indexed meetings with list of attendees
3. Detailed meeting minutes with complete information on brainstorming, agenda items, included or created action items, list of action items assignees, etc.
4. Actual indexed failing performance indicators, outcomes from course, and program evaluations included in CQI meetings
5. Trackable assignment of responsibility for action items with clearly indicated levels of priority allocated to specific groups or individuals
6. Electronically generated history of origin, path, and closure of corrective action items

Figure 8.17 shows EvalTools® 6 CIMS module displaying Faculty of Engineering, IU, typical committee's action items list indicating the date, time of assignment, closed or open status, assignment of responsibility, origin of action items, and the indexed failing outcomes and their PIs. In the left-hand bottom is indicated a "medium" priority action item related to Electromagnetic Theory course, EE 341, failing PI_1_22 on review of topics for coverage generated in an Electrical Engineering (EE) program term 371 review conducted on June 12 2017.

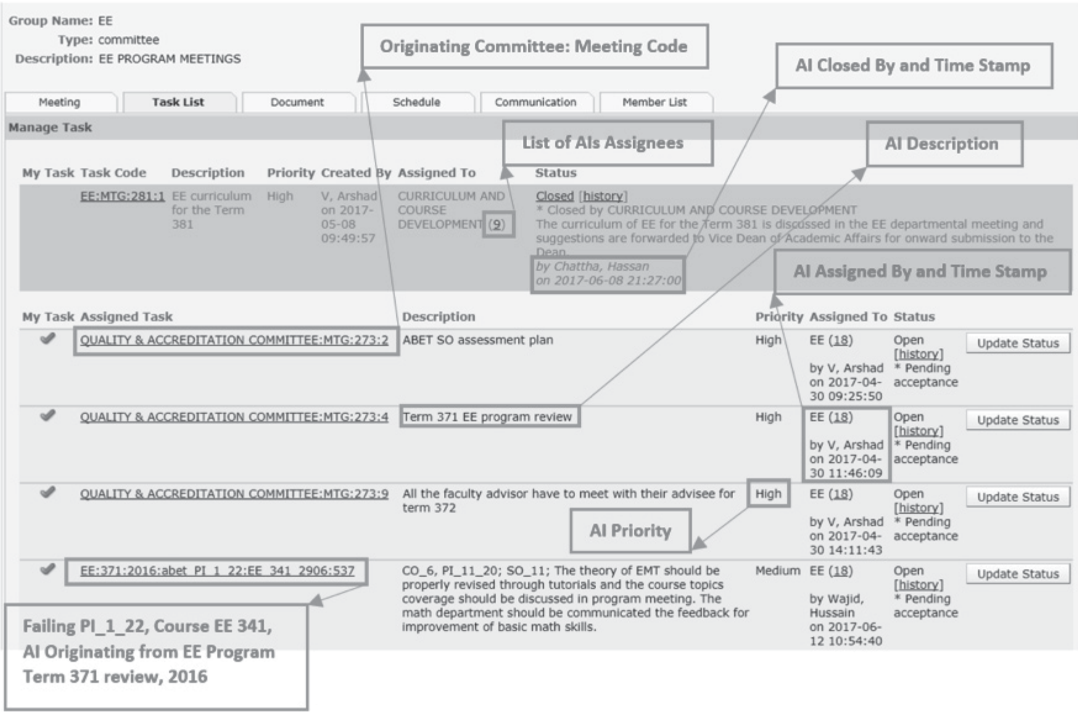


Figure 8.17: EvalTools® 6 CIMS module displaying Faculty of Engineering, IU, EE committee action items list, closed (gray-shaded) and open (yellow-shaded), with time stamps for AIs status change and originating from a program term 371 (2016) review for failing PIs in course assessments

CIMS systems will streamline the overwhelming task of recording, reporting, and monitoring hundreds of corrective actions of 22 committees generated from evaluation of outcomes information. Auditors from accreditation and quality assurance agencies are guaranteed that corrective actions and CQI activity are completely authentic and generated from documented observations of outcomes failures. The CIMS module employed using digital technology seamlessly implements the essential OBE requirement of sustaining all components and processes of an education process on outcomes.

Appendices

Appendix A: Example of splitting existing curricular grade giving assessments to questions, sub questions for high relative coverage of a specific Performance Indicator (PI), Course Outcomes (COs), and ABET Student Outcomes (SOs)

Class: ME_200_1585 ENGINEERING MECHANICS
Size: 20

⊞Course Outcomes:

Select	Assignment/ Activities/Events	Standards		
		CO	PI	SO
○	QZ-4_Q3	CO 7	abet_PI_5_2	abet_SO_5
○	MID-TERM-2_Q4	CO 7	abet_PI_5_2	abet_SO_5
○	Final Exam_Q5	CO 5	abet_PI_1_20	abet_SO_1
○	Final Exam_Q6	CO 9	abet_PI_5_6	abet_SO_5
○	Final Exam_Q7	CO 8	abet_PI_5_10	abet_SO_5
○	Final Exam_Q1	CO 3	abet_PI_1_20	abet_SO_1
○	Final Exam_Q2	CO 4	abet_PI_5_11	abet_SO_5

Appendix B: International Engineering Alliance (IEA) Knowledge and Problem Solving Profiles for Practicing Engineers, Engineering Technologists, and Technicians

1. IEA knowledge profile for practicing engineers, engineering technologist, and technicians

5.1 Knowledge profile

A **Washington Accord programme** provides:	A **Sydney Accord programme** provides:	A **Dublin Accord programme** provides:
WK1: A systematic, theory-based understanding of the **natural sciences** applicable to the discipline	**SK1:** A systematic, theory-based understanding of the **natural sciences** applicable to the sub-discipline	**DK1:** A descriptive, formula-based understanding of the **natural sciences** applicable in a sub-discipline
WK2: Conceptually-based **mathematics**, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline	**SK2:** Conceptually-based **mathematics**, numerical analysis, statistics and aspects of computer and information science to support analysis and use of models applicable to the sub-discipline	**DK2:** Procedural **mathematics**, numerical analysis, statistics applicable in a sub-discipline
WK3: A systematic, theory-based formulation of **engineering fundamentals** required in the engineering discipline	**SK3:** A systematic , theory-based formulation of **engineering fundamentals** required in an accepted sub-discipline	**DK3:** A coherent procedural formulation of **engineering fundamentals** required in an accepted sub-discipline
WK4: Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.	**SK4:** Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline	**DK4:** Engineering **specialist knowledge** that provides the body of knowledge for an accepted sub-discipline
WK5: Knowledge that supports **engineering design** in a practice area	**SK5:** Knowledge that supports **engineering design** using the technologies of a practice area	**DK5:** Knowledge that supports **engineering design** based on the techniques and procedures of a practice area
WK6: Knowledge of **engineering practice** (technology) in the practice areas in the engineering discipline	**SK6:** Knowledge of **engineering technologies** applicable in the sub-discipline	**DK6:** Codified **practical engineering knowledge** in recognised practice area.
WK7: Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability	**SK7: Comprehension of** the role of technology in society and identified issues in applying engineering technology: ethics and impacts: economic, social, environmental and sustainability	**DK7: Knowledge** of issues and approaches in engineering technician practice: ethics, financial, cultural, environmental and sustainability impacts
WK8: Engagement with selected knowledge in the **research literature** of the discipline	**SK8:** Engagement with the **technological literature** of the discipline	
A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 4 to 5 years of study, depending on the level of students at entry.	A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 3 to 4 years of study, depending on the level of students at entry.	A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 2 to 3 years of study, depending on the level of students at entry.

2. IEA problem-solving profile for practicing engineers, engineering technologist, and technicians

4 Common Range and Contextual Definitions

4.1 Range of Problem Solving

References to the Knowledge Profile are shown thus: (WK3, WK4 ...)

In the context of both Graduate Attributes and Professional Competencies:			
Attribute	***Complex Engineering Problems*** have characteristic WP1 and some or all of WP2 to WP7:	***Broadly-defined Engineering Problems* have characteristic SP1 and some or all of SP2 to SP7:**	***Well-defined Engineering Problems*** have characteristic DP1 and some or all of DP2 to DP7:
Depth of Knowledge Required	**WP1:** Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6 or WK8 which allows a fundamentals-based, first principles analytical approach	**SP1:** Cannot be resolved without engineering knowledge at the level of one or more of SK 4, SK5, and SK6 supported by SK3 with a strong emphasis on the application of developed technology	**DP1:** Cannot be resolved without extensive practical knowledge as reflected in DK5 and DK6 supported by theoretical knowledge defined in DK3 and DK4
Range of conflicting requirements	**WP2:** Involve wide-ranging or conflicting technical, engineering and other issues	**SP2:** Involve a variety of factors which may impose conflicting constraints	**DP2:** Involve several issues, but with few of these exerting conflicting constraints
Depth of analysis required	**WP3:** Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	**SP3:** Can be solved by application of well-proven analysis techniques	**DP3:** Can be solved in standardised ways
Familiarity of issues	**WP4:** Involve infrequently encountered issues	**SP4:** Belong to families of familiar problems which are solved in well-accepted ways	**DP4:** Are frequently encountered and thus familiar to most practitioners in the practice area
Extent of applicable codes	**WP5:** Are outside problems encompassed by standards and codes of practice for professional engineering	**SP5:** May be partially outside those encompassed by standards or codes of practice	**DP5:** Are encompassed by standards and/or documented codes of practice
Extent of stakeholder involvement and conflicting requirements	**WP6:** Involve diverse groups of stakeholders with widely varying needs	**SP6:** Involve several groups of stakeholders with differing and occasionally conflicting needs	**DP6:** Involve a limited range of stakeholders with differing needs
Interdependence	**WP 7:** Are high level problems including many component parts or sub-problems	**SP7:** Are parts of, or systems within complex engineering problems	**DP7:** Are discrete components of engineering systems
In addition, in the context of the Professional Competencies			
Consequences	**EP1:** Have significant consequences in a range of contexts	**TP1:**Have consequences which are important locally, but may extend more widely	**NP1:** Have consequences which are locally important and not far-reaching
Judgement	**EP2:** Require judgement in decision making	**TP2:** Require judgement in decision making	

Appendix C: Faculty of Engineering Course COs, PIs Development Process Example

EE 421 – Wireless and Mobile Communication

COURSE SYLLABUS

Spring Semester 2017

ORIGINAL COs DEVELOPED BY A NEW FACULTY MEMBER

1. **Understand** evolution of wireless communication systems and also understand and compare existing common mobile radio systems

   C01, abet_8_18: study the impact and benefits of wireless evolution on society

2. **Understand** modern wireless communication systems and wireless local area networks

   C02, abet_8_16:

3. **Compute** the number of channels per cell and maximum channel capacity for different frequency re-use systems

   C03, abet_5_x: calculate the no. of channels and channel capacity in wireless communication systems

4. **Compute** the number of users for a given blocking probability using trunking approach

   C04, abet_5_x: calculate the number of users in a mobile communication system for a given blocking probability using trunking approach

5. **Analyze** different propagation model for mobile communication

   C05, abet_11_x: Analyze different propagation model in mobile communication, i.e., Reflection, Ground Reflection (2-ray) model, Scattering

6. **Understand and Analyze** small scale fading and multipath, i.e., Rayleigh and Ricean Distribution

   C06, abet_11_x: Analyze small scale fading and multipath, i.e., Rayleigh and Ricean Distribution

7. **Understand and Analyze** digital modulation techniques

   C07, abet_11_x: Analyze digital modulation techniques, i.e., ASK, FSK, PSK

8. **Understand and Analyze** equalization, diversity, and channel coding

9. **Understand and Analyze** multiple access techniques for wireless communication systems, and also compute capacity of cellular systems

   C09, abet_5_x: Analyze MULTIPLE access techniques and compute capacity of wireless systems

10. **Understand** various kinds of wireless networks

INCORRECT LANGUAGE OF ORIGINAL COs:

1. **Understand** evolution of wireless communication systems and also **understand** and compare existing common mobile radio systems
2. **Understand** modern wireless communication systems and wireless local area networks
3. **Compute** the number of channels per cell and maximum channel capacity for different frequency re-use systems.
4. **Compute** the number of users for a given blocking probability using trunking approach
5. **Analyze** different propagation model for mobile communication
6. **Understand and analyze** small scale fading and multipath, i.e., Rayleigh and Ricean Distribution
7. **Understand and analyze** digital modulation techniques
8. **Understand and analyze** equalization, diversity, and channel coding
9. **Understand and analyze** multiple access techniques for wireless communication systems, and also **compute** capacity of cellular systems
10. **Understand** various kinds of wireless networks

QUALITY AND ACCREDITATION DEVELOPMENT PROCESS FOR COs AND PIs:

TARGET:

1. Proper coverage and distribution of Bloom's three domains cognitive, affective and psychomotor skills as per engineering standards required for this course
2. Implement Ideal Learning Distribution for reinforced 300 course level
3. Planned assessments' complexity, skills levels and methods of solution should have maximum possible alignment with the specific PIs developed

INPUT:

1. General Teaching and Learning Strategies:

   Lecture, term paper, No labs, No project

2. ABET SOs coverage:

   SO_1 or 'a': applying math, science and engineering knowledge; SO_5 or 'e': problem solving; SO_7 or 'g': communicate effectively; SO_8 or 'h': impact of engineering solutions; SO_10: contemporary issues; SO_11 or 'k': apply techniques, skills and tools for engineering practice.

3. Major course topics:

Chapter 1: Introduction to Wireless Communication System

Chapter 2: Modern Wireless Communication Systems

Chapter 3: The Cellular Concept— System Design Fundamentals

Chapter 4: Mobile Radio Propagation – Large Scale Path Loss

Chapter 5: Mobile Radio Propagation – Small Scale Fading and Multipath

Chapter 6: Modulation Techniques for Mobile Radio

Chapter 7: Equalization, Diversity, and Channel Coding

Chapter 8: Multiple Access Techniques for Wireless Communication

Chapter 9: Wireless Networking

4. Text and references:

Textbook: Theodore S. Rappaport "Wireless Communication, Principles and practice" 2nd edition, Prentice Hall.

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- A.F. Molisch, "Wireless Communications", 2nd Edition, Wiley, 2011.
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5. Any sample assessments

OUTPUT:

CO1

Chapter 1: Introduction to Wireless Communication System

Understand evolution of wireless communication system and also **understand** and compare existing common mobile radio system (ORIGINAL)

Define basic terms used for wireless communication systems, elaborate on their evolution and compare existing common mobile communication systems (MODIFIED)

PIs:

abet_8_18: study the impact and benefits of wireless evolution on society (ORIGINAL)

NEW_PI_SO_1: Cognitive understanding: Define basic terms used to describe elements of wireless communication systems such as types of stations, types of radio transmission systems and devices, types of mobile communication, etc.

NEW_PI_SO_8: Cognitive evaluation: Compare the types of services and functionality, level of infrastructure, hardware cost, carrier frequency, and complexity required for the subscriber segment and base station segment of given mobile communication systems.

NEW_PI_SO_8: Affective organizing values: Elaborate on the evolution of wireless communication systems, common paging systems, cordless, cellular, and personal communication standards used in North America, Europe and Japan, technological changes, impact in a global, economic, environmental, and societal context.

CO2

Chapter 2: Modern Wireless Communication Systems

Understand modern wireless communication system and wireless local area networks (ORIGINAL)

Explain modern wireless communication systems, their technology, standards and application

PIs:

NEW_PI_SO_8: Affective Organizing values: Explain first (1G), second (2G), third (3G) generations of wireless networks, the modifications in technology, supporting standards, advantages and applications

NEW_PI_SO_8: Cognitive understanding: Explain the technology, supporting standards and advantages of various wireless transmission protocol applications such as Wireless Local Loop (WLL) and LMDS: Wireless Local Area Networks (WLANs); Bluetooth and Personal Area Networks (PANs)

CO3

Chapter 3: The Cellular Concept— System Design Fundamentals

Compute the number of channels per cell and maximum channel capacity for different frequency re-use systems (ORIGINAL)

abet_5_x: calculate the no. of channels and channel capacity in wireless communication system. (ORIGINAL)

NEW_PI_SO_5: Cognitive analyzing: Solve given cellular system problems for half, full, or duplex channels systems; compute the number of channels for different cell re-use system; and determine equitable distribution of control and voice channels for each cell in given systems.

NEW_PI_SO_5: Cognitive analyzing: Estimate maximum channel capacity for given cellular system with specific signal to noise interference and path loss component using suitable approximations to calculate the frequency re-use factor and cluster size (estimation places this PI into analyzing learning level).

CO4

Chapter 3: The Cellular Concept— System Design Fundamentals

Compute the number of users for a given blocking probability using trunking approach (ORIGINAL)

Compute the number of users for a given blocking probability for given cellular systems (MODIFIED)

PIs:

abet_5_x: calculate the number of users in a mobile communication system for a given blocking probability using trunking approach (ORIGINAL)

NEW_PI_SO_5: Psychomotor complex overt: Calculate the number of users in a given mobile communication system for a specific blocking probability and different number of trunked channels by obtaining the total traffic intensity 'A' read from Erlang blocking probability charts using given/calculated user traffic intensity 'Au'

CO5

Chapter 4: Mobile Radio Propagation – Large Scale Path Loss

Analyze different propagation model for mobile communication (ORIGINAL)

Explain various aspects of mobile radio propagation and **Analyze** large scale path loss (MODIFIED)

abet_11_x: Analyze different propagation model in mobile communication, i.e., Reflection, Ground Reflection (2-ray) model, Scattering (ORIGINAL)

NEW_PI_SO_1: Cognitive understanding: ***Explain*** the three basic propagation mechanisms such as reflection, diffraction and scattering; and explain ground reflection 2-ray model by ***providing*** fundamental theory and properly labeled diagram

NEW_PI_SO_5: Cognitive analyzing: ***Calculate*** far field distance of an antenna with given dimension and frequency;

NEW_PI_SO_5: Cognitive analyzing: ***Calculate*** Brewster angle of a wave impinging on ground with certain permittivity;

NEW_PI_SO_5: Cognitive analyzing: ***Calculate*** received power of a mobile using Ground Reflection (2-ray) model

CO6

Chapter 5: Mobile Radio Propagation – Small Scale Fading and Multipath

Understand and **analyze** small scale fading and multipath, i.e., Rayleigh and Ricean Distribution (ORIGINAL)

Explain and Analyze fading in small scale multipath propagation (MODIFIED)

abet_11_x: Analyze small scale fading and multipath, i.e., Rayleigh and Ricean Distribution (ORIGINAL)

NEW_PI_SO_1: Cognitive understanding: ***Explain*** physical factors in radio propagation channel influencing small scale fading;

NEW_PI_SO_1: Cognitive understanding: ***Explain*** small scale multipath measurement techniques and systems such as direct pulse, spread spectrum sliding, and swept frequency measurements with the help of block diagrams.

NEW_PI_SO_5: Cognitive analyzing: ***Compute*** the received carrier frequency if a mobile is moving towards, away, or perpendicular to the direction of the arrival of transmitted signal;

NEW_PI_SO_5: Cognitive analyzing: Determine the spatial sampling interval required to make small scale propagation measurements for a given case with specific distance, frequency, velocity; ***Compute*** the Doppler spread

NEW_PI_SO_5: Cognitive analyzing: ***Compute*** far field distance of an antenna with given dimension and frequency;

NEW_PI_SO_5: Cognitive analyzing: ***Compute*** Brewster angle of a wave impinging on ground with certain permittivity;

NEW_PI_SO_5: Cognitive Analyzing: ***Compute*** received power of a mobile using Ground Reflection (2-ray) model

<u>CO7</u>

Chapter 6: Modulation Techniques for Mobile Radio

Understand and analyze digital modulation techniques (ORIGINAL)

Compare digital and analog modulation theory and **analyze** wireless communication systems using digital modulation techniques (MODIFIED)

abet_11_x: Analyze digital modulation techniques, i.e., ASK, FSK, PSK (ORIGINAL)

NEW_PI_SO_10: Affective Organizing values: ***Compare*** digital and analog modulation; ***elaborate*** the advantages and limitations of each by ***discussing*** bit error rate, Signal to Noise Ratio (SNR), power efficiency, bandwidth efficiency, system capacity, etc.

NEW_PI_SO_5: Cognitive Evaluation: ***Evaluate*** given wireless communication systems by ***determining*** the bandwidth, Signal to Noise Ratio (SNR), maximum theoretical data rate, etc.; ***compare*** this rate to given cellular standards

NEW_PI_SO_11: Cognitive Analyzing: Determine the baud and minimum bandwidth necessary to pass a binary signal of given frequency using Amplitude Shift Keying (ASK).

NEW_PI_SO_11: Cognitive Analyzing: Determine the peak frequency deviation, minimum bandwidth, and baud for a binary Frequency Shift Keying (FSK) signal with given mark, space frequency and an input bit rate.

NEW_PI_SO_11: Psychomotor Complex overt response: Determine the maximum and minimum upper and lower side frequencies for a BPSK modulator with given carrier frequency and an input bit rate; draw the output spectrum, determine the minimum Nyquist bandwidth, and calculate the baud.

CO8

Chapter 7: Equalization, Diversity and Channel Coding

Understand and **analyze** equalization, diversity, and channel coding (ORIGINAL)

Explain the fundamentals of equalization, diversity, and channel coding

NEW_PI_SO_8: Cognitive understanding: ***Describe*** equalization, diversity, and channel coding; ***provide*** the reasons how these techniques improve signal quality; their supporting systems, advantages and applications

CO9

Chapter 8: Multiple Access Techniques for Wireless Communication

Understand and **analyze** multiple access techniques for wireless communication system, and also compute capacity of cellular systems (ORIGINAL)

Analyze and **evaluate** wireless communication systems that use multiple access techniques (MODIFIED)

abet_5_x: Analyze MULTIPLE access techniques and compute capacity of wireless system (ORIGINAL)

NEW_PI_SO_5: Cognitive Analyzing: ***Compute*** the number of available channels in FDMA systems with given bandwidth;

NEW_PI_SO_5: Cognitive Analyzing: ***Compute*** the number of simultaneous users that can be accommodated in GSM using TDMA/FDD approach;

NEW_PI_SO_5: Cognitive Analyzing: ***Compute*** the time duration of a bit, slot, and frame in a GSM system with given time slots and data rate.

NEW_PI_SO_5: Cognitive Evaluating: ***Evaluate*** FDMA/TDMA/CDMA systems by ***calculating*** and ***comparing*** the channel capacity 'C/I' for each

NEW_PI_SO_5: Cognitive Analyzing: ***Compute*** the maximum number of users that can be supported in single cell CDMA system using omni directional base station antenna and the 3-sectors at the base stations.

CO10

Chapter 9: Wireless Networking

Understand various kinds of wireless networks (ORIGINAL)

Compare wireless and fixed phone networks and **explain** various networking systems, techniques and protocols for wireless communication

NEW_PI_SO_10: Affective Organizing values: ***Compare*** wireless and fixed phone networks such as Public switched Telephone Networks (PSTN); ***elaborate*** the advantages and limitations of each network; discuss the benefits of merging the two networks

NEW_PI_SO_8: Affective Organizing values: ***Explain*** first (1G), second (2G), third (3G) generations of wireless networks, the modifications in technology, supporting standards, advantages and applications

NEW_PI_SO_11: Affective Organizing values: ***Explain*** traffic routing techniques and protocols in wireless networks such as circuit switching, packet switching, common channel signaling (CCS), X.25 protocol, signaling system No.7 (SS7); ***discuss*** the methodology, technology; their benefits and limitations

CO11 (New CO)

Study existing cellular networking systems for a local provider **write** technical paper to discuss the methodology and systems.

NEW_PI_SO_7: Affective Internalization: ***Write*** clear technical reports following a given format ***providing*** the details of: (a) Literature survey conducted on an existing cellular networking system (b) ***Discuss*** the methodology employed and supporting systems and technology (c) ***Explain*** the practical advantages and limitations of the methods and technology employed by the provider (c) ***Provide*** conclusions with a reflection on learning experiences followed with a critical analysis of the systems and technology and suggestions for improvement. (d) ***List*** all references of literature survey conducted whether online materials, company documentation, manuals, consultation with engineers, etc.

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Biographies

Dr. William "Bill" Spady's experience and expertise in Outcome-Based Education (OBE) is unmatched globally. Known internationally as "The Father of OBE," he has earned the reputation as the recognized worldwide authority on future-focused, paradigm-shifting, personally-empowering approaches to Transformational OBE. For over four decades, he has spearheaded major OBE initiatives throughout North America, South Africa, Australia, the Philippines, Saudi Arabia, and the United Arab Emirates on expanding the vision, shifting the paradigm, and improving the performance of learners, educators, and educational systems. This work has bolstered his recognized expertise in organizational change, transformational leadership development, strategic organizational design, and elevated models of learning and living.

Recognized across the world as a dynamic and compelling consultant and presenter, Bill received his PhD in the Sociology of Education from the University of Chicago in 1967, and began his academic career as a professor at Harvard University's Graduate School of Education. This was followed by major national leadership positions in education and the founding of his own national consulting company in 1991. Since then, he has lectured at major educational conferences throughout the world on cutting-edge approaches to a range of topics related to OBE, leadership, human potential, paradigm change, and learner empowerment. Dr. Spady has published nine highly acclaimed professional books, scores of journal articles, and many solicited chapters in the books of others. A list of his books can be found on his website: williamspady.com. He has been the subject of three doctoral dissertations and has been honored with a Center on Transformational Leadership and Learning in the Philippines bearing his name.

Wajid Hussain is the Director for the Office of Quality & Accreditation at the Faculty of Engineering, Islamic University (IU) Madinah campus and a member of IU's Quality and Accreditation Committee for the Faculty of Engineering. By profession, he is an electrical/computer engineer with more than 20 years of engineering experience and mass production expertise of Billion Dollar Microprocessor Manufacture Life Cycle. Over the years, Wajid has managed several projects related to streamlining operations with utilization of state-of-the-art technology and digital systems, giving him significant experience working with International Organization for Standardization (ISO) quality systems. In addition, he has received specialized Quality Leadership Training at LSI Corporation and in 1999, received LSI's Worldwide Operations Review Award for his significant contributions to their Quality Improvement Systems. Most notably, Wajid was the lead product engineer supporting Apple's iPod and many other world-famous processors at LSI Corporation.

He is a specialist on Accreditation Board of Engineering and Technology ABET accreditation procedures and has extensive experience supporting and managing outcomes assessment to fulfill ABET accreditation requirements for several engineering, computing, and engineering technology programs. In addition, he is a Digital Integrated Quality Management Systems Expert for Automated Academic Student Outcomes-Based Assessments Methodology specializing in EvalTools® 6 by MAKTEAM Inc. USA. Wajid has been an invited keynote, panel speaker, or presenter at several international OBE conferences and has written multiple research papers on outcomes assessment at the American Society of Engineers for Education, Frontiers In Education, and several other international conferences. Moreover, he has developed several revolutionary outcomes assessment instruments and models based on John K. Estell's Faculty Course Assessment Reporting system and is the first to classify specific Performance Indicators in relation to all learning levels of Bloom's taxonomy and to implement world-class best assessment practices to support digital technology, automation, streamlining, and Continual Quality Improvement. The National Institute of Learning Outcomes Assessment has listed Wajid's model as one of best assessment practices in the world.

Joan Largo is the Dean of the School of Law and Governance of her alma mater, the University of San Carlos in Cebu City, Philippines, where she teaches Constitutional Law, Torts and Damages, Alternative Dispute Resolution, Appellate Law Practice, and Trial Technique. She is also a resident partner of the Cebu office of the law firm Romulo Mabanta Buenaventura Sayoc & de los Angeles.

Dean Largo is a graduate of Bachelor of Arts major in Political Science under full State scholarship and as class valedictorian and magna cum laude in 1995 at the University of San Carlos (USC) — Asia's oldest educational institution. After college, Largo began her law studies at University of San Carlos under full scholarship from the R.H. Goipeng Foundation. She graduated cum laude and class valedictorian in 1999. She passed the Bar Examination given in the same year with a general weighted average of 84.95% where the national passing percentage was only 16%, the lowest in the history of the Bar Examination. She then obtained her Master of Laws degree from the San Beda College Graduate School of Law, and graduated cum laude. For the said course, she wrote her first law book, Laws and Jurisprudence on Torts and Damages, published by Rex Book Store, Inc.

Dr. Francis Aldrine A. Uy is an innovative Outcome-Based Education (OBE) leader who brings his 16 years of vast experience in academic excellence and transformational leadership to our effort. Recognized as the OBE leading advocate in the Philippines, Uy is the Co-Founder and President of the Spady & Uy Center for Transformational Learning and Leadership Inc. He is an acknowledged researcher and author in the area of transportation engineering and civil systems, and through his directorships in various professional organizations, he is actively engaged in the international recognition and global mobility of Filipino engineers.

In addition to his current position as Dean of the School of Civil, Environmental, and Geological Engineering at the Mapua University (formerly Mapua Institute of Technology)—the first ABET-Accredited Civil and Environmental Engineering program in East Asia, Uy is also involved in governance and policy-making positions as a member of various government agencies and professional committees. He served as a Technical Committee Member for Civil Engineering, Commission on Higher Education (CHED), and Accreditation and Certification Board for Engineering and Technology Board Member for Civil Engineering of the Philippine Technological Council (PTC).

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Industrial Training Courses: A Challenge during the COVID19 Pandemic

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Abstract:
Industrial training courses require students to gain sufficient practical engineering experience that confirms theoretical knowledge by application to field work. The courses expose students to real life engineering activity involving problem solving, design, experimentation and manufacturing. Students get introduced to entrepreneurship, diverse collaborative work environments and quality systems that instill world class safety standards and professional ethics. Preventive measures and lockdowns during prolonged pandemic conditions have severely limited students' capability for in-person participation of onsite industrial training programs, thereby, adversely affecting the scope of training courses. This paper presents some plausible solutions to challenges faced by both instructors and students in fulfillment of essential outcomes for remote offerings of industrial training courses during the COVID19 pandemic. Essential aspects of an outcome based digital platform used for remote management, assessment and evaluation of industrial training courses are presented. A course template that facilitates virtual engineering roles as viable alternative to students' in-person participation in industry settings is explained. This study compares two course models offered prior to and during pandemic conditions for fulfillment of course outcomes, makes observations of required skills and knowledge, related deficiencies and some recommendations to help engineering programs enhance student learning in remotely offered industrial training courses.

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Industrial Training Courses: A Challenge during the COVID19 Pandemic

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***Abstract*—Industrial training courses require students to gain sufficient practical engineering experience that confirms theoretical knowledge by application to field work. The courses expose students to real life engineering activity involving problem solving, design, experimentation and manufacturing. Students get introduced to entrepreneurship, diverse collaborative work environments and quality systems that instill world class safety standards and professional ethics. Preventive measures and lockdowns during prolonged pandemic conditions have severely limited students' capability for in-person participation of onsite industrial training programs, thereby, adversely affecting the scope of training courses. This paper presents some plausible solutions to challenges faced by both instructors and students in fulfillment of essential outcomes for remote offerings of industrial training courses during the COVID19 pandemic. Essential aspects of an outcome based digital platform used for remote management, assessment and evaluation of industrial training courses are presented. A course template that facilitates virtual engineering roles as viable alternative to students' in-person participation in industry settings is explained. This study compares two course models offered prior to and during pandemic conditions for fulfillment of course outcomes, makes observations of required skills and knowledge, related deficiencies and some recommendations to help engineering programs enhance student learning in remotely offered industrial training courses.**

Keywords—OBE, outcomes, assessment, evaluation, ABET, industrial training

I. Introduction

Industrial training is recognized as an essential component of engineering education globally. Training courses provide crucial technical and transversal skills especially important for engineering graduates aspiring to compete in a global labor market. Over the last two decades, quality and accreditation agencies worldwide have emphasized the importance of integrating transversal competencies in engineering education curricula in order to prepare students for the engineering labor market [1,2]. Care and Luo defined transversal competencies as skills, values and attitudes required for learners' holistic development [3] and are also known in research literature as employability skills [4], professional skills [5] and twenty-first century skills [6]. Industrial exposure provides students with both the technical and transversal skills necessary for holistic development required by state of the art engineering education. According to Jesus and Urbano [7], "Industrial training activities can be defined as periods of engineering education outside the University geographical space that are oriented towards providing the students with knowledge and competences not easily obtained at class- rooms ... on the other hand, industrial refers here to any organized human group implied in producing goods or supplying services. In this sense, the term industry includes public or private manufacturing or services firms but also public administrations, co-operatives, trade unions, NGO´s, foundations and other collectives."

Several international accreditation agencies such as the Accreditation Board of Engineering Technology (ABET), International Engineering Alliance's (IEA) Washington Accord [8], EUR-ACE ® [9] and Saudi's National Commission for Academic Accreditation & Assessment (NCAAA) [10] strongly recommend that industrial training courses should be an integral part of the engineering curriculum to comprehensively cover their graduate attributes or Student Outcomes (SOs). The training programs provide students with hands on experience in practical engineering activity involving problem solving, design, experimentation, and manufacturing. Students also get introduced to entrepreneurship, diverse collaborative work environments and quality systems that instill world class safety standards and professional ethics. Since accreditation agencies base students' learning on an Outcome Based Education (OBE) model [11], all teaching, learning, assessment, evaluation, feedback and improvement efforts have to be related to outcomes information. An exhaustive study of 99 research articles [12] concluded that due to global accreditation requirements the number of published studies from 2000 to 2017 related to assessment and evaluation of transversal skills had significantly increased. They observed that in general, international quality standards for assessment and evaluation of transversal skills such as communication, innovation, creativity, lifelong learning or teamwork were undefined and deficient. Specifically, inadequate standards of language of learning outcomes, validity and reliability of assessments, and vague rubrics, all exacerbated the evaluation of transversal skills. Typical undergraduate engineering programs cover several hundred learning activities which are difficult to manage and assess using manual quality systems. These activities involve knowledge and skills corresponding to all the 3 Bloom's domains and their learning levels [13-16]. Therefore, assessment and evaluation of off campus student learning experiences dealing with real time technical and transversal skills would indeed be a complex affair [17]. Several publications have mentioned automated digital systems that facilitate learning management and outcomes assessment as possible solutions to streamlining the outcomes data collection and reporting efforts [15,16,18,19,20]. In this study, we shall present some samples of remote assessment and evaluation of student learning activity using digital web-based platform EvalTools 6 ® for summer training courses of the Electrical (EE), Mechanical (ME) and Civil (CE) engineering programs at the Islamic University (IU).

Since the end of February 2020, the Ministry of Education, Saudi Arabia has mandated stringent measures for educational institutions across the nation to observe strict social distancing norms and offer all courses remotely. Until further notice, students are barred from in-person class attendance on campus and cannot visit any industrial sites for vocational training. Engineering programs have no choice left but to consider employing digital platforms offering Learning Management (LMS) and Outcomes Assessment (OAS) Systems to facilitate effective delivery of remote classes. As mentioned earlier, industrial training courses have to be organized off campus at industrial sites to facilitate real time application of engineering theory and gain adequate exposure of professional experience much needed for enhancing transversal skills. In consideration of preventive measures and social distancing norms during the COVID19 pandemic, engineering programs have adopted course models that involve virtual or observatory roles for students instead of hands on field experience as previously available in training courses. In this paper, we introduce a novel course template blended with key elements of entrepreneurship as per the national Saudi 2030 Vision [27] for conducting industrial training courses during the COVID19 pandemic. Since virtual or observatory roles cannot offer the same level of rigor regarding real time practical experience or transversal skills as compared to that gained from industrial sites, programs need to review other alternatives that can alleviate the learning gap in remotely offered virtual industrial training courses. A qualitative review of coverage of learning distribution of required Course Outcomes (COs) for virtual training courses can further help understand the degree of deficient learning. Considerable information is available in research literature [28,29,30] regarding several options for remote, simulation and virtual science and engineering laboratories that could be utilized by engineering programs to enhance learning in remotely offered virtual industrial training courses.

II. Purpose of Study

The driving force behind this research is to examine the benefits of application of essential theory of the authentic OBE model for the implementation of a holistic and comprehensive educational process that maximizes opportunities for the attainment of successful student learning. The objective is to study remote assessment and evaluation of student learning activity using digital web-based platform EvalTools 6 ® for summer training courses of the electrical, mechanical and civil engineering programs.

In particular, the researchers sought to answer the following research questions:

1. Can web-based digital software be utilized for effective remote offerings of industrial training courses?
2. Do virtual engineering roles in remote offerings of industrial courses help students gain adequate practical experience and transversal skills?

III. Theoretical Framework

Educational institutions following the OBE model should ensure all learning activities, assessments, evaluations, feedback, and advising, help students attain the targeted outcomes. As stated in [12,17], student learning activity in most training courses is not based on comprehensive outcomes and specific performance criteria with detailed analytic rubrics for valid and reliable assessment and evaluation. To better understand the scope of this research and the limitations of current training courses with outcomes-based approaches, we begin with a brief introduction to some essential elements of OBE which were developed by the *High Success Network* [11].

A. OBE Model

The keys to having an outcomes-based system are:

a) Developing a clear set of learning outcomes around which all of the educational system's components can be focused; and
b) Establishing the conditions and opportunities within the educational system that enable and encourage all students to achieve those essential outcomes.

OBE's two key purposes that reflect its "*Success for all students and staff*" philosophy are:

a) Ensuring that all students are equipped with the knowledge, competence, and qualities needed to be successful after they exit the educational system; and
b) Structuring and operating schools so that those outcomes can be achieved and maximized for all students.

B. Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology; Ideal Learning Distribution

Performance Indicators (PIs) should be specific to accurately assess learning activity related to a given course topic in any phase of the curriculum and aligned to a specific level of proficiency [15,16,18,22]. Fig. 1 shows the design flow for the creation of holistic learning outcomes and their PIs for all courses corresponding to introductory, reinforced and mastery levels spanning the curriculum [15].

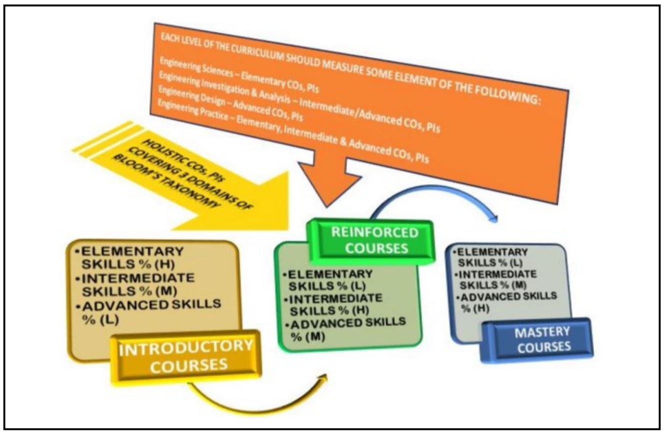


Fig. 1. Design flow for the creation of Advanced, Intermediate and Elementary COs, PIs covering 3 Domains of Bloom's Taxonomy

A novel *3-Level Skills Grouping Methodology* [15,16] as shown in Fig 2. was developed for each learning domain with a focus on grouping activities that are closely associated to a similar degree of skills complexity. COs and PIs designed following such an ideal distribution facilitate a thorough analysis of each phase of the learning process that result in comparatively easier mechanisms for early detection of student performance failures.

Skills Level	Cognitive Domain (Bloom, 1856; Anderson & Krathwohl, 2001)	Affective Domain (Krathwohl, Bloom & Masia, 1973	Psychomotor Domain (Simpson, 1972)
Elementary	1.Knowledge 2.Comprehension	1.Receiving phenomena 2.Responding to phenomena	1.Perception 2.Set 3.Guided response
Intermediate	3.Application 4.Analysis	3.Valuing	4.Mechanism 5.Complex overt response
Advanced	5.Evaluation 6.Creation	4.Organizing values into problems 5.Internalizing	6.Adaptation 7.Origination

Fig. 2. 3-Level Skills Grouping Methodology of Bloom's Revised Taxonomy

C. COs, PIs and Hybrid Rubrics

The Faculty of Engineering programs developed a state of the art digital database consisting of specific and generic PIs classified as per Bloom's 3 domains and their learning levels through a very exhaustive and elaborate ongoing process to comprehensively measure engineering activities corresponding to the ABET Engineering Accreditation Commission (EAC) SOs [15,16,22,23,31]. The PIs targeted assessment of various engineering activities corresponding to multiple skills levels in the introductory, reinforced and mastery level courses thus fulfilling Washington Accord engineering graduate knowledge, skills and professional competency profiles [16, 22, 23]. Design of COs and their PIs was meticulously completed following a *"design down"* mapping model [22] and using appropriate action verbs and subject content, thus rendering the COs, their associated PIs, and assessments at a specific skill level—elementary, intermediate or advanced. The essential aspects of COs and PIs design rules are listed below for better understanding of the potential for holistic results in teaching, assessment, evaluation and Continuous Quality Improvement (CQI).

Rules for COs Design:

- Use operational action verbs to demonstrate the target learning activity that has to be assessed
- The COs can target multiple activities covering 3 domains of Bloom's model and the 3-levels skills elementary, intermediate and advanced. But, each activity would have to be assessed by corresponding PIs.
- The COs should sequentially cover all major course topics
- The COs for a specific topic should measure both theory and experimental lab skills to ensure comprehensive learning related to a given topic.
- Write moderately generic COs with context of several specific PIs that will measure various learning activities mentioned in the COs.

Rules for PIs Design:

- The PIs should be approximately aligned to the operational action verb and nominal subject content in COs.
- The PIs should be at a similar skills level as the corresponding activity in the CO.
- The PIs should align with the complexity and methods used in assessments planned to measure corresponding learning activities mentioned in the CO
- The PIs should use topic specific language in addition to that of COs and indicate names of techniques, standards, theorems, technology, methodology etc.
- The PIs should provide major steps to analyzing, solving, evaluating, classifying etc. so they can be utilized to develop hybrid rubrics
- Several PIs should be used to assess multiple learning activities relating to multiple domains and 3-levels skills

Fig. 3 shows a detailed COs design methodology for a summer training course EE 390. The COs were meticulously developed to target essential learning of industrial training activity such as problem solving, design, experimentation, using new tools/equipment/software, teamwork, observing professional ethics and safety standards.

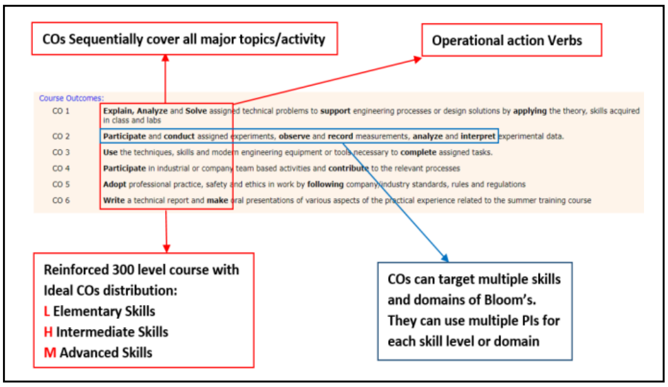
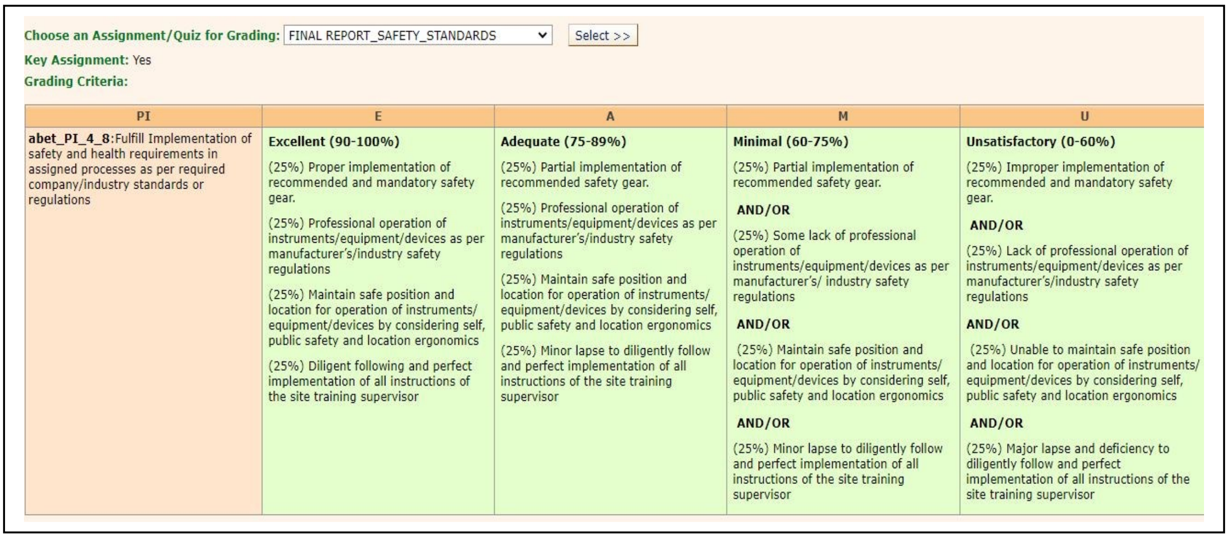


Fig. 3. Detailed COs design methodology for summer training course

Table 1 shows how holistic course delivery is achieved using accurate alignment of COs and their specific PIs which are classified according to Bloom's 3 learning domains and their learning levels. For instance, both CO3 and PI_6_42 are classified as a psychomotor domain of learning and aligned to an *adaptation* learning level. This format for COs design facilitates a holistic delivery of industrial training courses by appropriate selection of learning domains and learning levels for various activities to ensure *Mastery Learning* by using an ideal learning distribution [22]. Detailed topic specific hybrid rubrics which combine both analytic and holistic content are used to guide students for effective management of training activity and accurate estimation of their expected performances [22]. Fig. 4 shows a sample hybrid rubric for PI_4_8: *Fulfill Implementation of safety and health requirements in assigned processes as per required company/industry standards or regulations.*



Choose an Assignment/Quiz for Grading: FINAL REPORT_SAFETY_STANDARDS Select >>

Key Assignment: Yes

Grading Criteria:

PI	E	A	M	U
abet_PI_4_8: Fulfill Implementation of safety and health requirements in assigned processes as per required company/industry standards or regulations	**Excellent (90-100%)** (25%) Proper implementation of recommended and mandatory safety gear. (25%) Professional operation of instruments/equipment/devices as per manufacturer's/industry safety regulations (25%) Maintain safe position and location for operation of instruments/ equipment/devices by considering self, public safety and location ergonomics (25%) Diligent following and perfect implementation of all instructions of the site training supervisor	**Adequate (75-89%)** (25%) Partial implementation of recommended safety gear. (25%) Professional operation of instruments/equipment/devices as per manufacturer's/industry safety regulations (25%) Maintain safe position and location for operation of instruments/ equipment/devices by considering self, public safety and location ergonomics (25%) Minor lapse to diligently follow and perfect implementation of all instructions of the site training supervisor	**Minimal (60-75%)** (25%) Partial implementation of recommended safety gear. **AND/OR** (25%) Some lack of professional operation of instruments/equipment/devices as per manufacturer's/ industry safety regulations **AND/OR** (25%) Maintain safe position and location for operation of instruments/ equipment/devices by considering self, public safety and location ergonomics **AND/OR** (25%) Minor lapse to diligently follow and perfect implementation of all instructions of the site training supervisor	**Unsatisfactory (0-60%)** (25%) Improper implementation of recommended and mandatory safety gear. **AND/OR** (25%) Lack of professional operation of instruments/equipment/devices as per manufacturer's/industry safety regulations **AND/OR** (25%) Unable to maintain safe position and location for operation of instruments/ equipment/devices by considering self, public safety and location ergonomics **AND/OR** (25%) Major lapse and deficiency to diligently follow and perfect implementation of all instructions of the site training supervisor

Fig. 4. Hybrid rubric for implementing safety and health regulations during industrial training

TABLE I. INDUSTRIAL TRAINING COURSE DELIVERY USING COS AND ASSOCIATED PIS

Class: EE_390_276 Summer Training Size: 18	
CO 1 Problem solving /Design	**Explain, Analyze** and **Solve** assigned technical problems to **support** engineering processes or design solutions by **applying** the theory, skills acquired in class and labs
[abet_PI_1_103] Cognitive: Analyzing Observe and practice real engineering problem solving in an engineering industrial environment	
CO 2 Experimentation	**Participate** and **conduct** assigned experiments, **observe** and **record** measurements, **analyze** and **interpret** experimental data.
[abet_PI_6_18] Psychomotor: Adaptation Participate in assigned experiments, observe & record measurements, operation of appropriate test and experimental equipment's, analyze and interpret data	
CO 3 Tools & Techniques	**Use** the techniques, skills and modern engineering equipment or tools necessary to **complete** assigned tasks.
[abet_PI_6_42] Psychomotor: Adaptation Complete tasks assigned by your supervisor or team by using appropriate techniques, skills and modern engineering equipment or tools related to various industrial manufacturing/design/failure analysis/testing and maintenance processes; study company procedures, technical documentation, data sheets, operating instructions; document practical engineering experiences necessary to complete assigned tasks	
CO 4 Teamwork	**Participate** in industrial or company team based activities and **contribute** to the relevant processes
[abet_PI_5_10] Affective: Internalizing values Communicate effectively with assigned supervisors, team members and other stake holders; listen to given instructions; listen to others in the team and create a supportive team environment; effectively coordinate tasks with other team members; and complete assigned tasks in a timely manner	
CO 5 Professional ethics & Safety	**Adopt** professional practice, safety and ethics in work by **following** company/industry standards, rules and regulations
[abet_PI_4_8] Affective: Internalizing values Fulfill Implementation of safety and health requirements in assigned processes as per required company/ industry standards or regulations	
CO 6 Reports & Presentation	**Write** a technical report and **make** oral presentations of various aspects of the practical experience related to the summer training course
[abet_PI_3_9] Affective: Internalizing values Make effective oral presentations in a given time frame to defend field experience activity with required: professionalism, style, slide quality, delivery, response to questions; title, front matter, appropriate English(grammar/spelling/sentence structure); abstract/introduction; description of training program mission or goal of the summer training course; formal introduction of the company visited, relevant training processes; completion of assigned tasks; professional development and overall contribution to field training activities such as case studies/measurements/supervision and design, theory and field applications, research activities, conclusions & recommendations etc.	
[abet_PI_3_1] Affective: Internalizing values Write complete technical reports following appropriate standards, format and style with: title, front matter, list of tables and contents; details of overall organization of the report; proper English(grammar/spelling/sentence structure); neatly labeled sketches/diagrams; abstract/introduction; description of training program mission or goal of the summer training course; formal introduction of the company visited, relevant training processes; completion of assigned tasks; professional development and overall contribution to field training activities such as case studies/measurements/supervision and design, theory and field applications, research activities, conclusions & recommendations etc.	

D. *Performance Criteria*

A structured Faculty Course Assessment Report (FCAR) integrated with PIs uses the Excellent, Adequate, Minimal and Unsatisfactory (EAMU) performance levels in rubrics [15,24]. The EAMU scales are utilized in embedded online assessments to estimate the outcomes results for training performances. Details of EAMU performance scales and a scientific color coded flagging mechanism with heuristic rules is shown below in Table II.

TABLE II. EAMU PERFORMANCE SCALES AND COLOR CODED FLAGS FOR HEURISTIC RULES

Specification of EAMU performance indicator levels:	
Category –Scale%	**Description**
Excellent (E) (90 – 100)	Apply knowledge with virtually no conceptual or procedural errors
Adequate (A) (75 - 90)	Apply knowledge without significant conceptual errors and only minor procedural errors
Minimal (M) (60 – 75)	Apply knowledge with occasional conceptual errors and only minor procedural errors
Unsatisfactory (U) (0 - 60)	Significant conceptual and/or procedural errors when applying knowledge

Heuristic rules for Performance Vector Tables (PVT):	
Category	**General Description**
Red Flag	Any performance vector with an average below 3.3 and a level of unsatisfactory performance (U) that exceeds 10%
Yellow Flag	Any performance vector with an average below 3.3 or a level of unsatisfactory performance (U) that exceeds 10%, but not both
Green Flag	Any performance vector with an average that is at least greater than 4.6 and no indication of unsatisfactory performance (U)
No Flag	Any performance vector that does not fall into one of the above categories

IV. RESEARCH METHOD

This research paper involves study of implementation of state of the art digital technology with cutting edge OBE assessment methodology to remotely deliver holistic industrial training courses. Students are guided throughout the various phases of the industrial work by their training advisors using a versatile online *Biweekly Reporting* tool which is tightly aligned with the COs, PIs and hybrid rubrics. This helps students to remain focused on key learning areas aligned with the intended COs at industrial sites while continuously gauging their performance using rubrics related to each learning activity [25,31]. The *FORUM* tool effectively facilitates communication of individual and group experiences across industrial sites to catalyze collaborative work [25,31]. The performance data for COs and PIs is collected using direct and indirect assessments. The FCAR summative and formative data is quite detailed and for brevity samples of the assessment mechanism are presented in this paper. The course level CQI process dealing with ported old actions, reflections and follow up new actions are also shown. Some essential features of paperless reporting and documentation are displayed. Table III shows number of participating students and industrial sites remotely managed for industrial summer training courses from 2016-20 with EvalTools ® for the EE, ME and CE programs. We then present a course template specially designed and implemented in summer of 2020 for virtual offerings of industrial courses during the COVID19 pandemic. In conclusion, a comparison of the two course models is made and limitations of industrial training course offering during current pandemic conditions and some plausible recommendations for enhancing holistic learning are discussed.

TABLE III. INDUSTRIAL TRAINING PARTICIPANTS AND SITES 2016-20

Program		2016	2017	2018	2019	2020*
EE	Students	20	11	3	15	18
	Sites	5	3	3	12	4
ME	Students	18	17	6	19	19
	Sites	11	10	5	13	4
CE	Students	9	9	19	25	3
	Sites	6	4	13	14	1

*COVID19 course template implemented with virtual student roles

A. Assessment Methodology

The Faculty of Engineering implemented state of the art digital technology and assessment best practices to achieve holistic course delivery with realistic CQI. The following points summarize the essential elements of the integrated quality management system employed to effectively deliver remote industrial training courses:

1. OBE assessment model
2. ABET, EAC outcomes assessment model employing Program Educational Objectives (PEOs), 7 SOs and PIs to measure COs.
3. The FCAR utilizing the EAMU performance vector methodology [15,16,22,23,24].
5. Well-defined performance and heuristics criteria for course and program levels [15,24].
6. A digital database of specific PIs classified as per Bloom's 3 domains of learning and their associated levels [15,16,22,23].
7. Unique Assessments mapping to one specific PI [23].
8.Scientific Constructive Alignment for designing consolidated assessments aligned to specific PIs [16,23,31].
9. Integration of direct, indirect, formative and summative outcomes assessments for course evaluations [16].
10. Calculation of course level ABET SOs, COs data based upon weights assigned to various types of assessments, PIs and course levels [15,16].
11. Online *Biweekly Reporting* tool to guide and assess students with COs, PIs and their hybrid rubrics [15,31].
12. Online *FORUM* communication and collaboration tool to integrate feedback with course management [15,31].

B. FCAR, EAMU Performance Vector Methodology and Web-based Software EvalTools® 6

Web-based software EvalTools® 6 provides electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS), Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating streamlined faculty involvement for achieving realistic CQI. EvalTools® 6 [25] is chosen as the platform for outcomes assessment instead of Blackboard® since it is the only tool that employs the FCAR and EAMU performance vector methodology [24]. This methodology facilitates the use of existing curricular assignments for outcomes assessment to achieve a high level of automation of the data collection process. The EvalTools® 6 FCAR module provides summative/formative options and consists of the following components: course description, COs indirect assessment, grade distribution, course reflections, old action items and new action items, COs direct assessment, PIs assessment, SOs assessment, assignment list, learning domains and skills levels assessment distribution [15,16,22,23,24]. The FCAR uses the EAMU performance vector, conceptually based on a performance assessment scoring rubric, developed by Miller and Olds [26], to categorize aggregated student performance. Heuristic rules and indicator levels for EAMU performance vector have been explained in research work related to the FCAR [15,24].

V. RESULTS

In this section, we present some results of remote offering of industrial training courses by highlighting specific features of the biweekly reporting, FORUM, FCAR assessment and evaluation modules.

A. Biweekly Reporting Tool

The *Biweekly Reporting* tool is the most important online feature of EvalTools ® used by instructors to remotely manage and guide the student industrial training activity. It ensures students remain focused on essential areas of learning such as problem solving, design, experimentation, teamwork, observing professional ethics and safety regulations [25,31]. Fig. 5 shows a sample of the ME program's industrial training activities aligned to COs, PIs for experimental work and guided remotely by advisors. The report consists of three sections dealing with i) *Training Site Information* ii) *Training Aspects Related to COs* and iii) *General Questions*.

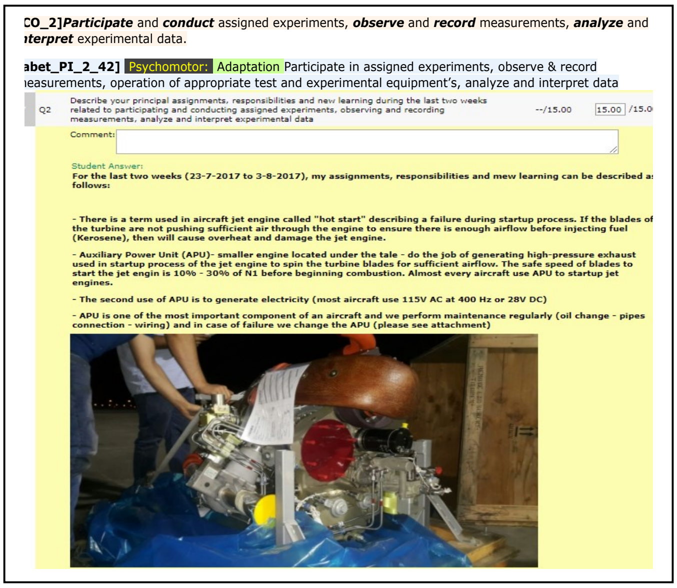


Fig. 5. Biweekly reports aligned to COs and PIs for managing and assessing student industrial training activities

B. FORUM Tool

The FORUM tool is an effective communication and collaboration platform for integrating feedback from industrial training students to course assessment. Students post individual and group experiences and communicate with their colleagues, other teams and their advisors. Advisors are able to post comments, activity, follow up on any query and congratulate student achievements. A comprehensive rubric for grading posts on the FORUM is available for view and application to both students and their advisor [25,31].

C. FCAR Assessment, Evaluation and CQI

As shown in Fig. 6, the FCAR presents several comprehensive reports displaying scientifically color coded, consolidated COs, SOs, PIs histogram plots, summative learning distribution data, and CQI information [15]. Detailed students' EAMU performance results for various assessments linked to each CO are listed sequentially [23]. The FCAR assessment and evaluation reports are comprehensive and details of which cannot be covered by the scope of this paper

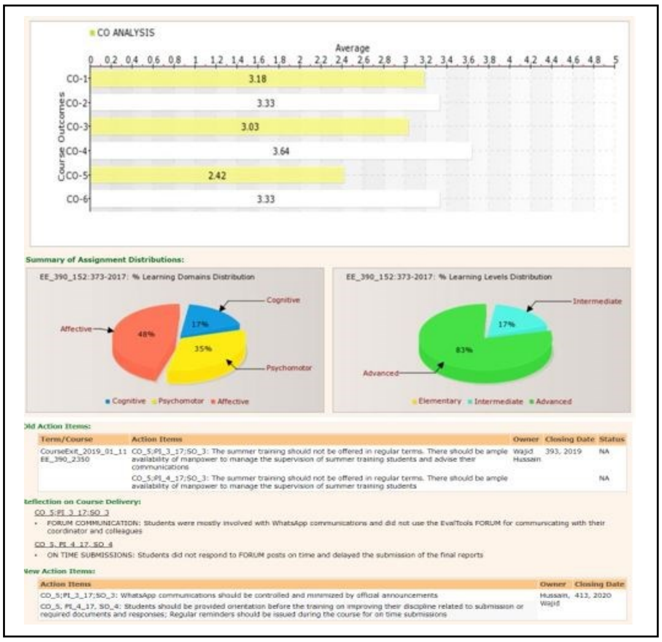


Fig. 6. . Section of FCAR evaluation report showing consolidated COs plot, learning distribution and CQI information

VI. Training Course Template During Covid19

In many countries, current pandemic conditions have limited mobility and routine business activity. The education sector in particular, has drastically shifted to online digital solutions as a substitute for regular in-person class, training, examination or administrative activity. Especially, off campus industrial training courses could not offer students the privilege of direct physical participation in onsite engineering activity. To make up for the loss in learning due to lack of direct industry exposure, we present a course template that would offer students a reasonable remote and virtual learning experience as an alternative to an onsite in-person participation. As shown in Table III, this course template was offered to 40 engineering students in the summer term of 2020. Assessment of various activity was carried out by the vocational committee and the advisor. The COs and PIs for this template remain unchanged. However, the assessment criteria are modified. A set of criteria was outlined for qualification of the training plan:

1. Training plan should be relevant to the area of specialization and comprehensively cover all COs.
2. Training plan should involve virtual observation and remote participation of relevant engineering activity.
3. Industrial organization for summer training can be designated by recommendation of advisor and/or student selection.

The criteria for an acceptable organization are:

1. Availability of an authorized industry supervisor; and/or
2. Availability of industry related training activity and associated information on public domain; and
3. Sufficient training information to comprehensively cover all COs.

TABLE IV. Assessment Policy - Virtual Training Course

Assessment	% Total Grade	Passing Grade	Action if Not Passed
Training Plan Evaluation^{VC}	15%	9 %	Repeat training
Interim Evaluations 1&2^{A} (viva 3rd & 6th weeks)	12 %	18 %	-
Bi-weekly Reports (1-4)^{A}	12 %		
FORUM Communication^{A}	4 %		
Timely Report Submission^{A}	2 %		
Final Written Report^{VC}	25%	15%	Resubmit report
Oral Presentation^{VC}	30%	18%	Repeat presentation

VC Vocational Committee; A Advisor

Table V shows the schedule for a comprehensive training plan consisting of 11 phases. A top down approach is adopted to instill a holistic industrial learning experience blended with key elements of entrepreneurship as per the Saudi Vision 2030 [27]. The students begin with reviewing the history of the industry, organization, organizational structure, business model and target markets. They then select a department and virtual engineering role to work in. Students construct the operational structure and process flow of their department using information either directly from the organization's website or extracted from other sources on the public domain such as research literature, technical blogs or YouTube videos. The professional engineering experience I & II involve problem solving, design, experimentation, teamwork activity for which students employ remote labs or virtual training roles to simulate relevant activity approved by advisors. According to research [28, 29, 30], several options for remote, simulation and virtual laboratories are available and offered by either established universities or other private and governmental initiatives such as Virtual Labs ® by EDX, V-labs ®, Virtual Engineering ®, Labster ®, Praxilabs ® etc. In phase 10, students critically analyze their virtual engineering experience by comparing key aspects of the work environment for their organization, with that of a competitor. Finally, they submit a final report as per given template and make remote streaming video presentations in defense of their training experience.

TABLE V. Schedule of Phases. Learning Activity and Assessment for Summer Training Course with Virtual Student Roles

Week	Phase	Activity	Assessment	Resources
-1	**1. Assignment of Engineering Areas:** Vocational committee would provide a list of engineering areas to students to select their choice of industry for training.	Advisors assignment	N/A	Vocational Committee
-1	**2. Team Formation & Select Organization:** Form student summer training course teams of 3-4 students each; select organization for completing the summer training plan with access to sufficient information on public domain that comprehensively cover all subsequent phases listed below including all course outcomes; submit an initial training plan proposal with references that provide adequate information for completion of your summer training course.	1) Team formation 2) Select organizations which fulfill training plan requirements	N/A	Vocational Committee + Advisor + Web search
0	**3. Review and Approve Training Plan:** Vocational committee to review and approve teams and proposed training plans.	Finalization of training plan which covers all COs	Training Plan Proposal	Vocational Committee
1	**4. Overview of Industry and Organization:** Explain the history of industry and relation with area of engineering selected; history of organization, branches; commercial and/or scientific focus of organization; elaborate on the overall engineering concept(s) applied for commercialization; products and services; target markets; local and international competitors;	Collaborative Work, Research and Report	1. BWR1 2. Forum	▪ Web search ▪ Corporate web sites

2	**5. Organizational and Operations Structure and Flow:** Provide mission statement; organizational structure and hierarchy; elaborate on overall operational structure and process flow for delivery of final products and services; ISO status; quality standards of products and services; key aspects of organizational, operational ethics, team work; implementation of overall safety, and international or local regulatory standards followed;	Collaborative Work, Research and Report	1. BWR1 2. Forum	▪ Corporate web sites
3 & 4	**6. Overview of Major Departments and Operations:** Broadly overview role and functioning of major departments; operational structure and process flow for some key functions such as prototyping, large scale manufacturing, testing, research, engineering service; high level focus on engineering design, problem solving, experimentation; brief overview of application and use of novel technology, software and equipment; team work, professional ethics, quality standards, corporate culture;	Collaborative Work, Research and Report	1. Viva1 2. BWR2 3. Forum	▪ Corporate web sites ▪ Technical blogs ▪ YouTube
5	**7. Your Training Department and Role:** Select a specific department of the organization and virtual engineering position to work in; provide the mission statement of the this department; explain why you selected this department and position with consideration of your personal interests, academic strengths in relation to skills sets and knowledge areas, research and career prospects; describe the role of your department in the overall operational process of the organization; explain in detail the job function of the virtual engineering position you selected;	Collaborative Work, Research and Report	1. BWR3 2. Forum	▪ Corporate web sites ▪ Technical blogs ▪ YouTube ▪ Job sites (Linkedin)
6	**8. Professional Engineering Experience-I:** Observe, identify and report in detail engineering problem solving, design and experimentation processes and activity conducted in your department and role; explain state of the art technology, software or equipment you found in use and its benefits and/or limitations;	Collaborative Work, Virtual Observation, Remote Participation, Study and Report	1. Viva2 2. BWR3 3. Forum	▪ Corporate web sites ▪ Technical blogs ▪ YouTube ▪ Research Literature ▪ Virtual labs ▪ Training courses
7	**9. Professional Engineering Experience-II:** Use any purchased or open source tools, software for simulating some engineering activity relevant to your role and explain your experience; elaborate on the Quality Assurance process and list any ISO, safety or other regulatory codes followed in your department and role; observe, identify and report professional ethics, team work and corporate culture exhibited in your department and role;	Collaborative Work, Virtual Observation, Remote Participation, Study and Report	1. BWR4 2. Forum	▪ Corporate web sites ▪ Technical blogs ▪ YouTube ▪ Research Literature ▪ Virtual labs ▪ Training courses
8	**10. Critical Analysis:** Critically compare any aspect(s) of this department's engineering activity, equipment, process or work environment with that of another organization; elaborate on any risks or hazards you were exposed to; critically analyze the final product, service with respect to realistic constraints such as economic, environmental, safety/health, sustainability, political, societal etc.; explain what you liked about your role, any possible caveats to working in this department or organization; provide any recommendations for improvement; list any possible research topics that you could identify for your final year Capstone Design Project;	Collaborative Work, Critical Analysis and Report	1. BWR4 2. Forum	▪ Corporate web sites ▪ Technical blogs ▪ YouTube ▪ Research Literature
9	**11. Submit Final Report and Make Oral Presentations:** Submit final report; cover all aspects of the 6 phases (2-8) of your summer training activity as per given template; include the phase 8 into conclusions of your report; make an elaborate streaming video presentation of your summer training experience; cover all 8 phases while comprehensively addressing all the course outcomes; provide adequate references of all citations to information related to the organization;	Report and Video Presentation	Final Report & Presentation	▪ Final report & Presentation template

VII. Discussion and Conclusion

The purpose of this study is to examine the benefits and limitations of using an outcome based digital platform for remote offering of industrial training courses. As per the literature review presented in the introduction to this paper, remote management of industrial courses is a complex affair and requires advanced digital technology and supporting assessment methodology to implement holistic learning. The most intricate part is to remotely manage and assess student training activity according to the intended COs in an off campus location. The *Biweekly Reporting*, collaborative *FORUM* tools and remote employer online surveys are specially designed to ensure that the COs are integrated with every major phase of training to help advisors guide students in a progressive manner and achieve *Mastery Learning*. Automatically generated real-time performance information and state of the art features for effective monitoring and on time feedback facilitate seamless alignment of student learning activity with the intended COs. The Faculty of Engineering EE, ME and CE programs successfully managed training activity for 171 students remotely by using web-based software EvalTools ® during the years 2016-19 at 99 regional and international industrial sites.

Onsite in-person training provides holistic learning opportunities involving hands-on practical experience and required exposure to professional ethics, collaborative work and quality standards related to real-life engineering situations at industrial sites that cannot be adequately gained in virtual roles. The Office of Quality and Accreditation performed a qualitative analysis of the learning distribution coverage in Bloom's 3 domains for COs related to onsite and virtual offerings of industrial training courses by collecting feedback from two leading international OBE and assessment experts. The results of this analysis in Table VI show that excepting for a medium (M) coverage for COs learning distribution in the cognitive domain, both psychomotor and affective domains exhibit a low (L) learning distribution. Therefore, adequate development of skills in the affective and psychomotor learning domains would be difficult to achieve in virtual training.

TABLE VI. COs Learning Distribution for Onsite and Virtual Offering of Industrial training Courses

CO	Onsite			Virtual		
	C	P	A	C	P	A
1 Problem solving, design	H	H	H	M	L	L
2 Experimentation	H	H	H	M	L-M	L
3 Techniques, Tools	H	H	H	M	L	L
4 Teamwork	H	H	H	M	L	L
5 Professional ethics, safety	H	H	H	M	L	L

C Cognitive P Psychomotor A Affective

However, engineering programs can still consider a virtual role as a viable, but temporary alternative to onsite training if the course plan would help students remotely achieve acceptable levels of cognitive learning related to problem solving, design, experimentation, professional ethics, and collaborative work at state of the art industrial sites. Adequate levels of cognitive learning have been achieved at IU by remotely conducting detailed case studies involving problem solving, design or experimentation in select engineering roles while focusing on fulfilment of specific quality standards and professional ethics. Essential aspects of this engineering activity were then replicated on a reduced scale using virtual labs, simulation or other tools.

Research Question 1: *Can web-based digital software be utilized for effective remote offerings of industrial training courses?* Yes. State of the art modules of EvalTools ® such as *Biweekly Reporting*, *FORUM*, digital database of PIs and hybrid rubrics, and FCAR facilitate effective management of remote course delivery, assessment and CQI.

Research Question 2: *Do virtual engineering roles in remote offerings of industrial courses help students gain adequate practical experience and transversal skills?* No. The results of a qualitative analysis shown in Table VI indicate that virtual roles can achieve acceptable levels of cognitive learning related to several essential elements of industrial training activity but cannot attain adequate learning distribution in both psychomotor and affective domains.

In summary, this study presents a viable but temporary alternative to onsite industrial training during global pandemic conditions by offering students a versatile course template that comprises of virtual engineering roles blended with essential entrepreneurial knowledge and skills.

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ABET Accreditation During and After COVID19 - Navigating the Digital Age

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Abstract:
Engineering accreditation agencies and governmental educational bodies worldwide require programs to evaluate specific learning outcomes information for attainment of student learning and establish accountability. Ranking and accreditation have resulted in programs adopting shortcut approaches to collate cohort information with minimally acceptable rigor for Continuous Quality Improvement (CQI). With tens of thousands of engineering programs seeking accreditation, qualifying program evaluations that are based on reliable and accurate cohort outcomes is becoming increasingly complex and is high stakes. Manual data collection processes and vague performance criteria assimilate inaccurate or insufficient learning outcomes information that cannot be used for effective CQI. Additionally, due to the COVID19 global pandemic, many accreditation bodies have cancelled onsite visits and either deferred or announced virtual audit visits for upcoming accreditation cycles. In this study, we examine a novel meta-framework to qualify state of the art digital Integrated Quality Management Systems for three engineering programs seeking accreditation. The digital quality systems utilize authentic OBE frameworks and assessment methodology to automate collection, evaluation and reporting of precision CQI data. A novel Remote Evaluator Module that enables successful virtual ABET accreditation audits is presented. A theory based mixed methods approach is applied for evaluations. Detailed results and discussions show how various phases of the meta-framework help to qualify the context, construct, causal links, processes, technology, data collection and outcomes of comprehensive CQI efforts. Key stakeholders such as accreditation agencies and universities can adopt this multi-dimensional approach for employing a holistic meta-framework to achieve accurate and credible remote accreditation of engineering programs.

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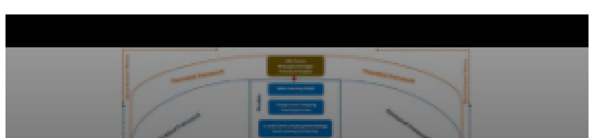

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ABET Accreditation During and After COVID19 - Navigating the Digital Age

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ABSTRACT Engineering accreditation agencies and governmental educational bodies worldwide require programs to evaluate specific learning outcomes information for attainment of student learning and establish accountability. Ranking and accreditation have resulted in programs adopting shortcut approaches to collate cohort information with minimally acceptable rigor for Continuous Quality Improvement (CQI). With tens of thousands of engineering programs seeking accreditation, qualifying program evaluations that are based on reliable and accurate cohort outcomes is becoming increasingly complex and is high stakes. Manual data collection processes and vague performance criteria assimilate inaccurate or insufficient learning outcomes information that cannot be used for effective CQI. Additionally, due to the COVID19 global pandemic, many accreditation bodies have cancelled onsite visits and either deferred or announced virtual audit visits for upcoming accreditation cycles. In this study, we examine a novel meta-framework to qualify state of the art digital Integrated Quality Management Systems for three engineering programs seeking accreditation. The digital quality systems utilize authentic OBE frameworks and assessment methodology to automate collection, evaluation and reporting of precision CQI data. A novel *Remote Evaluator Module* that enables successful virtual ABET accreditation audits is presented. A theory based mixed methods approach is applied for evaluations. Detailed results and discussions show how various phases of the meta-framework help to qualify the context, construct, causal links, processes, technology, data collection and outcomes of comprehensive CQI efforts. Key stakeholders such as accreditation agencies and universities can adopt this multi-dimensional approach for employing a holistic meta-framework to achieve accurate and credible remote accreditation of engineering programs.

INDEX TERMS OBE, ABET, outcomes, assessment, performance indicators, program evaluation, continuous quality improvement (CQI).

I. INTRODUCTION

Outcome Based Education (OBE) is an educational theory that bases every component of an educational system on essential outcomes. At the conclusion of the educational experience, every student should have achieved the essential or culminating outcomes. Classes, learning activities, assessments, evaluations, feedback, and advising should all help students attain the targeted outcomes [1]–[7], [67]. OBE models have been adopted in educational systems at many levels around the world [8], [9]. A list of current signatories of the Washington Accord presents strong evidence of a global migration towards OBE [10]. The Accreditation Board of Engineering and Technology (ABET) is a founding member of the Washington Accord since 1989 [11]. Recently, the Canadian Engineering Accreditation Board (CEAB) updated its accreditation criteria to adopt the OBE model [12]. In 2014, the National Commission of Academic Accreditation and Assessment (NCAAA) in Saudi Arabia was established, using the OBE model [13]. This shift makes institutions focus more on assessing the expected learning outcomes rather than the quality of the

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offered curriculum. However, competition to improve rankings of programs has forced many institutions to pursue minimal requirements (for speed) during accreditation processes [14]–[16], [67]. Accreditation was the prime driver for outcomes assessment [14], [15] and the topic of more than 1,300 journal articles between 2002 and 2004 [17]. Consequently, several aspects of established accreditation processes in many institutions may not truly reflect the paradigm and principles of authentic OBE [16]–[22], [67]. Another exhaustive systematic study of 99 research articles by Cruz, Saunders-Smits and Groen (2019) [23] concluded that due to global accreditation requirements the number of published studies from 2000 to 2017 related to assessment and evaluation of transversal skills had significantly increased. They observed that international quality standards for assessment and evaluation of transversal skills such as communication, innovation/creativity, lifelong learning or teamwork were undefined and deficient. Specifically, inadequate standards of language of learning outcomes, validity and reliability of assessments, and vague rubrics, all exacerbated the evaluation of transversal skills.

The current format of measuring ABET, Engineering and Accreditation Commission (EAC) revised 7 Student Outcomes (SOs) and associated Performance Indicators (PIs), and evaluation of the alignment of the Program Educational Objectives (PEOs) is definitely a cumbersome affair for programs and institutions that utilize manual processes. The general advice provided was to be selective in using assessments for measuring these SOs to minimize overburdening faculty and program efforts for accreditation [11], [24], [67]. This may be acceptable for the fulfillment of accreditation criteria, but from the OBE model, student-centered point of view, it does not facilitate CQI. Consequently, assessments become deficient, tend to become summative and do not include formative processes, since good assessment practice refers to all activities which can provide necessary feedback to revise and improve instruction and learning strategies [25], [26]. Additionally, the learning outcomes data measured by most engineering institutions is rarely classified into all three learning domains of the revised Bloom's taxonomy [27] and their corresponding categories for levels of learning. Generally, institutions classify courses of a program curriculum into three levels: *Introductory*, *Reinforced*, and *Mastery*, with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for effective program evaluations. This approach presents a major deficiency for CQI in a student-centered OBE model because performance information collected at just the *Mastery* level is at the final phase of a typical quality cycle and is too late for implementing remedial efforts. Instead, student outcomes and performance information should progress from the elementary to advanced levels and must be measured at all course levels for the entire curriculum [24], [28], [29], [67]. A holistic approach for a CQI model would include a systematic measurement of PIs in all three Bloom's domains of learning and provide information on attainment of learning within each domain's learning levels.

Compliance for outcomes assessment has been quoted by many [22], [30]–[36], [67] as a major issue in achieving realistic CQI. Many faculty members are not keen to get involved in the assessment process, mostly because the manual assessment and evaluation tools employed lack integration of essential components, require manual data entry, and multiple analytical computations to often yield results which do not accurately represent the actual state of student learning. Instructors are, therefore, unable to realize the tangible benefits of using valid outcomes assessment processes that enhance teaching and learning in an authentic OBE model. Myriad complexities attributed to improper tools that do not integrate multiple components of direct/indirect outcomes assessment for identification of failures, remedial actions and CQI may be identified as the root cause for the lack of faculty involvement. Therefore, there is a dire need to explore ways to improve faculty engagement in the assessment process at the course and program levels. A paper-free web-based digital system with a user-friendly interface would help encourage faculty participation while integrating multiple outcomes assessment processes for CQI. The indispensable necessity of the state of the art digital solutions to automate and streamline outcomes assessment for achieving excellent CQI results and accreditation has been adequately explained in research literature [20], [32], [34]–[37], [67].

ABET's CQI criterion CR4 requires programs to track quality improvement resulting from corrective actions for failures in student performance extracted from evaluating outcomes at the course and program levels [11]. Gloria Rogers' training slides suggest that quality processes can take about 6 years to fully complete a cycle of assessment and evaluation activity. Therefore, ABET evaluators generally require 6 years of CQI data to be available in record with programs and at least 2 years of well documented course materials, SOs based objective evidence and other CQI information as display material during audit visits [11]. A detailed study of an accreditation effort in Canada, in 2011, estimated that the University of Alberta, Edmonton engineering programs spent more than a million dollars, collected more than a ton of data and exhausted more than 16,000 hours of preparation time for the Canadian Engineering Accreditation Board (CEAB) accreditation visit [19]. Similarly, engineering programs worldwide allocate staggering amounts of time and resources for preparing CQI data and display materials for accreditation, but unfortunately, since they employ manual CQI processes, assessment and evaluation data is often deficient and lacks the rigor and quality required by a student-centered authentic OBE model to attain the required standards of holistic learning. Jeffrey Fergus, chair of the ABET Engineering Accreditation Commission (EAC) also echoed a similar opinion regarding ABET's criterion 4, CR4 or *Continuous Improvement* as being the most challenging for engineering programs worldwide [39]. Several aspects of manual CQI models have been highlighted as being problematic such as standards of learning outcomes statements, vague performance criteria, lack of topic-specific analytic rubrics, reliability and validity issues with assessment and evaluation criteria, random sampling of outcomes data, lack of proper alignment, lack of comprehensive coverage of Bloom's three domains of learning, lengthy quality and evaluation cycles, inability to achieve real-time learning improvements in cohorts etc. [21]–[26], [28], [29], [42], [43], [44], [46], [49], [67].

Several digital solutions have been proposed in recent literature to alleviate the aforementioned issues with manual CQI systems [19], [20], [32], [34]–[37], [40], [41], [45]–[48], [67]. In consideration of the latest ground breaking developments related to digital automation of CQI processes, several accreditation bodies such as ABET have incorporated special terms in their accreditation policy (*I.E.5.b.(2))* to accommodate engineering programs that choose to maintain digital display materials for accreditation audits [11]. Several ABET symposia conducted in the last 5 years have consistently presented digital technology as viable options for automating the otherwise cumbersome manual CQI processes [11]. Additionally, the COVID19 global pandemic conditions, by force majeure, have altered the normal protocol of onsite accreditation visits. Many accreditation agencies have either deferred or announced virtual visits for the upcoming accreditation cycles [10]–[13], [18], [50], [51]. Virtual visits would mandate engineering programs to maintain digital documentation for reporting CQI information to enable remote audits. Therefore, the current prolonged pandemic conditions resulted in an unplanned and inadvertent boom in the digitization of education. This means both accreditation agencies and engineering programs have challenges to develop guidelines and frameworks for implementing CQI systems using practical digital solutions that are based on authentic OBE frameworks and fulfill the requirements of international engineering quality standards.

The two top standards of the Council for Higher Education Accreditation, (CHEA) recognition criteria as stated by Eaton (2012) are 1) *Advance academic quality*: accreditors have a clear description of academic quality and clear expectations that the institutions or programs they accredit have processes to determine whether quality standards are being met and 2) *Demonstrate accountability*: accreditors have standards that call for institutions and programs to provide consistent, reliable information about academic quality and student achievement to foster continuing public confidence and investment [38]. Now, with thousands of engineering programs seeking accreditation in the US alone, and given the list of issues prevalent in CQI processes, qualifying credible program evaluations based on reliable and accurate outcomes information is becoming increasingly complex, high stakes and far reaching. Accreditation agencies are faced with a challenging task of implementing high standards, encompassing auditing frameworks and processes with fully trained staff to remotely examine and qualify CQI systems employed by engineering programs. The IEA and ABET have therefore, not indicated any changes in their accreditation criteria after COVID19 [10], [11]. However, the auditing frameworks should encompass essential OBE theory, best practices for assessment, use of digital quality systems, automated data collection and reporting mechanisms, to remotely audit programs' CQI efforts for the attainment of SOs.

In this research, we explore a meta-framework for examining Integrated Quality Management Systems (IQMS) implemented at the Faculty of Engineering programs for ABET accreditation using Mixed Methods Theory Based Impact Evaluations (MMTBIE) [52]. Evaluations that focus on summative program outcomes sometimes are called impact evaluations [53]. The Evaluation Gap Working Group (2006) concluded as part of the consideration of credible program evaluations that many impact evaluations fail to provide strong evidence because, even when changes are observed after the program has been initiated, often, the evaluators are unable to demonstrate that the changes were likely caused by the underlying program—potentially leading at best to unsubstantiated evidence, and at worst to misleading or even harmful conclusions [53]. A succinct statement of research findings made by the Evaluation Gap Working Group (2006) clearly sums up a general state of current program interventions, "*Of the hundreds of evaluation studies conducted in recent years, only a tiny handful were designed in a manner that makes it possible to identify program impact*" (p. 17) [53]. Onwuegbuzie and Hitchcock (2017) stated that programs in education that are currently taking place across various countries, or are being planned, need rigorous impact evaluations that provide trustworthy evidence of change for future decision making [52]. They noted that to date, the majority of impact evaluations across various fields, including the field of education, have involved the use of quantitative methods, namely, experimental methods, quasi-experimental methods, and non-experimental methods [54]. However, as per the work of James Bell Associates (2008), qualitative methods are preferred over quantitative ones, especially when examining process effects, whereby data are collected on a regular and continual basis to monitor and describe how specific services, activities, policies, and procedures are being implemented throughout the program [55]. Qualitative methods are also employed when conducting a theory-based impact evaluation, wherein the causal chain from inputs to outcomes and impact are mapped out, and the assumptions underlying the intervention are tested [56]; or when conducting what is known as a participatory impact assessment, whereby staff work with local stakeholders to develop their own evaluation [57]. The principle of mixing methods has a long history in program evaluation work [58] which continues to the present [59], but unfortunately, mixed methods techniques have probably been underutilized in impact evaluations. Onwuegbuzie and Hitchcock (2017) emphasized a strong need for an evaluation meta-framework that is comprehensive, flexible, and meets enhanced complexity of programs. Their work provided a new and comprehensive definition of impact evaluations—called comprehensive impact evaluation—that draws out the importance of collecting and analyzing both quantitative and qualitative data, thereby resulting in a rigorous approach that can allow for strong inferences. Based on Donaldson's (2007) [60] view they expanded mixed methods impact evaluations by incorporating evaluation theory (i.e., guiding criteria that indicate what an appropriate evaluation is and how evaluation should be conducted), social science theory (i.e., a framework for understanding the nature and etiology of desired or undesired outcomes and for developing intervention strategies for influencing those outcomes), and/or program theory (i.e., checking assumptions that underlie the specific interventions and how they are expected to bring about change). Building on White's (2009) work [61] dealing with theory-based impact evaluations, they outlined an 8-phase MMTBIE:

Phase 1: understand the local and broader context;
Phase 2: understand the construct(s) of interest;
Phase 3: map out the causal chain that explains how the intervention is expected to produce the intended outcomes;
Phase 4: collect quantitative and qualitative data to test the underlying assumptions of the causal links;
Phase 5: determine the type and level of generalizability and transferability;
Phase 6: conduct a rigorous evaluation of impact;
Phase 7: conduct a rigorous process analysis of links in the causal chain; and
Phase 8: conduct a meta-evaluation of the process and product of the MMTBIE.

The phases are arbitrary but based on prior work related to theory based impact evaluations, they follow the general steps for evaluation. In this study, we discuss various aspects of relevant phases of this meta-framework and utilize key elements of the 8 phases as indicators to examine the CQI processes implemented at the Electrical Engineering (EE), Civil Engineering (CE) and Mechanical Engineering (ME) programs of the Islamic University in Madinah. Engineering programs seeking accreditation and quality standards in a digital age during and after the COVID19 global pandemic, would therefore, benefit from publications that provide detailed and practical guiding frameworks based on an authentic OBE model, to help implement state of the art digital quality management systems, that seamlessly automate collection and reporting of CQI data for remote audits. Program evaluation using a novel meta-framework presented in this study, would help accreditation auditors consider a range of aspects such as the context, construct, causal links, processes, technology, data collection and outcomes results of CQI activity required for credible remote audits of automated digital quality systems.

II. PURPOSE OF STUDY

The driving force behind this research is to examine the benefits and limitations of the application of essential theory of an authentic OBE model for the implementation of a holistic and comprehensive educational process that maximizes opportunities for the attainment of successful student learning. The objective is to conduct a MMTBIE of state of the art IQMS implemented at the Faculty of Engineering's EE, CE and ME programs (2014-20) using digital technology and OBE methodology for ABET accreditation. In particular, the researchers sought to answer research questions that would help the engineering programs fulfill ABET EAC criterion related to CR4, *Continuous Improvement* [11]. Do the IQMS implemented at the EE, CE and ME programs:

1. Adequately fulfill essential elements of the philosophy, paradigm, premise and principles of authentic OBE?
2. Comprehensively cover all aspects of ABET's outcomes assessment model?
3. Include sustainable instruments or processes for data collection and reporting of learning outcomes information?
4. Provide a listing and description of the assessment processes used to gather the data upon which the evaluation of each student outcome is based? (ABET, 2019 EAC criteria, self-study template, CR4: section A.1)
5. Achieve a practical and manageable frequency of carrying out assessment processes? (ABET, 2019 EAC criteria, self-study template, CR4: section A.2)
6. Provide performance criteria and heuristic rules to clearly indicate the expected level of attainment for each of the student outcomes? (ABET, 2019 EAC criteria, self-study template, CR4: section A.3)
7. Provide summaries of the results of the evaluation process and an analysis illustrating the extent to which each of the student outcomes is being attained? (ABET, 2019 EAC criteria, self-study template, CR4: section A.4)
8. Provide tools and resources to effectively document and maintain the results of evaluations? (ABET, 2019 EAC criteria, self-study template, CR4: section A.5)
9. Clearly indicate generated corrective actions and a follow-up sequence to closure? (ABET, 2019 EAC criteria, self-study template, CR4: section B)
10. Provide a practical example to support engineering programs and accreditation agencies for seamless implementation and remote evaluation of quality standards in engineering education using digital technology during the COVID19 pandemic and beyond?

III. RESEARCH FRAMEWORK

A. METHODOLOGY

This research involved an OBE theory based qualitative analysis of benefits and limitations of manual and automated CQI systems obtained using a selective literature review covering accreditation topics in relevant engineering education and educational psychology literature. An in-depth description of the theoretical, conceptual and practical frameworks are followed by quality management details of the 6 Plan Do Check Act (PDCA) quality cycles. The main features of the EvalTools® *Remote Evaluator Module's* scientific collation and reporting of digital CQI data on a cloud-based environment are examined [67]. A summary of a qualitative comparison of various types of CQI data and key aspects of the manual and automated approaches for their reporting

TABLE 1. Appendices summarizing evidentiary information for evaluation of IQMS using a novel meta-framework.

Appendices	Process/ Technology	Tools/ Instruments	Survey Results	Meeting Minutes	Reports
A: Faculty Course Assessment Report (FCAR)	✓	✓			✓
B: Performance Vector Table, Course & Program Level WFs	✓	✓			
C: PIs & Hybrid Rubrics	✓	✓			
D: SOs, PIs & Learning Domains Evaluations	✓	✓			✓
E: SOs, PIs Executive Summary Reports				✓	✓
F: Academic Advising Based on Outcomes	✓	✓			✓
G: Continuous Improvement Management Systems (CIMS)	✓	✓		✓	
H: Sustainability & Course Work Load		✓			
I: EvalTools® Remote Evaluator Module	✓	✓			
J: 6 PDCA Quality Cycles	✓	✓	✓	✓	✓
K: Meta-analyses Results	✓	✓	✓	✓	✓

is presented. Finally, we explore the application of a meta-framework for examining IQMS for achieving ABET accreditation, based on a recent study proposing MMTBIEs [52] that outlined 8 phases following the general steps for evaluation.

In this study, we will utilize the recommended conditions, actions, and specific questions of the 8 phases of the MMTBIEs meta-framework as indicators to examine the IQMS implemented at the Faculty of Engineering. The results of this study provide a multidimensional approach for rigorous remote verification of increasingly complex and high stakes evaluations based on reliable and accurate cohort learning outcomes for engineering programs and accreditation agencies. The MMTBIE approach presented comprehensively fulfills the requirements of ABET accreditation criterion, CR4 on Continuous Improvement. The findings of this study are expected to enlighten decisions by accreditation bodies and engineering programs to select the right course of action during and after the COVID19 global pandemic for collection, documentation and reporting of massive amounts of CQI data required for remote engineering accreditation audits. Appendices attached to this paper provide necessary evidentiary information related to the processes and technology implemented in the 6 PDCA quality cycles, tools/instruments used, survey results, relevant meeting minutes of program level quality improvement decisions, samples of CQI reports, and tabulated results of evaluation using the meta-framework. Table 1 summarizes the evidentiary information provided in the appendices.

B. PARTICIPANTS

The MMTBIE of the IQMS implemented at the Faculty of Engineering EE, CE and ME departments from 2014 to 2019 involved 43 faculty members and 823 students from multiple cohorts of the 4-year bachelor of science programs.

C. MANUAL AND AUTOMATED CQI SYSTEMS – A QUALITATIVE ANALYSIS

A selective literature review related to engineering program evaluations for accreditation was completed to conduct an effective OBE theory based qualitative analysis of CQI systems. We primarily considered research on accreditation topics in popular engineering education and educational psychology journals and conference proceedings spanning the last 15 years. The results of the literature review were parsed using an OBE theory based qualitative analysis of CQI systems to yield the summary below:

1. Accreditation is the prime driver for outcomes assessment for most higher education institutions in the US and worldwide [14], [15], [17].
2. Most essential principles of authentic OBE philosophy and paradigm are either not targeted nor achieved [14], [19], [21]–[24], 28], [29], [42], [46], [49], [55], [62], [67].
3. Learning models are generally not understood and used comprehensively as the founding framework for CQI efforts [3], [16], [42], [49], [62], [67]
4. Language of Course Outcomes (COs) and associated PIs is deficient and lacks alignment with actual learning activities [3], [16], [28], [29], [42], [49], [62]–[64], [67].
5. PIs are mostly generic and lack the required specificity to achieve required validity and reliability in assessment and evaluation [16], [21], [23], [24], [26], [28], [29], [35], [40]–[42], [46], [49], [67]–[69].
6. Most rubrics are generic, simplistic and vague, and lack the necessary detail to accurately assess several hundred complex student learning activities of any engineering specialization [16], [21], [24], [42], [67]–[69].
7. Majority of assessment models just target learning activity in the cognitive domain. Learning activity related to psychomotor and affective domains are mostly, not assessed [6], [16], [20]–[22], [24], [28], [29], [40]–[42], [46], [49], [62], [64], [67]–[69].
8. CQI information for all students is not collected, documented or reported [5], [19], [22], [24], [26], [28], [29], [35], [40]–[42], [43], [44], [53]
9. Most program evaluations are based on a small set of random samples of student activity [20], [22], [24], [28], [29], [35], [40], [41], [44], [46], [67], [70]–[74].
10. Independent raters are used to apply generic rubrics to past course portfolios [35], [41], [42], [46], [67], [70], [72], [74].
11. Real-time corrective actions using formative assessments are rarely implemented [22], [24], [28], [29], [35], [36], [41], [43], [44], [67], [72].
12. Course evaluations do not incorporate appropriate weightage for aggregating outcomes results from various types of assessments [22], [24], [40], [46], [49], [67].

13. Program evaluations do not incorporate appropriate weightage for aggregating multiple course and skill levels [20], [24], [36], [40], [41], [46], [49], [63], [67].
14. CQI efforts are not realistic and programs mostly employ reverse engineering to link corrective actions to outcomes evaluations results [24], 34], [36], [37], [41], [43], [46], [67]
15. Academic advising systems are not based on student outcomes information [35], [67]

The findings of this selective literature review helped identify several major issues with prevalent manual CQI systems, and also reinforced our opinions developed from first-hand observations of more than a decade of regional and international accreditation and consulting experience. In summary, the several issues highlighted, contradict fundamental OBE frameworks, implement obsolete assessment practices or work against the fundamental principles of CQI. Programs and accreditation agencies should ensure that authentic OBE theory is the foundational source from which assessment concepts are induced, those, in turn would support the development of practical frameworks to implement sustainable CQI systems. Accountability of programs through evaluating student achievement is intrinsically important for governing bodies and key stakeholders, as it reinforces and provides monitoring of high standards and rigor in engineering programs.

IV. THEORETICAL, CONCEPTUAL AND PRACTICAL FRAMEWORKS

The philosophy, paradigm, premises and principles of Authentic OBE form the basis for theoretical frameworks that lead to the development of crucial models which act as the foundation of the IQMS implemented at the Faculty of Engineering. Several essential concepts are then induced from OBE theory, best practices for assessment and ABET criterion 4, CR4 on continuous improvement. Essential techniques and methods based on this conceptual framework are then used to construct a practical framework consisting of automation tools, modules and digital features of a state of the art, web-based software, EvalTools® [48]. As shown in Figure 1, EvalTools® facilitates seamless implementation of CQI processes based on an authentic OBE model and consisting of 6 comprehensive Deming-Shewart (1993), PDCA quality cycles [65]:

Q_1: COs, PIs and hybrid rubrics development
Q_2: Course evaluation, feedback and improvement
Q_3: Program term review
Q_4: PIs 3-year multi-term review
Q_5: SOs Multi-term review
Q_6: PEOs 5-year review

A. THEORETICAL FRAMEWORK

Educational institutions following the OBE model should ensure all learning activities, assessments, evaluations, feedback, and advising help students to attain the targeted outcomes. International and regional QA agencies and academic advising organizations strongly recommend that educational institutions implement all CQI processes based on learning outcomes.

1) OBE MODEL

To better understand the scope of this research and the limitations of prevalent CQI systems 'following' outcomes-based approaches, we begin with a brief introduction to some essential elements of OBE which were developed by associates at the High Success Network [1], [2].

The keys to having an outcomes-based system are:

a. Developing a clear set of learning outcomes around which all of the educational system's components can be focused; and
b. Establishing the conditions and opportunities within the educational system that enable and encourage all students to achieve those essential outcomes.

OBE's two key purposes that reflect its "*Success for all students and staff*" philosophy are:

a. Ensuring that all students are equipped with the knowledge, competence, and qualities needed to be successful after they exit the educational system; and
b. Structuring and operating educational systems so that those outcomes can be achieved and maximized for all students.

OBE's 4 power principles are:

a. ***Clarity of focus*:** Firstly, this helps educators establish a clear picture of the desired learning outcomes they want and provides students with indications of their expected performance [3], [4]. Secondly, student success on this demonstration becomes the top priority for instructional planning and designing student assessment [3], [4]. Thirdly, the clear picture of the desired learning outcome is the starting point for curriculum, instruction, and assessment planning and implementation, all of which must perfectly align with the targeted outcomes [3], [4]. And fourthly, the instructional process in the classroom begins with the teacher's actions, sharing, explaining, and modeling the outcome from day one and continually thereafter, so that clearly indicates what is required so the "*no surprises*" philosophy of OBE can be fully realized. This enables students and teachers to work together as partners toward achieving a visible and clear goal [1]–[3].
b. ***Expanded Opportunity*:** requires staff to give students more than one chance to learn important things and to demonstrate that learning. Initially, those who implemented OBE applied this approach to small segments of learning that students could accomplish in relatively short amounts of time. But the definition of outcomes and their demonstration has expanded dramatically over the past two decades, which has forced a rethinking of the entire concept of opportunity and how it is structured and implemented in educational institutions [1]. There are at least five dimensions of opportunities: Time, Methods and Modalities, Operational Principles, Performance

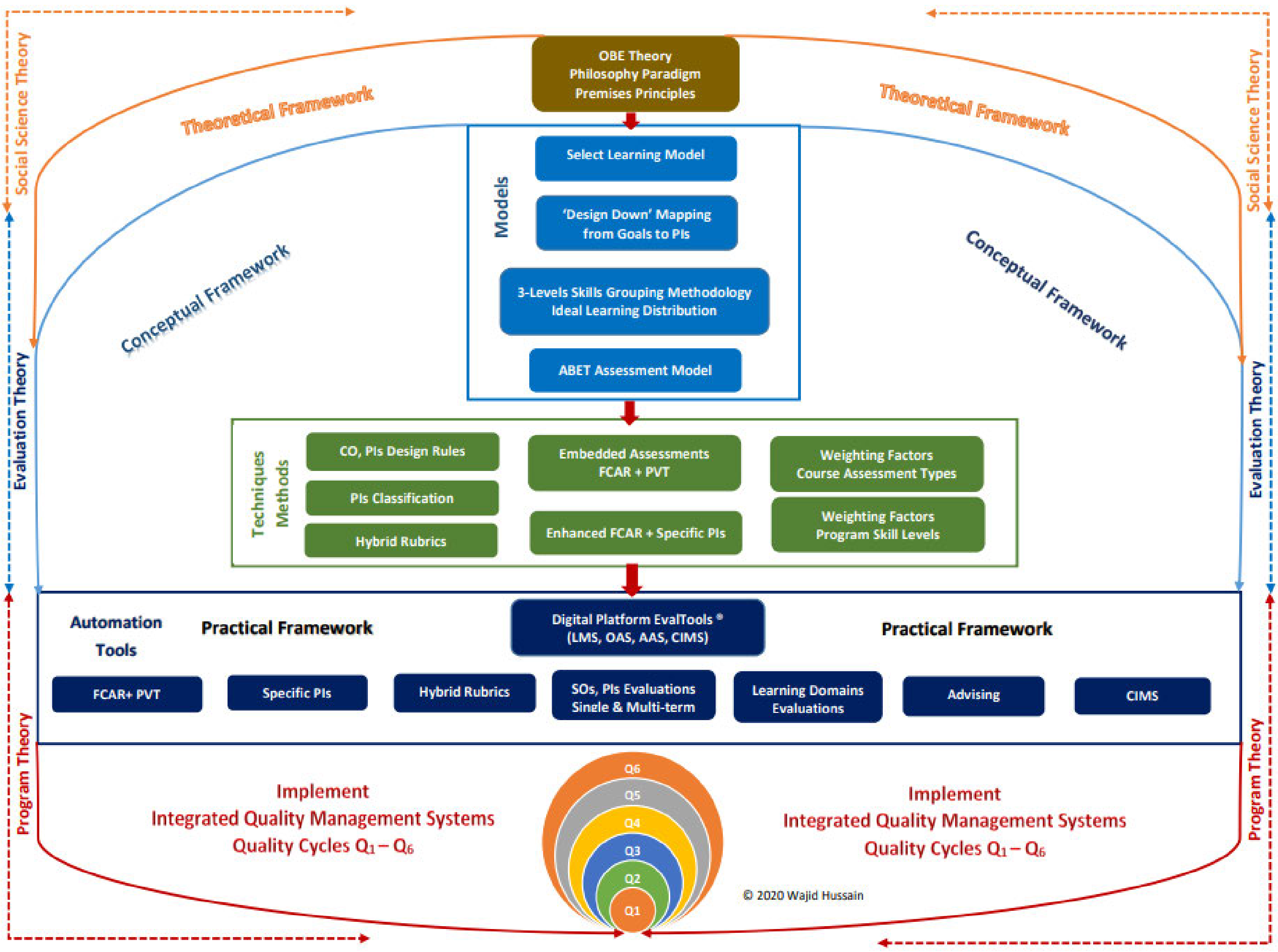


FIGURE 1. **Theoretical, conceptual and practical frameworks.**

Standards, and Curriculum Access and Structuring, which are all significant in expanding students' opportunities for learning and success [1], [2], [5].

c. ***High Expectations*****:** means increasing the level of challenge to which students are exposed and raising the standard of acceptable performance, they must reach to be called "*finished*" or "*successful*". OBE systems have applied this principle to three distinct aspects of academic practice: standards, success quotas, and curriculum access. First, most OBE systems have raised the standard of what they will accept as completed or passing work. This is done, of course, with the clarity of focus, expanded opportunity, and design down principles [1], [2], [4]. As a result, students are held to a higher minimum standard that ever before. Second, most OBE systems have changed their thinking about how many students can or should be successful. They have abandoned bell-curve or quota grading systems in favor or criterion-based systems, and this change of perspectives and practices reinforces the previous strategy [1], [2], [4]. Third, realizing most students will rise only to the level of challenge they are afforded, many OBE systems have eliminated low-level courses, programs, or learning groups from the curriculum [1], [2], [4], [5].

d. ***Design Down*****:** means staff begin their curriculum and instructional planning where they want students to ultimately end up and build back from there. This challenging but powerful process becomes clear when we think of outcomes as falling into three broad categories: culminating, enabling, and discrete. Culminating outcomes define what the system wants all students to be able to do when their official learning experiences are complete [3], [4]. In fully developed OBE systems, the term "*culminating*" is synonymous with exit outcomes. But in less fully developed systems, culminating might apply to what are called program outcomes and course outcomes [3], [4]. Enabling outcomes are the key building blocks on which those culminating outcomes depend. They are truly essential to students' ultimate performance success. Discrete outcomes, however, are curriculum details that are "*nice to know*" but not essential to a student's culminating outcomes [3], [4]. The design down process is governed by the "*Golden Rules*". At its core, the process requires staff to start at the end of a set of significant learning experiences – its culminating point – and determine which critical learning components and building blocks of learning (enabling outcomes) need to be established so that students successfully arrive there. The term "*mapping back*" is often used to describe the first golden rule. The second rule states that staff must be willing to replace or eliminate parts of their existing programs that are not true enabling outcomes [3], [4]. Therefore, the challenges in a design down process are both technical – determining the enabling outcomes that truly underline a culminating outcome – and emotional – having staff be willing to eliminate familiar, favorite, but necessary, curriculum details [2]–[5].

From a future-focused, transformational perspective, the four defining principles of OBE are restated as [3]:

a. *Clarity of Focus* on future role-performance abilities of significance.
b. *Continuous Opportunities* to engage in and develop role-performance abilities.
c. *High Engagement* in authentic contexts that advance performance abilities.
d. Bring role-performance learning and engagement down to young learners too.

In summary, all components of educational systems that implement an OBE model should focus on aiding all students to successfully attain the targeted outcomes for achieving intended learning aimed by international standards of engineering education and curriculum [11], [65].

Based on authentic OBE theory, best practices for assessment and ABET accreditation requirements, several concepts were formulated to aid in the development of models; tools, techniques, methods and processes that act as essential guidelines for employing practical frameworks to implement the IQMS at the Faculty of Engineering. The following sections elaborate on conceptual frameworks dealing with selecting learning models; defining goals, objectives, outcomes and performance indicators; developing rubrics; curriculum design; course delivery; assessment and evaluation; and CQI efforts.

B. CONCEPTUAL FRAMEWORK – MODELS

1) SELECTING LEARNING MODELS

An important observation made by the Faculty of Engineering is that Bloom's 3 learning domains present an easier classification of specific PIs for realistic outcomes assessment compared with other models that categorize learning domains as knowledge, cognitive, interpersonal, communication, IT, numerical and/or psychomotor skills [13]. In addition, categories of learning domains which seem very relevant for the engineering industry and career-related requirements may not be easy to implement practically when it comes to classification, measurement of PIs, and realistic final results for evaluating CQI.

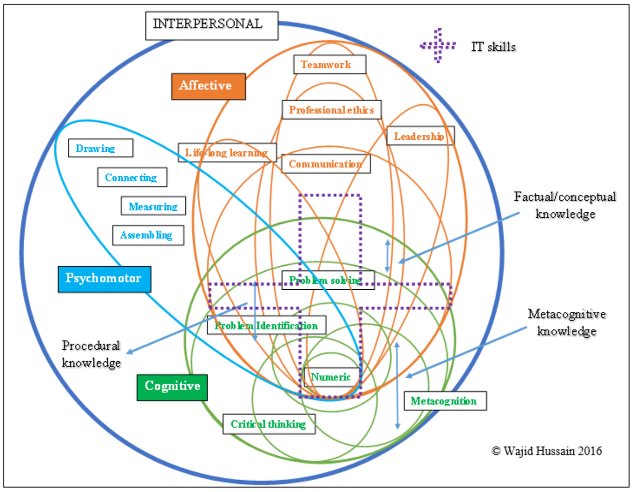


FIGURE 2. The learning domains wheel for snapshot analysis and selection of Learning Domains Categories to achieve realistic outcomes measurement with easier PIs classification process.

A hypothetical *Learning Domains Wheel* as shown in Figure 2 was developed by the Faculty of Engineering to analyze the popular learning domains models available, including Bloom's, with a perspective of realistic measurement of outcomes based on valid PIs classification that does not result in a vague indicator mechanism for CQI in engineering education [24]. Learning domains categories mentioned in this paper specifically refer to broad categories with well-defined learning levels selected for the classification of specific PIs [24]. The *Learning Domains Wheel* was implemented with Venn diagrams to represent details of the relationship of popular learning domains categories, interpersonal skills, and the types of knowledge [24]. A detailed explanation of the coverage of required engineering knowledge and skills sets for popular learning models including the NCAAA 5 domains model [13] presented valid and logical arguments based on issues related to redundancy in selecting domains for PIs classification.

The cognitive domain involves acquiring factual, conceptual knowledge dealing with remembering facts and understanding core concepts. Procedural and metacognitive knowledge focus on problem-solving, which includes problem identification, critical thinking and metacognitive reflection. Remembering facts, understanding concepts and problem solving are essential, core and universal cognitive skills that would apply to all learning domains [7], [75]. Problem identification, definition, critical thinking and metacognitive reflection are some of the main elements of problem-solving skills. The main elements of problem-solving skills apply to all levels of learning for the three domains. Activities related to any learning domain require operational levels of four kinds of knowledge: factual, conceptual, procedural and metacognitive [75] that are proportional to the expected degree of proficiency of skills for effective execution of tasks. For example, successfully completing psychomotor tasks for solving problems involves acquiring specialized factual, conceptual, procedural and metacognitive knowledge of various physical processes with acceptable levels of proficiency. Similarly, an affective learning domain activity, such as implementing a code of professional ethics, involves acquiring factual, conceptual, procedural and metacognitive knowledge related to industry standards, application process, level of personal responsibility and impact on stakeholders. Hence, the psychomotor and affective domains skills overlap with the cognitive domain for the necessary factual, conceptual, procedural and metacognitive areas of knowledge [24].

The learning domains categories such as interpersonal, IT, knowledge, cognitive, communication, numerical skills etc., exhibit significant areas of overlap as shown in the *Learning Domains Wheel* in Figure 2. A high-level grasp of the relationship of these categories demonstrates the process of the selection of learning domain categories. For example, interpersonal skills, as shown in Figure 2, is too broad a category, thereby presenting serious problems in PIs classification and realistic outcomes measurement when grouped with other skills sets such as learning domains categories [24]. Numerical skills are used for decision- making activities in the affective domain and also for the effective execution of psychomotor activities in physical processes. Numerical skills are an absolute subset of cognitive skills for any engineering discipline. IT skills cover some areas of psychomotor (connection, assembly, measurement, etc.), affective (safety, security, etc.) and cognitive (knowledge of regional standards, procedural formats, etc.) domains. Leadership and management skills require effective communication and teamwork [24]. This large overlap of skills within multiple learning domains presents a serious dilemma to engineering programs in the PIs classification and measurement process. A difficult choice must be made whether to select the most appropriate learning domain category and discard the others or repeat mapping similar PIs to multiple learning domain categories for each classification [24]. Defining the learning levels for the overlapping categories to precisely classify PIs would also be challenging [24]. Finally, learning domain categories with significant areas of overlap would result in the repeated measurement of common PIs in multiple domains and the accumulation of too many types of PIs in any single learning domain category, thus obscuring specific measured information. Therefore, for practical reasons the categories of learning domains have to be meticulously selected with a primary goal of implementing a viable PIs classification process to achieve realistic outcomes measurement for program evaluation [24].

Crucial guidelines were logically derived from the *Learning Domains Wheel* for the selection of the learning domains categories and listed as follows [24]:

1. Very broad learning domains categories consist of many skill sets that will present difficulty in the classification of PIs when grouped with other categories and will result in the redundancy of outcomes data; for example, interpersonal skills grouped with IT, communication or psychomotor, etc.
2. Avoid selection of any two skills sets as learning domains categories when one is an absolute subset of another. Just select either the most relevant one or the one which is a whole set. For example, select cognitive or numeric skills, but not both; if both are required, select cognitive as a category since it is a whole set. Numeric skills, its subset, can be classified as a cognitive skill.
3. If selecting a certain skill set that is a whole set as a learning domains category, then it should not contain any other skills sets which are required to be used as learning domains categories; e.g., do not select affective as a learning domains category since it is a whole set if you also plan on selecting teamwork skills as a category.
4. A learning domain category could contain skills sets which will not be utilized for PIs classification; e.g., affective learning domain category containing leadership, teamwork and professional ethics skills sets; leadership, teamwork and professional ethics will NOT be a learning domain category but will be classified as affective domain skill sets.

Bloom's 3 domains, cognitive, affective and psychomotor, are not absolute subsets of one another. They contain skill sets as prescribed by the 11 or 7 ABET EAC SOs which are not learning domains categories. Therefore Bloom's 3 learning domains satisfy selection guidelines derived from the *Learning Domains Wheel* and facilitate a relatively easier classification process for specific Pis [24]. Calculation of term-wide weighted average values for ABET SOs using this classification of specific PIs resulted in realistic outcomes data since most of the PIs were uniquely mapped to each of the 3 domains with minimal overlap and redundancy [24].

2) 'DESIGN DOWN' MAPPING MODEL FROM GOALS TO PERFORMANCE INDICATORS

A "*design down*" [2]–[5] mapping model was developed as shown in Figure 3 exhibiting authentic OBE design-down flow from goals, PEOs, SOs, course objectives, COs to PIs. This figure illustrates trends in levels of breadth, depth, specificity and details of technical language related to the development and measurement of the various components of a typical OBE "*design down*" process [2]–[5]. Goals and objectives are futuristic in tense and use generic language for broad application. The term 'w/o' (without) in the figure highlights the essential characteristics of goals and objectives. Goals and objectives do not contain operational action verbs, field-specific nominal subject content, or performance scales. Student and course outcomes do not contain performance scales. Performance scales should be implemented with the required descriptors in rubrics [68].

PIs should be specific to collect precise learning outcomes information related to various course topics and phases of a curriculum while addressing various levels of proficiency of a measured skill [24], [42]. Adelman's thorough

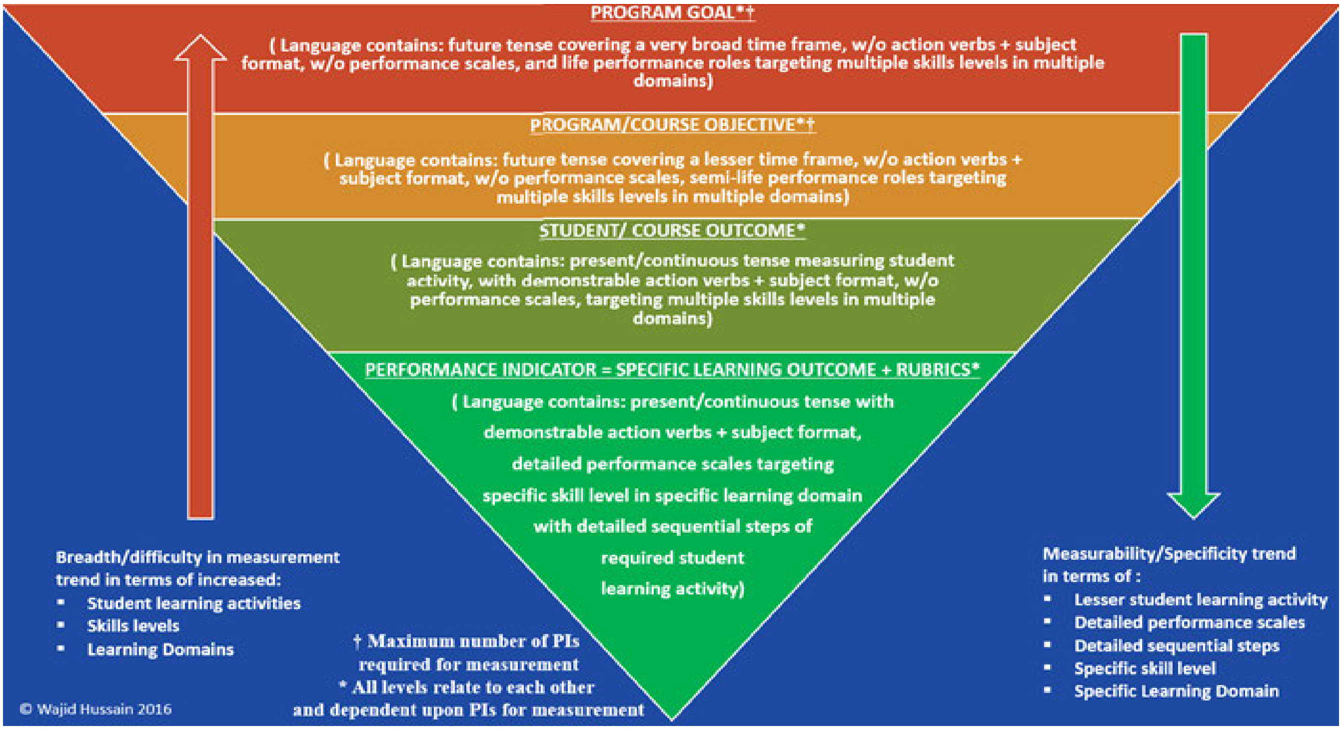


FIGURE 3. OBE design down mapping from goals, PEOS, SOs, COs to PIs.

work strengthens our argument that the required language of learning outcomes for cognitive and psychomotor learning activities should be specific [16]. He assertively states that verbs describing a cognitive or psycho-motor operation act on something, i.e. they have a specific nominal context. The nominal context can be discipline/field-specific, e.g. error analysis in chemistry; an art exhibit in 2-D with 3 media. Field-specific statements are endemic to learning outcome statements in Tuning projects. Finally, without a specific nominal context you do not have a learning outcome statement [16]

3) BLOOM'S 3 DOMAINS TAXONOMIC LEARNING MODEL AND 3-SKILLS GROUPING METHODOLOGY; IDEAL LEARNING DISTRIBUTION

Figure 4 shows the design flow for the creation of holistic learning outcomes and their PIs for all courses corresponding to *Introductory, Reinforced* and *Mastery* levels spanning the curriculum.

The Faculty of Engineering programs studied past research [24], [41], which grouped Bloom's learning levels in each domain based on their relation to the various teaching and learning strategies. With some adjustments, a new *3-Level Skills Grouping Methodology* [24], [41] as shown in Table 2 was developed for each learning domain with a focus on grouping activities which are closely associated to a similar degree of skills complexity. Ideally, all courses should measure the elementary, intermediate and advanced level skills with their COs, specific PIs and associated assessments. However, *Introductory* level courses should measure a greater proportion of the elementary level skills with their COs, PIs and assessments.

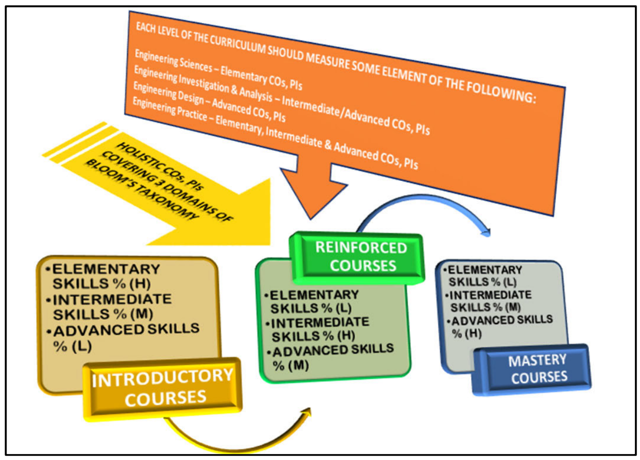


FIGURE 4. Design flow for the creation of advanced, intermediate and elementary COs, PIs covering three domains of Bloom's taxonomy and spanning courses in different phases of the curriculum.

On the other hand, *Mastery* level courses should measure more of the advanced, but fewer intermediate and elementary level skills [24], [35], [41]. Figure 5 indicates an ideal learning level distribution of COs and PIs for the *Introductory*, *Reinforced* and *Mastery* level courses. The measurement of outcomes and PIs designed following such an ideal distribution result in a comprehensive database of learning outcome information, which facilitate a thorough analysis of each phase of the learning process and enable a comparatively

TABLE 2. 3-level skills grouping methodology of bloom's revised taxonomy.

Skills Level	Cognitive Domain (Bloom, 1856; Anderson & Krathwohl, 2001)	Affective Domain (Krathwohl, Bloom & Masia, 1973	Psychomotor Domain (Simpson, 1972)
Elementary	1.Knowledge 2.Comprehension	1.Receiving phenomena 2.Responding to phenomena	1.Perception 2.Set 3.Guided response
Intermediate	3.Application 4.Analysis	3.Valuing	4.Mechanism 5.Complex overt response
Advanced	5.Evaluation 6.Creation	4.Organizing values into problems 5.Internalizing	6.Adaptation 7.Origination

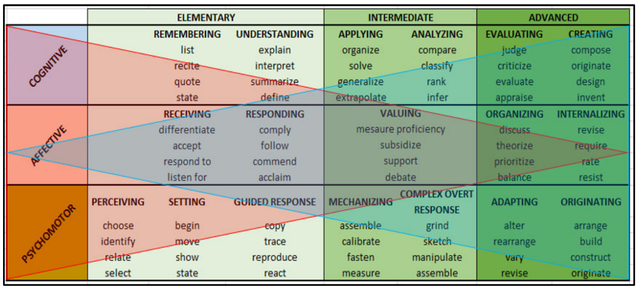


FIGURE 5. An ideal learning level distribution scenario for COs, PIs and associated assessments for Introductory (Indicated by Shaded Red Triangle Looking L to R) to Mastery (indicated by a shaded blue triangle looking R to L) level courses.

easier mechanism for early detection of student performance failures at any stage of a student's education [24], [35], [41].

4) ABET ASSESSMENT MODEL

The OBE model was chosen due to the many benefits discussed earlier and to fulfill regional and ABET accreditation standards. ABET accreditation criteria CR2: *PEOs*; CR3: *SOs;* and CR4: *Continuous Improvement* [11] have been implemented in the assessment model, which require that programs make decisions using assessment data collected from students and other program constituencies, thus ensuring a quality program improvement process. This also requires the development of quantitative/qualitative measures to ensure students have satisfied the COs, which are measured using a set of specific PIs/assessments and, consequently, the program level ABET SOs [11], [35], [36], [40]–[42], [46], [49], [67], [70]. Figure 6 shows the outcomes assessment model adopted by the Faculty of Engineering. The assessment model involves activities such as a comprehensive review of the PEOs, SOs, PIs/assessments and COs leading to further improvement in the program. All activities in the various phases of the CQI process actively involve faculty members [24], [35], [42], [67]

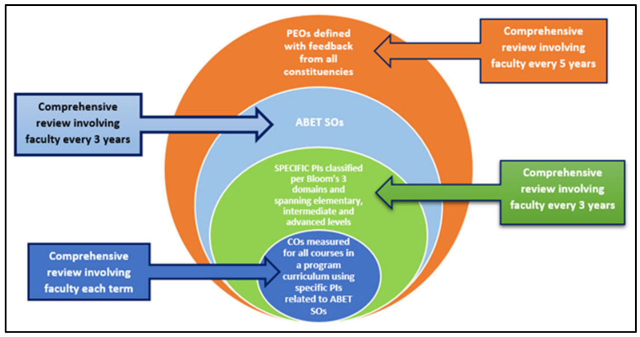


FIGURE 6. Faculty of engineering's outcomes assessment model.

C. CONCEPTUAL FRAMEWORK – TECHNIQUES, METHODS

1) EMBEDDED ASSESSMENTS USING FCAR, EAMU PERFORMANCE VECTOR METHODOLOGY

Cross (1998) mentioned the importance of classroom based assessments and explained how they can improve teaching and learning, "*Most people think of assessment as a large-scale testing program conducted at institutional or state levels to determine what students have learned in college … I believe that we should be giving more attention to small-scale assessments conducted continuously in college classrooms by discipline-based teachers to determine what students are learning in that class… The advantage of thinking small in assessment is that the classroom is the scene of the action in education. If the ultimate purpose of assessment is to improve teaching and learning, then the results of a successful assessment must eventually bear directly on the actions of teachers in their classrooms. This means that the feedback from any assessment must reach classroom teachers and be perceived by them as relevant to the way they do their jobs. One way to do that, albeit not the only way, is to start in the classroom collecting assessment data that teachers consider relevant*" [76].

Due to accreditation requirements for assessment and evaluation, the majority of programs have planned assessments and satisfaction ratings on a macro level. These are generally referred to as outcomes assessment measures [77] and involve using standardized tests, focus groups, independent raters, vague and generic rubrics. However, these plans do not adequately assess student learning goals specific to the university's program, nor do they provide information that would help instructors improve student learning in their courses. On the other hand, reinforcing Cross's (2005) opinions [76], well-planned course level assessments can provide better opportunities for data collection of SOs data for accreditation evaluations. Course embedded assessments are also referred to as "*classroom-based*" assessments. Course embedded assessment is the process of using artifacts generated through routine classroom activities to assess the achievement of SOs. Teaching materials and routine classroom assignments are designed to align with COs and corresponding PIs. Ammons and Mills (2005) clearly state the benefits of alignment of embedded assessment to instructors, "*Course-embedded* *assessment may have strong appeal to faculty who want to engage in a systematic way of reflecting on the relationship between teaching and learning*" [78]. Embedded assessments build on the daily work (assignments, exams, course projects, reports, etc.) of students and faculty members. These assessments help avoid the use of external independent raters that are usually employed for rescoring past course portfolios for accreditation purposes. According to Ammons and Mills (2005), the major benefit of course embedded assessment is that "the instruments can be derived from assignments already planned as part of the course, data collection time can be reduced" [78]. Gerretson and Golson (2004) stated that the advantage of assessment at the classroom level is that it "*uses instructor grading to answer questions about students learning outcomes in a nonintrusive, systematic manner*" [79]. A composite advantage of course embedded assessments in regards to the fulfillment of accreditation requirements are that they can be used at the course level to help instructors determine attainment of COs, and can be used at the program level to assist in measuring to what degree the program level SOs are being met. Embedded Assessments is not just of interest to the instructor teaching the course, but also to other faculty members in the program whose courses build on the knowledge and skills learned in the course [78].

The basis of the embedded assessment model in FCAR is the EAMU performance vector [46], [80], [81]. The EAMU performance vector [81], [82] counts the number of students that passed the course whose proficiency for that outcome was rated *Excellent, Adequate, Minimal*, or *Unsatisfactory* as defined by: *Excellent*: scores >= 90%; *Adequate*: scores >= 75% and < 90%; *Minimal*: scores >= 60% and < 75%; and *Unsatisfactory*: scores < 60%. Program faculty report failing COs, SOs, PIs, comments on student indirect assessments and other general issues of concern in the respective course reflections section of the FCAR. Based upon these course reflections, new action items are generated by faculty. Old action items are carried over into the FCAR for the same course if offered again. Modifications and proposals to a course are made with consideration of the status of the old action items [46], [80], [81].

2) DESIGN RULES FOR COs AND PIs

Combining Spady's (1992,1994 a, b) fundamental guidelines related to the language of outcomes [3]–[5], key concepts from Adelman's work (2015) on verbs and nominal content [16], and some essential details on the hierarchical structure of outcomes from Mager's work (1962) [83] led to a consistent standard for learning outcome statements that were accurately aligned to the course delivery using a structured format for COs and specific PIs.

Essential principles for learning outcome statements are summarized as below:

1. Intended outcomes must be measurable
2. Language of outcomes should describe what learner's do using operational action verbs
3. Conditions of learning activities should be described by nominal subject content
4. Level of acceptable performance must be clearly indicated (PIs)
5. Multiple statements can be used for each learning outcome (PIs)

These essential principles for learning outcome statements help develop detailed design rules for COs and PIs. This enables holistic course delivery that is tightly aligned to outcomes with achievement of ideal learning distribution in all the 3 domains of learning and sequential coverage of all major topics [35], [42], [64], [67].

a: RULES FOR COs DESIGN

1. Use operational action verbs to describe the target learning activity that will be assessed
2. The COs can target multiple activities covering 3 domains of Bloom's and the 3-levels skills elementary, intermediate and advanced skills. But, each activity would have to be assessed by a corresponding PI.
3. The COs should sequentially cover all major course topics
4. The COs for a specific topic should assess both theory and experimental lab skills to ensure comprehensive learning related to the topic.
5. Write moderately generic COs with the context of several specific PIs to measure multiple target learning activities.

b: RULES FOR PIs DESIGN

1. The PIs should be approximately aligned to the operational action verbs and nominal subject content in COs.
2. The PIs should be at a similar skill level as the corresponding activity in the CO.
3. The PIs should align with the complexity and methods used in assessments planned to measure corresponding learning activities mentioned in the CO
4. The PIs should be more specific than COs and indicate names of techniques, standards, theorems, technology, methodology etc.
5. The PIs should provide major steps to analyzing, solving, evaluating, classifying etc. so they can be utilized to develop hybrid rubrics
6. Several PIs should be used to assess multiple learning activities relating to multiple domains and 3-levels skills.

Figure 7 shows an example of detailed COs design methodology for an EE program's course.

The design of COs and their PIs was meticulously completed by using appropriate action verbs and subject content, thus rendering the COs, their associated PIs, and assessments at a specific skill level—elementary, intermediate or advanced. Figure 8 shows an example from a ME course (ABET SOs 'a-k' example applicable to SOs '1-7'). In this example, CO_7: *Calculate and measure velocity and flow rate of fluid dynamics problems using Bernoulli equations*; and its associated specific PI_11_39: *Analyze the friction*

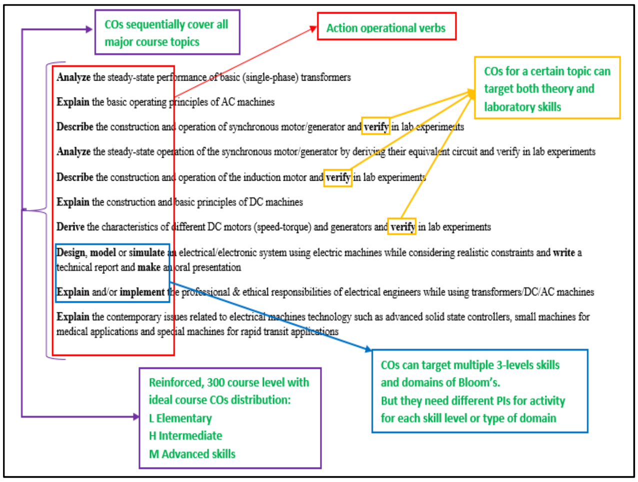


FIGURE 7. Detailed COs design methodology.

effects in viscous fluid flow in a circular pipe; calculate the Reynolds number to classify as laminar or turbulent flow; obtain the friction factor: by extracting from Moody's charts (turbulent flow); or by using analytical equations (laminar flow); calculate the major and minor pressure losses for laminar and turbulent flows using pressure drop equations; measured by assessment Final Exam Q3 are of similar complexity and at the same level of learning. The corresponding category of learning is *reinforced-cognitive-analyzing*. Therefore, COs would be measured by PIs and assessments strictly following the *3-Level Skills Grouping Methodology* [24], [41].

3) HYBRID RUBRIC

The hybrid rubric is a combination of the holistic and analytic rubric developed to address the issues related to (a) *validity*: precision and accuracy of an assessment's alignment with outcomes, PIs; and (b) *inter/intra-rater reliability*: detail of specificity of acceptable student performances; when dealing with the assessment of complex and very specialized engineering activities. The hybrid rubric is an analytic rubric embedded with a holistic rubric to cater to the assessment of several descriptors that represent all the required major steps of specific student learning activity for each PI/dimension listed [42]. The hybrid rubric's advantage is reinforced by the finding of an exhaustive empirical research that reviewed 75 studies on rubrics, summarized their benefits, and concluded that the top most benefit is from rubrics that are *analytic, topic-specific*, and complemented with exemplars and/or rater training [11]. Figure 9 shows an ABET SO 'e', specific PI dealing with problem-solving: *"Simplify a given algebraic Boolean expression by applying the k-map and express in POS form"*, and its hybrid rubric.

The hybrid rubric also contains a column to indicate the percentage of total score allocation for each descriptor (major step of learning activity) corresponding to a certain PI [42]. The scales implemented are obtained from Estell's FCAR [80], E, A, M and U performance vectors [46], [80], [81] that stand for the *Excellent*: (100-90)%, *Adequate*: (89-75)%, *Minimal* (74-60)% and *Unsatisfactory*: (0-60)% categories respectively. Spady's OBE philosophy - four power principles of authentic OBE [2]–[5] are applied here as guidelines for the development and implementation of specific PIs and hybrid rubrics [42]:

1. *Clarity of focus*: Subject specialists within a program form sub-groups to select appropriate course content, topics, learning activities and their skills/complexity levels based on student standards for the development of specific PIs and their hybrid rubrics. The language of specific PIs and hybrid rubrics should have sufficient transparency in meaning to promote easy faculty comprehension and application resulting in perfect implementation of scientific constructive alignment and use of the "*unique assessments*" philosophy [22], [24], 35], [38], [48], [49], [50], [62], [63], [67], [69], where a single assessment does not map to more than one specific PI. The language of the specific PIs and descriptors should have an approximate correspondence with student learning activities, so both, students and faculty, can clearly understand the various scales of performance expectations [42].
2. *High expectations:* The *Excellent* scale 'E', of the hybrid rubric, should clearly identify required steps for excellent performance in using a specific major method, say 'M_i', for performing a certain task. A major method would be a complex engineering activity involving several unique steps for completing a specific task. There should be only one specific hybrid rubric designed to assess one major method or technique applied to complete a particular task. Any alternative major methods, say 'M_1, $M_2 \ldots M_n$', that complete the same task, let's say 'T', and deemed necessary curricular content by the instructor, should be assessed independently, with rubrics of their own. This would eradicate the possibility of producing "excellent" performing engineering graduates who have partial knowledge of necessary curricular content or lack required engineering skills [42].
3. *Expanded opportunity:* Use hybrid rubrics and their descriptors to be consistent in rating assessments. Give the student prior notice on what is expected by rehearsing examples of problems using the developed hybrid rubrics. Provide feedback on student graded work clearly highlighting performance issues. Use criterion-based standards and provide opportunities to improve based on some minimally required expectations [42]. Employ weighted averaging to scientifically aggregate a combination of various types of assessments and student performances [20], [24], 36], [40], [41], [46], [49], [63], [67]. Strictly avoid using pure averaging to conduct a quantitative evaluation of outcomes assessments [5].
4. *Design down:* Develop PIs, hybrid rubrics in perfect alignment with the institutional mission, PEOs, SOs and COs. To achieve this, mission statements and PEOs should be designed scientifically, and avoiding the use of vague and redundant language. Learning outcome and

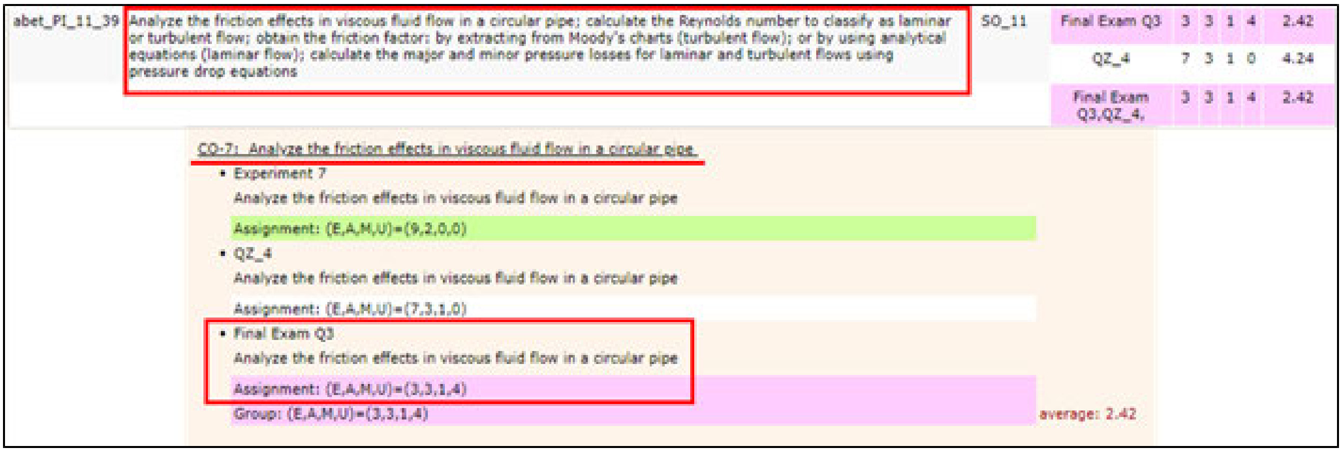
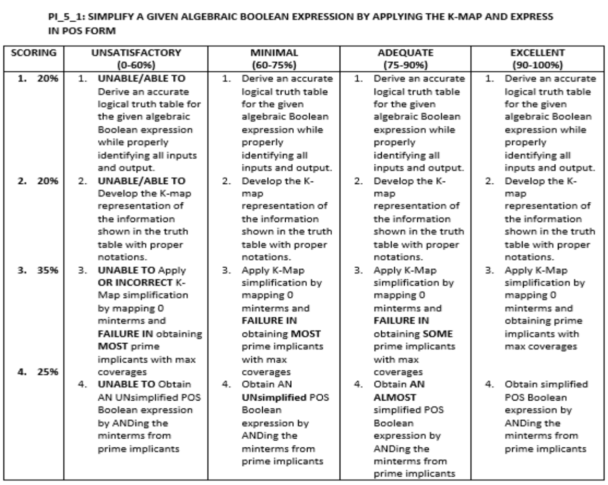


FIGURE 8. Example of a ME course showing CO_7, PI_11_39 and assessment Final Exam Q3 assigned to *reinforced-cognitive-analyzing* Skill Level Based on the 3-Level Skills Grouping Methodology.

PIs information should be used for the implementation of scientific constructive alignment to develop and align assessments with their teaching/learning strategies, scoring, evaluation, feedback and CQI efforts [42].



PI_5_1: SIMPLIFY A GIVEN ALGEBRAIC BOOLEAN EXPRESSION BY APPLYING THE K-MAP AND EXPRESS IN POS FORM

SCORING	UNSATISFACTORY (0-60%)	MINIMAL (60-75%)	ADEQUATE (75-90%)	EXCELLENT (90-100%)
1. 20%	1. **UNABLE/ABLE TO** Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.
2. 20%	2. **UNABLE/ABLE TO** Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.
3. 35%	3. **UNABLE TO** Apply **OR INCORRECT** K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **MOST** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **MOST** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **SOME** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and obtaining prime implicants with max coverages
4. 25%	4. **UNABLE TO** Obtain AN UNsimplified POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain AN **UNsimplified** POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain AN **ALMOST** simplified POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain simplified POS Boolean expression by ANDing the minterms from prime implicants

FIGURE 9. A specific PI and hybrid rubric for assessing ABET SO 'e' "Ability to identify, formulate and solve engineering problems".

The Hybrid Rubrics support and facilitate instruction and intelligent design of outcomes assessments. An important point to note is that based on the type of student learning activity, the dimensions of a hybrid rubric can consist of *interdependent, sequential steps* such as steps 1, 2, 3 and 4; or *independent, non-sequential components* such as semantics of English language, structure of system, theoretical/mathematical model, operational information, neat sketches etc. The dimensions of rubrics can also be a combination of these two types of information. The detailed specific/generic PIs model adopted by the Faculty of Engineering enables the development of hybrid rubrics that contain dimensions with a maximum spread of breadth and depth of a course topic or student learning activity. The weightage distribution of the various steps or components of rubrics conveniently supports the development and implementation of grading for assessments targeting various knowledge and skills levels. The comprehensive breadth and depth of content covered in dimensions of hybrid rubrics enables instruction and provides detailed guidance to students in various learning activities related to problem-solving, design, experimentation, teamwork, report writing, presentation etc. Faculty members are not bound to apply the entire content of developed hybrid rubrics to the design of all assessments in a course. They can flexibly extract and appropriate necessary content from comprehensive rubrics to design assessments targeting measurement of required skills and/or knowledge corresponding to specific levels of learning in a course. Instructors can select specific dimensions or portions of multiple dimensions of rubrics and apply their corresponding grading distribution to the design of assessment.

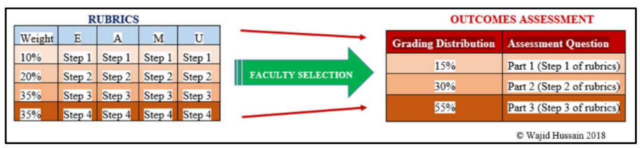


FIGURE 10. Intelligent outcomes assessment design based on faculty selection of appropriate content from hybrid rubrics.

Considering an example as shown in Figure 10, if a faculty member would like to use steps 1, 2 and 3 of a comprehensive rubric, which has 4 interdependent, sequential steps sharing 10, 20, 35 and 35 % respectively of the total weightage? Then the designed assessment can contain three parts corresponding to three required steps 1,2 and 3; where parts 1, 2 and 3 are assigned a grading distribution of 15, 30 and 55 %, respectively. The CE, EE and ME programs have initiated the development and implementation of Hybrid Rubrics in 2017, targeting major learning activities in fundamental engineering courses. According to the assessment plan, at the end of 2019, Hybrid Rubrics covered major engineering knowledge areas and skill sets related to most of the core engineering courses. Implementation of Hybrid Rubrics in instruction and

TABLE 3. Hybrid rubric showing EAMU scales, descriptors and score distribution for PI_11_54.

PI	E	A	M	U
abet_PI_11_54:Draw the stress transformation for plane stress condition in mechanical components using Mohr's circle graphically using geometrical instruments or AutoCAD; Extract the orientation and direction of the state of the stress from given element; compute the stress transformation for plane stress condition in mechanical components using Mohr's circle graphical method; extract the information related to principal stresses, orientation and direction of other stresses from the solution; determine the normal and shear stresses of given orientation	**Excellent (90-100%)** (10%) Accurately extract the orientation and direction of the state of stress from the given element in the problem. (15%) Accurately mark stresses on the graph paper indicating different orientation with proper signs. (50%) Accurately draw a neatly labeled Mohr's circle on a scaled x-axis and y-axis. (25%) Accurately extract and represent on the plot values and direction for the Principle, average, maximum and minimum normal and shear stresses. Accurately extract and represent the unknown parameters in Mohr's circle (stress values at some different orientation of the element)*. *If required in the question	**Adequate (75-89%)** (10%) Accurately extract the orientation and direction of the state of stress from the given element in the problem. (15%) Accurately mark stresses on the graph paper indicating different orientation with proper signs. (50%) Accurately draw a neatly labeled Mohr's circle on a scaled x-axis and y-axis. (25%) Minor errors to extract and represent on the plot values and direction for the Principle, average, maximum and minimum normal and shear stresses. Minor errors to extract and represent the unknown parameters in Mohr's circle (stress values at some different orientation of the element)*. *If required in the question	**Minimal (60-75%)** (10%) Accurately extract the orientation and direction of the state of stress from the given element in the problem. (15%) Accurately mark stresses on the graph paper indicating different orientation with proper signs. (50%) Minor errors to draw a neatly labeled Mohr's circle on a scaled x-axis and y-axis. (25%) Multiple errors to extract and represent on the plot values and direction for the Principle, average, maximum and minimum normal and shear stresses. Multiple errors to extract and represent the unknown parameters in Mohr's circle (stress values at some different orientation of the element)*. *If required in the question	**Unsatisfactory (0-60%)** (10%) Major errors to extract the orientation and direction of the state of stress from the given element in the problem. AND/OR (15%) Major errors to mark stresses on the graph paper indicating different orientation with proper signs. AND/OR (50%) Major errors to draw a neatly labeled Mohr's circle on a scaled x-axis and y-axis. AND/OR (25%) Major errors to extract and represent on the plot values and direction for the Principle, average, maximum and minimum normal and shear stresses. Major errors to extract and represent the unknown parameters in Mohr's circle (stress values at some different orientation of the element)*. *If required in the question

assessment design will be an ongoing parallel effort involving intense tuning and continuous improvement. Once the implementation of rubrics achieves an acceptable standard for core engineering courses with significant benefits to instruction and assessments design, instructors can then focus on elective courses for the development and implementation of Hybrid Rubrics.

Table 3 shows an ABET SO 'k', techniques, tools and skills, ME program's specific PI "[abet_PI_11_54] Psychomotor: Adaptation *Draw the stress transformation for plane stress condition in mechanical components using Mohr's circle graphically using geometrical instruments or AutoCAD; Extract the orientation and direction of the state of the stress from given element; compute the stress transformation for plane stress condition in mechanical components using Mohr's circle graphical method; extract the information related to principal stresses, orientation and direction of other stresses from the solution; determine the normal and shear stresses of given orientation*" and its hybrid rubric.

The hybrid rubric also contains a column to indicate the percentage of total score allocation for each descriptor and the EAMU scales. The Office of Quality and Accreditation at the Faculty of Engineering has developed elaborate, step by step, instructional videos for developing hybrid rubrics for the CE. ME and EE programs [84]–[86].

ME 224 Mechanics of Materials course final exam Q6 example (Term 382 ABET SOs 'a-k') illustrates how course outcomes, their PIs are used to develop hybrid rubrics and apply them in instructions and assessments. This example shows how CO5, PI_11_54 accurately align to final exam Q6 and how its hybrid rubric (Table 3) is used to develop the grading policy (Table 4).

The CO6: *Calculate stress transformation on different planes in a member subjected to normal and shear loading,* utilizes PIs:

- [abet_PI_11_54] Psychomotor: Adaptation *Draw the stress transformation for plane stress condition in mechanical components using Mohr's circle graphically using geometrical instruments or AutoCAD; Extract the orientation and direction of the state of the stress from given element; compute the stress transformation for plane stress condition in mechanical components using Mohr's circle graphical method; extract the information related to principal stresses, orientation and direction of other stresses from the solution; determine the normal and shear stresses of given orientation;*
- [abet_PI_5_79] Cognitive: Analyzing *Extract the orientation and direction of the state of the stress from given element; compute the stress transformation for plane stress condition in mechanical components using Mohr's circle equations; extract the information related to principal stresses, orientation and direction of other stresses from the solution; determine the normal and shear stresses of given orientation.*

Question 6: For a given state of stress, determine
(a) Orientation of the principles planes,
(b) Value of the principle stresses, and
(c) Maximum shear stress.

Solve it by using a Mohr circle. You may cross-check your graph by an analytical equation, if time permits. (20: 2, 3, 10, 5).

Use a graph paper attached and any calculation on this page. The graph should be properly labeled for all the values and axes.

Final Exam Question 6 has been allocated 20 points out of which 2 points for extracting information from the element, 3 points for marking the graph properly, 10 points for accurately drawing the point, followed by the right Mohr's circle on the labelled graph and 5 points for extracting information from the Mohr's circle.

TABLE 4. Grading scheme applied to final exam question 6.

(10%) Extract the correct orientation and direction of the applied stress on the element.
(15%) Mark the graph paper with accurate singing of tensile and compressive stress as well as normal and shear stress.
(50%) Draw the accurate point's on the graph, draw the Mohr's circle.
(25%) Extract the values from the Mohr's circle like Principle stress, shear stress and maximum shear stress and any other value based on different orientation of the stress.

4) WEIGHTING FACTORS

Realistic measurements of learning outcomes are achieved by specifying weights (similar to what has been suggested regarding the relevance of weights for learning outcomes measurement by Moon, 2007 [6]; Liu and Chen, 2012 [81]) to different assessments according to a combination of their course grading policy and type. The first rationale in order of priority is the type of assessment so that higher weight is assigned to laboratory/design related assessments compared to purely theoretical assessments since laboratory/design work cover all three domains of Bloom's taxonomy [27] cognitive, psychomotor and affective (as suggested by Salim, Hussain & Haron, 2013 [62]) or final exams over quiz since the final exam is more comprehensive and well-designed than a quiz and the students are generally more prepared for a final exam with many of their skills reaching a higher level of maturity and proficiency by then [41]. The second rationale in priority is to account for the percentage contribution of the given assessment to the final grade, which is derived from the course grading scale [41]. Table 5 shows the 4 course formats developed by the Faculty of Engineering at Islamic University to calculate the weighting factors for different assessment types. The rationale for developing a standardized assessment template for the Faculty of Engineering programs is:

a) To classify four kinds of course formats (refer Table 5)
   i. Courses without labs and without project/term paper
   ii. Courses without labs and with project/term paper
   iii. Courses with labs and without project/term paper
   iv. Courses with labs and with project/term paper
b) To classify assessments as initial, culminating, complex etc. and emphasize major assessment components that are holistic and the true reflection of actual students learning involving 3 domains of learning: cognitive, psychomotor and affective.
c) To develop appropriate weighting factors for different assessments in various course formats to accurately reflect combination of grading scale and level of learning.

Faculty first select the course format which matches their course design to obtain the multiplication factors for different assessment types. Then for a specific assessment type in the given course, its final weighting factor % is calculated by obtaining the product of its course grading scale and multiplication factor [24], [35]. The formula for calculating the Weighting Factor (WF) for specific assessments is shown by Equation (1).

TABLE 5. Different course assessments formats for ce program.

DIFFERENT COURSE ASSESSMENTS FORMATS:

1. COURSES WITH NO LABS + NO PROJECT/TERM PAPER

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	40%	8
MID TERM EXAM - 1	25%	5
MID TERM EXAM - 2	25%	5
QUIZ	5%	1
HW	5%	1
TOTAL	100%	-

2. COURSES WITH NO LABS + PROJECT/TERM PAPER

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	30%	6
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
PROJECT/TERM PAPER	30%	6
TOTAL	100%	-

3. COURSES WITH LABS + NO PROJECT/TERM PAPER

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	25%	5
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
LAB EXAMS	30%	6
LAB REPORTS	5%	1
TOTAL	100%	-

4. COURSES WITH LABS + PROJECT/TERM PAPER

ASSESSMENT TYPE	%WEIGHT FACTOR	MULTIPLICATION FACTOR
FINAL EXAM	25%	5
MID TERM EXAM - 1	15%	3
MID TERM EXAM - 2	15%	3
QUIZ	5%	1
HW	5%	1
LAB EXAMS	15%	3
LAB REPORTS	5%	1
PROJECT/TERM PAPER	15%	3
TOTAL	100%	-

$$\begin{aligned}\text{WF (Assessment X)} &= \text{Grading Scale \% (Assessment X)} \\ &\quad \times \text{Multiplication Factor (Assessment X)} \end{aligned} \tag{1}$$

D. PRACTICAL FRAMEWORK – DIGITAL PLATFORM EVALTOOLS ®

Several software applications are cited in literature including True Outcomes® for outcomes assessment due to the inadequacy of Blackboard® [32]. EvalTools® 6 is chosen as the platform for outcomes assessment instead of Blackboard® since it is the only tool that employs the FCAR and EAMU performance vector methodology [35], [41], [46], [48], [80]. This methodology facilitates the embedded assessments model by using existing curricular scores for outcomes measurement and assists in achieving a high level of automation of the data collection process. Mead and Bennet (2009) have also explicitly stated the practical efficacy of embedded assessments aligned with learning outcomes, thus avoiding unwanted resources spent on creating additional assessments [29]. Unfortunately, the focus of their work is predominantly on cognitive skills. They specifically mention the development of specific performance criteria and associated rubrics to be able to effectively create assessments that are accurately aligned to target student engineering activity in courses. The enhanced FCAR + Specific PIs methodology employed by EvalTools ® provides effective CQI with embedded assessment technology and supports a holistic delivery coverage of curriculum by covering all the 3 domains and associated learning levels of Bloom's Taxonomy.

The EvalTools® 6 FCAR module provides summative and formative options and consists of the following components: course description, COs indirect assessment, grade distribution, COs direct assessment, assignment list, course reflections, old action items, new action items, SOs and PIs assessment [35], [41], [46], [48], [80]. Web-based software EvalTools® 6 provides electronic integration of Administrative Assistant System (AAS), Learning Management System (LMS), Outcomes Assessment System (OAS) and Continuous Improvement Management System (CIMS) facilitating faculty involvement for realistic CQI [35], [41], [46], [48], [80]. The CIMS feature electronically integrates Action Items (AIs) generated from program outcomes term reviews with the Faculty of Engineering standing committees' meetings, tasks list and overall CQI processes.

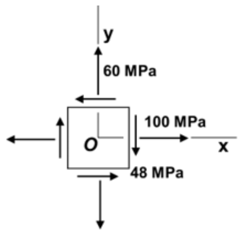


FIGURE 11. ME 224 final exam Q6 problem.

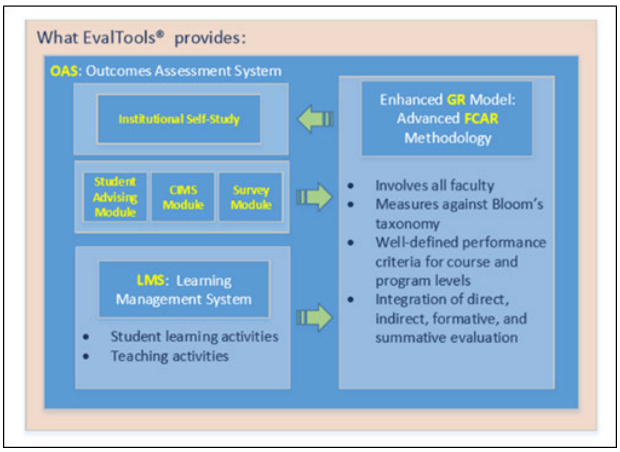


FIGURE 12. EvalTools ® 6 system architecture (reproduced with permission from Makteam Inc.)

Figure 12 shows the architecture design of EvalTools® 6. EvalTools®6 uses a database abstraction layer to interface with the database [48]. This design allows interface to any database; however, MySQL is used as the primary database server. Sessions and Class files are separate from the presentation layers. The structure of the architecture shown in Figure 12 has proven adaptive and agile for design changes or add-on modules [48].

EvalTools® is designed for day-to-day classroom activity and for gauging whether learning and teaching delivery is meeting standards. Its outcomes assessment module, in particular, integrates proven best assessment practices including a rubric-driven assessment model and an FCAR assessment model. EvalTools® product suite comprises of the following independent and yet integrated products [48]:

- EvalTools® Survey – an online survey system that handles end-of-term survey, alumni survey, senior-exit survey, employer survey and other customizable surveys
- EvalTools® LMS – covers essential elements for managing day-to-day classroom activities such as lessons, assignments, grade book, etc.
- EvalTools® OAS – an Outcomes Assessment System that is unique in its class and covers best assessment practices. It has a proven 14 years' record of aiding universities for ABET accreditation. Recently, it also enabled universities to achieve excellent results with Middle-States accreditation
- EvalTools® CIMS – A Continuous Improvement Management System which electronically integrates corrective actions generated by outcome assessments and evaluation with the concerned stakeholders

1) FCAR AND PVT

The FCAR was initially developed by John K. Estell, Commissioner, Computing Accreditation Commission (CAC) ABET Inc. The FCAR has gradually expanded to include Performance Indicators (PIs) [46] and later classification of PIs according to Bloom's three domains and their learning levels [24], [41], [42], [67]. The Performance Vector Table (PVT) is explained in the later part of this section. The PVT Table facilitates the collection of outcomes data for all students assessed in the class [82]. Results of outcomes assessments are evaluated based on performance criteria, which have been published in much cited research on FCAR evaluations [46], [80]. The FCAR presents a structured format for the presentation of various aspects of course evaluations. The FCAR template utilized in the web-based software EvalTools® 6 provides formative and summative options for real-time and deferred action based course evaluations. Two diagnostic options are available for faculty course evaluation purposes i) *FCAR basic*: displays old ported actions, new actions, reflections and EAMU vector results without plots for all assessments corresponding to each CO and ii) *FCAR analytic*: displays detailed histogram plots for student performances in all assessments with their weighting factors corresponding to each CO [46], [48], [67].

The overall FCAR structure consists of multiple items indicated in Figures A1-A6 of Appendix A. Figure A7 of Appendix A shows the process flow [42] for the FCAR + specific/generic PIs model classified per Bloom's 3 domains using a *3-Levels Skills Grouping Methodology* adopted by the EE, ME and CE programs at the Islamic University in Madinah [24], [41], [42]. The FCAR model implements ABET criteria which require the development of quantitative/ qualitative measures to ensure students have satisfied the COs which are measured using a set of specific or generic PIs/assessments and consequently the program level ABET SOs. Course faculty is directly involved in the teaching and learning process and interacts closely with all the enrolled students. An ideal CQI cycle would therefore include the course faculty in most levels of its process, to generate and execute action items that can directly target real-time improvement in student performances for ongoing courses. Models that involve program faculty or

TABLE 6. Heuristic rules for performance criteria.

Specification of EAMU performance indicator levels:

Category –Scale%	Description
Excellent (E) (90 – 100)	Apply knowledge with virtually no conceptual or procedural errors
Adequate (A) (75 - 90)	Apply knowledge without significant conceptual errors and only minor procedural errors
Minimal (M) (60 – 75)	Apply knowledge with occasional conceptual errors and only minor procedural errors
Unsatisfactory (U) (0 - 60)	Significant conceptual and/or procedural errors when applying knowledge

Heuristic rules for Performance Vector Tables (PVT):

Category	General Description
Red Flag	Any performance vector with an average below 3.3 and a level of unsatisfactory performance (U) that exceeds 10%
Yellow Flag	Any performance vector with an average below 3.3 or a level of unsatisfactory performance (U) that exceeds 10%, but not both
Green Flag	Any performance vector with an average that is at least greater than 4.6 and no indication of unsatisfactory performance (U)
No Flag	Any performance vector that does not fall into one of the above categories

assessment teams that are not directly involved with the enrolled students will definitely not support real-time CQI which is an essential element of an authentic OBE system. The noteworthy aspect of this model shown in Figure A7 is that course faculty is involved in most CQI processes, whether at the course or program level [41], [42], [67]. The FCAR methodology applies various performance criteria for outcomes assessment and evaluation of individual students, class groups or programs [24], [41], [42], [46], [80]. Table 6 below illustrates EAMU PI levels, Heuristic rules for PVT and Heuristic rules to classify performance vectors in PVT [24], [35], [41], [45], [46]. An important point to note is that descriptors for EAMU scales shown in Table 6 are generic and applied to all PIs unless instructors opt to apply topic-specific descriptors of hybrid rubrics for assessing certain PIs of interest.

In Figure B1 (Appendix B), we see the performance vector for a civil engineering course, CE_201 Statics, showing the performances of 16 students for seven Course Outcomes (COs). In this clipped portion of the entire table generated by EvalTools® 6, we see COs 1, and 2 assessed for all 16 students in the class using multiple assessments. Aggregation of different types of assessments aligned to a specific learning outcome at the course level is achieved using a scientific weighted averaging scheme. This scheme gives priority to certain types of assessments over others based on their coverage of learning domains, percentage of course grading scales and maturity of students' learning at the time of taking the assessments. Details of this weighted averaging approach have been provided by Hussain, Addas and Mak (2016) [24]. The CO1: '*Define fundamental concepts of statics, system of units and perform basic unit conversions*'; is

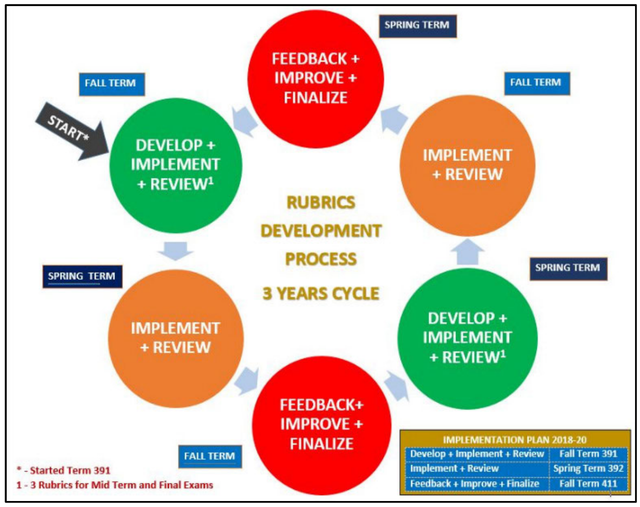


FIGURE 13. A recent 3 years cycle for development and implementation of hybrid rubrics.

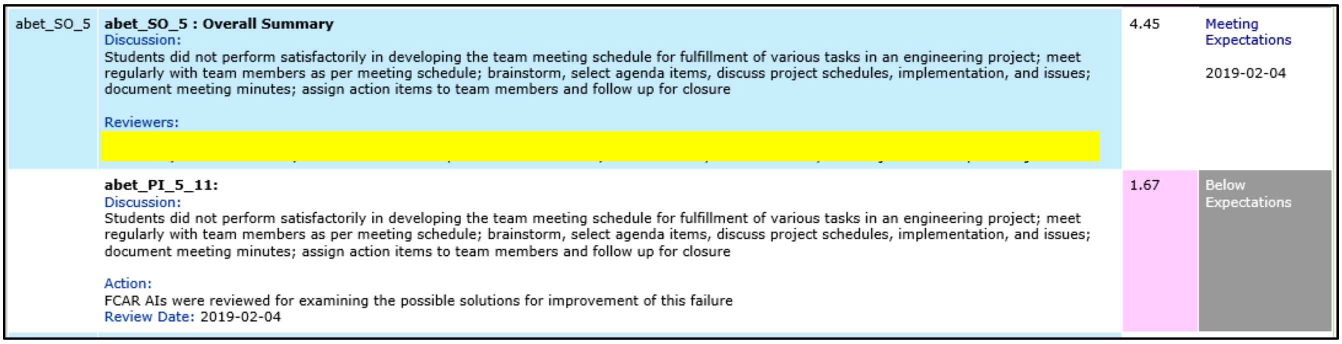
assessed for every student in the class using multiple relevant assignments such as quiz 1 (QZ_1) and midterm-1 question 1 (Mid Term-1 Q-1), which are aligned to specific performance indicators and aggregated together using this scientific weighted averaging scheme. The performance vector provides details of each student's performance in multiple assessments aligned to PIs that correspond to all the COs. Figure 14 summarizes the aggregate score achieved for all COs and their EAMU vectors for CE_201 Statics course. EvalTools® 6, employing the FCAR assessment model, facilitates electronic storage of the outcomes and assessment information for each student collected from several courses in every term. The FCARs from each course are further processed into a PVT for each SO.

Assessment Level WFs Calculation Procedure

EvalTools® 6 Weighting factor calculation procedure for EAMU performance vector methodology facilitates the allocation of weights to different types of assessments. Assessments such as final exams capture student performances at maximum levels of maturity and therefore deserve higher weightage as compared to other initial assessments. On the same note, assessments that involve complex learning activities such as engineering design related to multiple learning domains also necessitate their dominance in overall outcomes aggregation.

Steps Employed by EvalTools® 6 to calculate the EAMU Vectors [24], [35], [46], [81]

1. Faculty use EvalTools® 6 Assignment Setup Module to identify an assignment with a set of specific questions, or split an assignment to use a specific question or sub-question for outcomes assessment with relatively high coverage of a certain PI mapping to CO, ABET SO (for EAMU calculation).
2. EvalTools® 6 removes students who received DN, F, W or I in a course from EAMU vector calculations, and enters student scores on the selected assignments and questions for remaining students.



abet_SO_5	**abet_SO_5 : Overall Summary** Discussion: Students did not perform satisfactorily in developing the team meeting schedule for fulfillment of various tasks in an engineering project; meet regularly with team members as per meeting schedule; brainstorm, select agenda items, discuss project schedules, implementation, and issues; document meeting minutes; assign action items to team members and follow up for closure Reviewers:	4.45	Meeting Expectations 2019-02-04
	abet_PI_5_11: Discussion: Students did not perform satisfactorily in developing the team meeting schedule for fulfillment of various tasks in an engineering project; meet regularly with team members as per meeting schedule; brainstorm, select agenda items, discuss project schedules, implementation, and issues; document meeting minutes; assign action items to team members and follow up for closure Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2019-02-04	1.67	Below Expectations

FIGURE 14. ABET SOs (1-7) evaluation module for term 391 (Fall 2018) showing PIs assessed for abet revised SO 5 (teamwork skills).

3. For each student, EvalTools® 6 calculates the weighted average percentage on the assessments, a set of questions selected by faculty. Weights for assessments are set according to the product of their percentage in the course grading scale and multiplication factor based on the course format (refer Table 5) and entered in the weighting factor section of the Assignment Setup Module.
4. EvalTools® 6 uses the average percentage to determine how many students fall into the EAMU categories using the pre-selected EAMU assessment criteria (refer Table 6).
5. EvalTools® 6 calculates the EAMU average rating by rescaling to 5 for a weighted average based on a 3-point scale as shown in Equation (2).

$$EAMU\ average = \frac{3*E+2*A+1*M+0*U}{E+A+M+U} * \left(\frac{5}{3}\right) \tag{2}$$

Table 7 shows an example of how EAMU vectors are computed for a specific PI. Assessments HW3 and HW8 are selected for measuring a specific PI ABET_PI_5_3. These assessments are weighted according to the course grading policy and multiplication factor. Let's say the weights are 5% for HW3 and 7% for HW8. The percent-weighted score is computed by Equation (3): The PI EAMU classification for each student in the class, as indicated in the second column is obtained from this % weighted average. The PI EAMU vector (3,1,1,2) for the entire class in the last column is obtained based on the count of students belonging to each of the categories as defined by: *Excellent*: scores >= 90%; *Adequate*: scores >= 75% and < 90%; *Minimal*: scores >= 60% and < 75%; and *Unsatisfactory*: scores < 60%. In this case, there are 3 students with scores belonging to E; 1 student in A; 1 student in M; and 2 students in U; categories. Finally, the weighted average of the EAMU vector for this specific PI_5_3 is 2.86, which is obtained as per Equation (2).

$$\begin{aligned}\%\ \text{weighted avg.} &= \frac{\left(\frac{20}{30} * wf1 + \frac{40}{60} * wf2\right)}{wf1+wf2} * 100 \\ &= \left(\frac{20}{30} * 5 + \frac{40}{60} * 7\right) / (5+7) * 100 \\ &= 66.67 \end{aligned} \tag{3}$$

TABLE 7. Calculation of aggregated EAMU† for A PI.

Student	abet_PI_5_3	Hw3 (30)	% weighted (wf=5%)	Hw8 (60)	% weighted (wf=7%)	Percent-weighted
student 1	M	20	3.33	40	4.67	66.67
student 2	U	10	1.67	8	0.93	21.67
student 3	E	30	5.00	57	6.65	97.08
student 4	U	26	4.33	10	1.17	45.83
student 5	E	28	4.67	60	7.00	97.22
student 6	E	29	4.83	53	6.18	91.81
student 7	A	29	4.83	40	4.67	79.17
	EAMU	(4,1,1,1)		(2,1,2,2)		(3,1,1,2)
	Average	3.81		2.38		2.86

†Excellent: 90%-100%; Adequate: 75%-89.99%; Minimal: 60%-74.99%; Unsatisfactory: 0-59.99%

In Figure B3 (Appendix B) is a CE_201 Statics course example showing Final Exam Q1 WF calculation using equation (1). The course format 1 from Table 5 is applied since there are no labs and/or project assessments in this course. The WF for Final Exam Q1 is calculated as 80%. Figure B4 (Appendix B) shows a portion of the analytical FCAR for CE_201 Statics course. CO6 is aggregated for assessments QZ4 (WF 1.25%), Final Exam Q1 (WF 80%) and Q2 (WF 80%). The Final Exam Q1 and Q2 dominate QZ4 contribution in the overall weighted average computation of CO6.

Program Level Skills Aggregation and Weighting Factors [24]

The philosophy behind the implementation of this *Hierarchy-Frequency Weighting-Factor Scheme* (HFWFS) for program learning domains evaluations is to consider a combination of two critical factors:

(a) to implement a hierarchy of skills by giving prevalence to those assessments that measure skills of the highest order over others. For example, mastery-advanced level PIs will have a higher prevalence than those for the reinforced-advanced level; and

(b) to consider the counts of assessments implemented in a certain learning level since outcomes assessment is directly equivalent to learning. Table 8 shows the calculation of weighting factors for various learning levels of the *Mastery, Reinforced* and *Introductory* courses, which are then applied

TABLE 8. Calculation of weighting factors for various learning levels of Mastery, reinforced and introductory courses.

ABET SO_1, SO 'a'	Course level- PI level	Counts(i) in term 361	%Learning Distribution [LD(i)]	% Progressive Distribution [PD(i)]	% Relative Distribution [RD(i)]	Weights WF(i) = LD(i) x RD(i)
Learning level (i)		DATA FROM EVALTOOLS	{counts(i)/total}×100	∑ LD(i)	{PD(i)}/Min{LD(i)}	{LD(i) × RD(i)}
1	MASTERY-ADV		0.00%	100.00%	3.04	0.00%
2	MASTERY-INTER		0.00%	100.00%	3.04	0.00%
3	MASTERY-ELEM	14	20.00%	100.00%	3.04	60.87%
4	REINFORCED-ADV	1	1.43%	80.00%	2.43	3.48%
5	REINFORCED-INTER	6	8.57%	78.57%	2.39	20.50%
6	REINFORCED-ELEM	21	30.00%	70.00%	2.13	63.91%
7	INTRODUCTORY-ADV		0.00%	40.00%	1.22	0.00%
8	INTRODUCTORY-INTER	5	7.14%	40.00%	1.22	8.70%
9	INRTODUCTORY-ELEM	23	32.86%	32.86%	1.00	32.86%
	TOTAL	70				

to measured PIs in given course levels to compute the final program ABET SO 'a' value.

The detailed calculation for each column in Table 8 is reported in past research [41] and also shown here:

The Learning Distribution % (LD)

Equation (4) shows the percentage of total assessments implemented in all courses for each learning level. Table 8 shows that for ABET SO 'a' (SO_1), 6 assessments out of 70 were implemented in reinforced-level courses measuring intermediate level PIs for all 3 domains composite. Assessments in this level accounted for 8.57% of learning.

$$LD(i) = \frac{count\ (i)}{Totalcount} \times 100 \tag{4}$$

The Progressive Distribution % (PD)

Equation (5) calculates PD by summing LD values according to the hierarchy of the skills levels. Mastery courses and advanced skill levels are assigned the highest progressive distribution value.

$$PD(i) = \sum_{1}^{i} LD(i) \tag{5}$$

The Relative Distribution % (RD)

Equation (6) calculates RD by dividing the PD(i) value with LD(m): the non-zero minimum value (learning level 'm') of the set of LD values corresponding to all the learning levels 1 to i.

$$RD\ (i) = \frac{PD(i)}{Min - non - zero\{LD(1), LD\ (2)\ , \ldots\ LD(i)\}} \tag{6}$$

The Weighting Factors WF(i) for the various measured learning levels given by Equation (7) for ABET SO 'a' (SO_1) are calculated by multiplying LD(i) with RD(i).

$$WF\ (i) = LD\ (i) \times RD(i) \tag{7}$$

ABET SOs Weighted Average Values Calculations for Program Evaluations

This section illustrates how the weighted average value of 3.42 for ABET SO 'f' (SO_6) highlighted in Table 9 is obtained. The values in the rightmost column WF(i) in Table 9 are the weights for different learning levels related to ABET SO 'f'. Figure B5 shows the detailed list of specific PIs measured by the CE program in term 382 (Spring 2018) for ABET SO 'f' (SO_6) and classified according to Bloom's 3 domains and learning levels.

Table 9 shows the weighted average values, weighting factors WF(i) for learning levels, Bloom's learning levels for specific PIs measured from reinforced and introductory level courses for ABET SO 'f' program evaluation. Figure B6 (Appendix B) shows WFs defined for 3-Level Skills *Advanced, Intermediate* and *Elementary* measured in *Mastery, Reinforced* and *Introductory* courses. Since assessments corresponding to SO 'f' (SO_6) in term 382 (Spring 2018) covered PIs and skills targeting an advanced level of the *Affective* domain: *Internalization;* in just *Mastery* and *Reinforced* courses, the WFs for other skill levels were obviously defined as zero and thus not taken into account. For example, consider the ABET_PI_6_5 shown in Table 9. It is classified as an *Affective* domain *Internalizing* level per Bloom's learning model and is an *Advanced* skill level per the *3-Level Skills Grouping Methodology* [24], [41]. This PI is measured in a *Mastery* course *CE_482*, *Contracts and Construction Engineering*. It has an EAMU value of 3.21. From Figure B6 (Appendix B), the PI weighting factor for the Advanced level is 300. The column labeled Avg*WF displays 963 as the product of the EAMU weighted average value 3.21 with the PI weighting factor 300. The final ABET SO 'f' weighted average value is calculated according to Equation (8). The sum of values in column Avg*WF is 3162.25. This sum value is then divided by 925, the sum of the column WF, giving 3.42 as highlighted in yellow in Table 9.

2) SPECIFIC PIs DATABASE

The Faculty of Engineering programs have developed a state of the art digital database consisting of specific and generic PIs classified as per the 3 Bloom's domains and their learning levels through a very exhaustive and elaborate ongoing process to comprehensively measure engineering activities corresponding to ABET SOs for various skills levels in the *Introductory, Reinforced* and *Mastery* level courses while fulfilling Washington Accord engineering graduate attributes, knowledge, and professional competency profiles [68]. Figure C1 (Appendix C) shows portions of the database for PIs corresponding to ABET SO1 and SO7. Each PI is allocated an index and classified into affective, psychomotor and cognitive domains of Bloom's taxonomy and their learning levels. The [abet_PI_1_67]: Cognitive Analyzing *Calculate the volume flow rate or pressure difference at specific points in containers for flow problems by applying Bernoulli's equation that relates the total energy density at one point on a streamline to the value at another point* is classified as Cognitive Analyzing related to ABET SO_1 on problem-solving due to cognitive learning activity related to study of given flow parameter, pressure and energy density combinations. Samples of PIs classification corresponding to various revised ABET SOs (1-7) are listed below. Justifications are provided based on the type of learning activity for the PIs classification as *cognitive domain with learning levels*: creating, evaluating, analyzing, applying, understanding

TABLE 9. ABET SO 'F' calculation for CE program term 382 evaluation showing EAMU weighted average values, weighting factors, Bloom's learning levels for specific PIs measured in reinforced and mastery level courses.

PI			Course Code	Name	Course Level	E	A	M	U	Avg.	WF	Avg X WF	Bloom's Learning Level	3-Level Skills Grouping
Code	EAMU	Avg.												
abet_PI_6_5	(0,0,1,0)	3.21	CE_482_2256	CONTRACTS AND CONSTRUCTION ENGINEERING	Mastery	4	4	5	0	3.21	300	963	Internalizing values	Advanced
abet_PI_6_6	(0,0,0,2)	3.12	CE_321_2217	SOIL MECHANICS	Reinforced	0	5	6	2	2.05	25	51.25	Internalizing values	Advanced
			CE_482_2256	CONTRACTS AND CONSTRUCTION ENGINEERING	Mastery	5	4	2	2	3.21	300	963	Internalizing values	Advanced
abet_PI_6_26	(0,1,0,0)	3.96	CE_417_2229	STEEL STRUCTURES DESIGN	Mastery	3	5	0	0	3.96	300	1188	Internalizing values	Advanced
											Σ WF = 925	Σ avg * WF = 3165.25		
											Σ (avg * WF)/Σ WF = 3.42			

$$ABET\ SO\ 'a'\ weighted\ average = \frac{\sum_{PI\_6\_26}^{PI\_6\_5} Avg \times WF}{\sum_{PI\_6\_26}^{PI\_6\_5} WF} \tag{8}$$

or remembering; *psychomotor domain with learning levels*: origination, adaptation, complex overt response, mechanism, guided response, set or perception; and *affective domain with learning levels*: internalizing, organizing values into priorities, valuing, responding or receiving.

a: COGNITIVE LEARNING DOMAIN

1- [abet_PI_1_1] Cognitive: Understanding Explain the mechanical properties of materials like yield strength, Young's modulus, ultimate tensile strength, fatigue strength, creep strength, toughness, brittleness, ductility, hardness, elongation, brittleness etc.

Justification: Student learning activity related to understanding fundamental ME theory for problem solving, ABET SO '1' is classified as an understanding learning level of Bloom's cognitive domain. Since students describe the required fundamentals of ME theory, this PI is classified as an understanding learning level.

2- [abet_PI_1_76] Cognitive: Analyzing Analyze flow distribution in given fluid mechanics problems; calculate/use velocity profile from given internal flow conditions (pipes, plates, rectangular duct etc.) or provided information; apply Newton's law of friction to calculate shear stress for laminar or turbulent flow at the wall or inside the flow

Justification: Student learning activity related to problem-solving for ABET SO '1' is classified as an analyzing learning level of Bloom's cognitive domain. Since students analyze given ME problems and perform appropriate formulation to solve, this PI is classified as an analysis learning level.

3- [abet_PI_1_1] Cognitive: Understanding Describe the fundamentals of communication systems, such as amplitude and frequency modulation (AM, FM), pulse modulation (amplitude, width and position), sampling, division multiplexing (frequency and time)

Justification: Student learning activity related to understanding fundamental EE theory for problem solving, ABET SO '1' is classified as an understanding learning level of the Bloom's cognitive domain. Since students describe required fundamentals of EE theory, this PI is classified as an understanding learning level.

4- [abet_PI_1_85] Cognitive: Analyzing Determine the geometric properties for different cross sections such as circular, rectangular, rods, wide flanges, channels, angles, tees, etc.; compute centroid, first moment, second moment of inertia, polar moment of inertia, radius of gyration, sectional modulus and elastic modulus

Justification: Student learning activity related to problem solving ABET SO '1' is classified as an analyzing learning level of Bloom's cognitive domain. Since students analyze given CE problems and perform appropriate formulation to solve, this PI is classified as an analysis learning level.

b: PSYCHOMOTOR LEARNING DOMAIN

1- [abet_PI_6_27] Psychomotor: Adaptation Implement required testing procedures on manufactured components using standardized testing equipment as per various engineering standards (AISI, ASTM, ISO, ASME, etc.,) to assess stress, strain, cracks, excessive deformations, necking, strength, ductility etc., identify the root cause of failures to apply corrective measures for qualifying the manufactured component

Justification: Student learning activity related to the setup of experimental apparatus for ABET SO '6' is classified as an adaptation level of Bloom's psychomotor domain. Since students adapt standard ME experimental procedures in various experiments, this PI is classified as an adaptation learning level.

2- [abet_PI_6_2] Psychomotor: Adaptation Design and construct different types of control systems and setups such as proportional control and proportional-integral derivative control schemes, temperature process control, servomotor, motor-generator torque, two tank level system, second order line etc.; assemble or connect the circuit as per specifications or design requirements and choose appropriate components/modules/equipment

Justification: Student learning activity related to the setup of experimental apparatus for ABET SO '6' is classified as an adaptation learning level of Bloom's psychomotor domain. Since students adapt standard electrical engineering experimental procedures in various experiments, this PI is classified as an adaptation learning level.

3- [abet_PI_6_7] Psychomotor: Adaptation Setup equipment such as Vicat apparatus, sieve etc.; prepare the cement and water paste using appropriate proportions; calibrate needle, scale and bowl etc.; make observations of gauge and needle for determining the properties like initial and final setting time, normal consistency of cement, soundness, specific gravity, paste strength, hardness, fineness modulus for various types of cement such as OPC, SRC, LHC, RHC and special cement like slag, Pozzolan, fly ash, silica foam, rice husk ash etc.

Justification: Student learning activity related to the setup of experimental apparatus for ABET SO '6' is classified as an adaptation learning level of Bloom's psychomotor domain. Since students adapt standard CE experimental procedures to perform various experiments, this PI is classified as an adaptation learning level.

c: AFFECTIVE LEARNING DOMAIN

1- [abet_PI_2_23] Affective: Internalizing values Develop the mathematical model of the solution to the design problem: Apply selected methods for design with appropriate engineering principles; Select specific engineering parameters corresponding to the variable and/or required specifications related to materials for performing complete mathematical analysis of the final proposed design; Calculate yield strength, ultimate strength, fatigue strength, creep strength, toughness, hardness, elasticity, ductility, compressibility and collapsibility etc.; Analyze microstructure, chemical composition, phases etc. to fulfill both the customer requirements and realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability considerations

Justification: Student learning activity related to design for ABET SO '2' is classified as an internalization learning level of the Bloom's affective domain. Since students learning activity is driven by design objectives related to fulfillment of customer requirements and realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability, this PI is classified as an internalization learning level.

2- [abet_PI_5_4] Affective: Internalizing values Contribute actively to prepare the team contract with collaboration of team members and faculty; define conditions of team contract such as general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution; elaborate individual and team member strengths and weaknesses with faculty and colleagues related to the definition of team roles; collect and verify CVs appropriately aligned to required roles; submit signed team contract with finalized assignment of team roles

Justification: Student learning activity related to teamwork for ABET SO '5' is classified as an internalization learning level of Bloom's affective domain. Students actively participate in preparing a team contract that consists of general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution. Since the efficacy of the team operation depends on the team contract defining professional ethics, this PI is classified as an internalization learning level.

3) HYBRID RUBRICS

EvalTools® provides dual features to instructors wherein they can program rubrics tailored to assessments in courses or utilize the rubrics aligned to the PIs databases. The hybrid rubrics are used by both students and instructors for estimating the level of performances and verify score marking for various assessments. The database consists of rubrics related to PIs for the 7 ABET SOs classified according to three domains of Bloom's taxonomy. As shown in Figure 13, The Faculty of Engineering Quality and Accreditation (QA) Office in close coordination with all faculty members of the EE, ME and CE programs has employed a 3 years rotating plan for development and implementation of a sophisticated database of hundreds of rubrics. The plan was implemented in term 391 (Fall 2018) wherein 3 rubrics were developed covering major learning activities in every core course for application in Mid-terms 1 and 2, and Final exams. The second iteration for development of a set of 3 additional rubrics began in term 411 (Spring 2020).

Table 10 shows COs, PIs and rubrics implemented at the CE, EE and ME programs [2014-19] for various types of learning activities such as teamwork, safety regulations, professional ethics, experimentation, capstone design,

TABLE 10. Summary of counts of COs, PIs, SOs and hybrid rubrics implemented for the EE, CE and ME programs.

SKILLS	COURSE OUTCOMES	THEORY & PROBLEM SOLVING		DESIGN		COMMUNICATION		SAFETY, STANDARDS & PROFESSIONAL ETHICS		TEAMWORK		EXPERIMENTATION		LIFELONG LEARNING		TOTAL	
OUTCOMES	COS	SO1		SO2		SO3		SO4		SO5		SO6		SO7			
PROGRAM		PIS	RUBRICS	PIS	RUBRICS	PIS	RUBRICS	PIS	RUBRICS	PIS	RUBRICS	PIS	RUBRICS	PIS	RUBRICS	PIS	RUBRICS
CE	192	194	65	77	14	23	6	78	8	14	1	77	20	9	2	472	116
ME	176	144	51	54	13	15	1	53	11	11	2	62	36	7	2	346	116
EE	144	211	70	58	6	20	1	64	4	12	1	47	29	13	2	425	113
ENGR	56	76	0	15	0	18	0	51	0	18	0	26	0	10	0	214	0
SUMMARY	568	625	186	204	33	76	8	246	23	55	4	212	85	39	6	1457	345

problem solving, report writing, poster and oral presentations, metacognition in lifelong learning. Appendix C *PIs and Hybrid Rubrics* provides samples of PIs and Hybrid Rubrics databases on the EvalTools® platform.

4) SOs, PIs EVALUATIONS

The complete assessment strategy for each measured ABET SO and estimation of program-level competencies is provided in the 3 phase SOs, PIs and learning domains evaluation modules' term summary [24], [41], [67]. The term summary contains detailed information on the type of assessments used, their course levels, counts, learning distributions, and skill levels of the associated performance indicators [24], [41], [67]. Any existing deficiencies in current assessment models for measured ABET SOs are identified through a detailed 3 phase program term review process conducted by faculty members. Student performances at the course level are measured using PIs and then aggregated at the program level with scientific weighting factors for a corresponding term to contribute to the final SO value [24], [41], [67]. Figure D1 (Appendix D) shows a sample PIs evaluation snapshot showing the revised 7 ABET SOs results for the EE program term 391 (Fall, 2018). In this case, the SO_7 related to lifelong learning is examined for any failing PIs. Color- coded results correspond with the performance criteria and heuristics rules mentioned in Table 6. As shown in Figure D2 (Appendix D), PIs evaluations list the SOs results with contributing courses which can be accessed using the activate FCAR options. This enables reviewers with the capability to audit any potential issues with course reflections and subsequent actions. The PIs and SOs evaluation is focused on failing SOs and PIs for analysis and discussions relating to improvement. Figure D3 (Appendix D) shows the PI review comments for PI_4_7 and ABET SO '4' for the EE program in term 391. All the comments of the reviewers from PIs evaluations are rolled up into the SOs evaluation executive summary report. A cut portion of the executive summary report showing ABET SO_5 for the EE program term 391 (Fall 2018) is shown in Figure 14 below. An overall summary with final status of performance for revised ABET SO 5 is shown as *Meeting Expectations*. A list of reviewers and failing PIs with any documented corrective actions are reported in the executive summary.

EvalTools® provides the following program term review evaluation reports in printable word or pdf format [41], [67]:

a) SO executive summary
b) Detailed SO/PI executive summary
c) SO/PI Performance Vector Table PVT summary and
d) Course reflections/action items

Cut portions of these reports are presented in Appendix E for better understanding.

5) LEARNING DOMAINS EVALUATIONS

In the programs' term review learning domains evaluation, estimated learning distributions in Bloom's 3 domains and their 3 skills levels are compared with target ideal values to generate several CQI activities such as the modification or development of: teaching and learning activities; course outcomes; course topics; and assessments and associated PIs to correct the existing learning distribution deficiencies [41]. The FCAR embedded assessment methodology, *Hierarchy Frequency Weighting-Factors Scheme* (HFWFS) combined with digital technology, promotes easy development and usage of formative assessments, making each phase of the course, curriculum delivery transparent to all stakeholders and provides precise information of where and why performance weaknesses exist for timely remedial actions. The implemented assessment and evaluation methodology encourages faculty to use relevant information for real-time modifications. The generation of assessments and their mapping to specific PIs for measurement followed up with failure identification, and remedial action is a total faculty affair, thereby creating the ideal situation for CQI in engineering education [24], [41], [42], [67]. Since assessments are equivalent to learning in the OBE model [25], [89], the Faculty of Engineering has decided to consider the type of assessments, their frequency of implementation, and the learning levels of measured specific PIs in Bloom's 3 domains for courses and overall program evaluations [41]. At the course level, the types of assessments are classified using the course formats chart to calculate their weighting factors [24], [35], [41], [67], which are then applied using the setup course portfolio module of EvalTools® 6 [23]. The results can be seen in the FCAR and are used for course evaluations. The program level ABET SO evaluations employ a weighting scheme HFWFS, which considers the frequency of assessments implemented in courses for a given term to measure PIs related to specific learning levels of Bloom's domains [41].

Figure 15 shows the EE program term 382 (Spring, 2018) composite learning domains evaluation data for 11 ABET

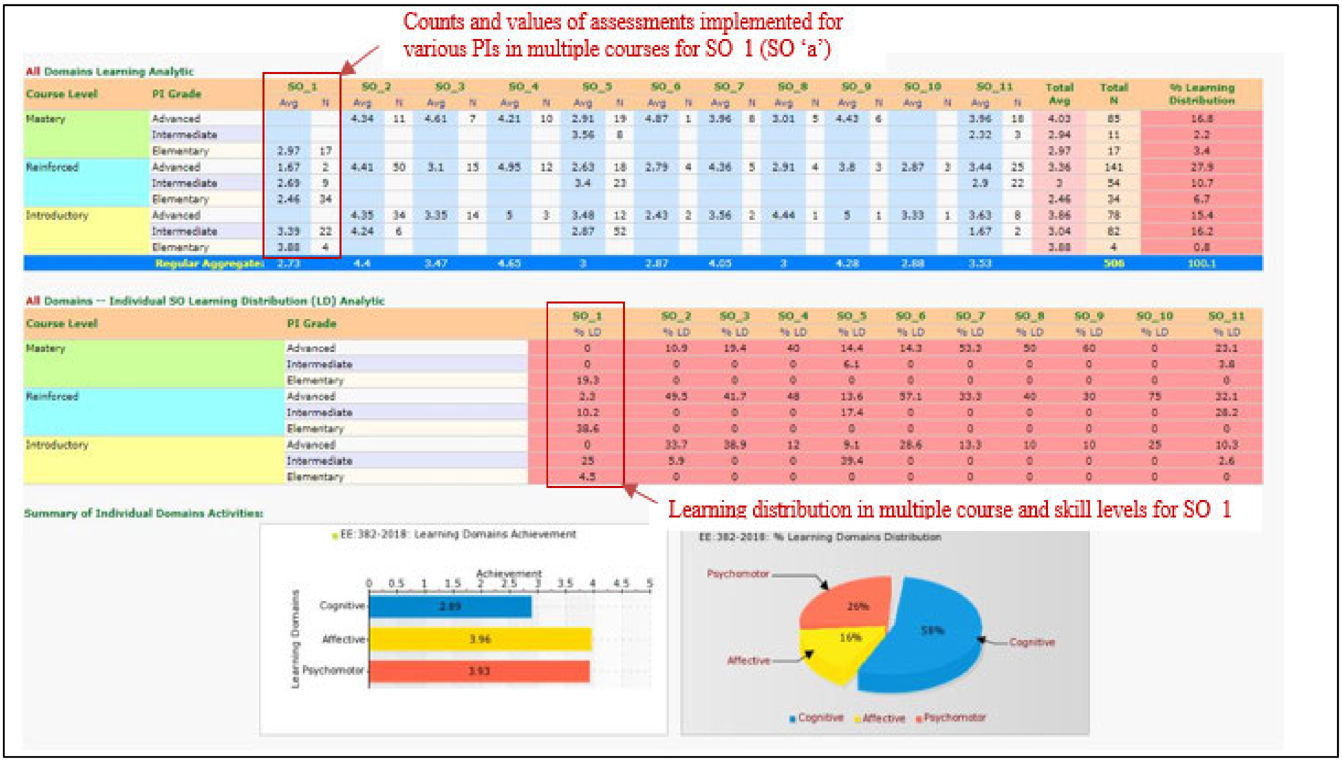


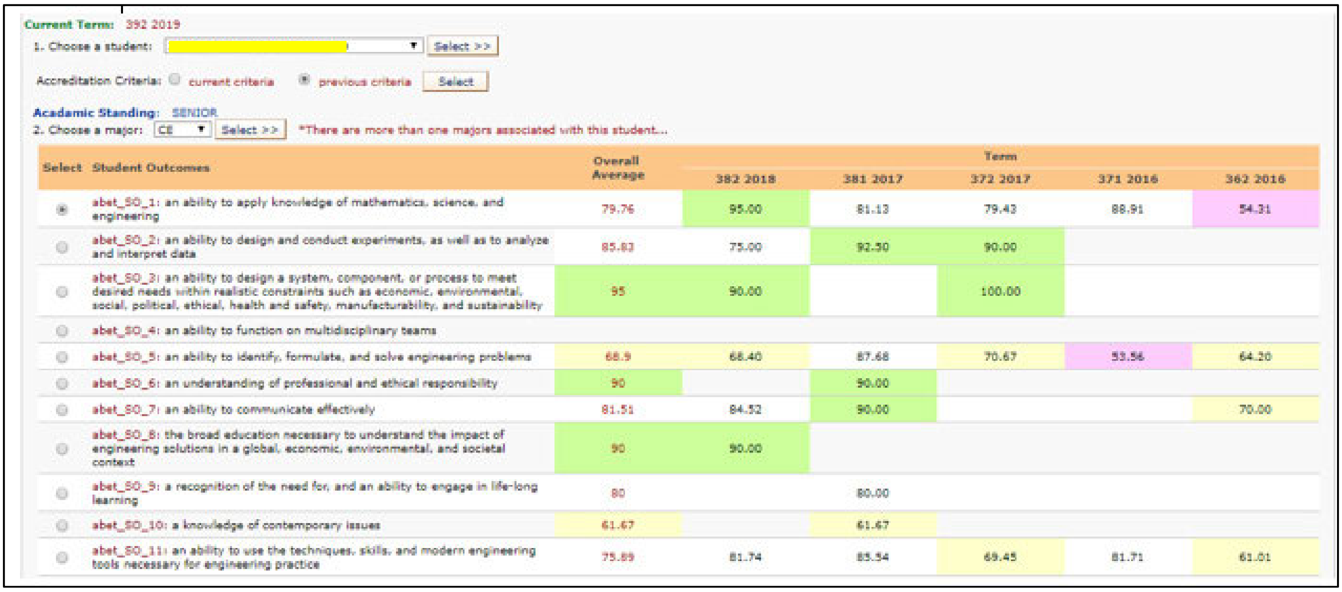
FIGURE 15. Learning domains evaluation for EE program showing all 3 domains' composite data with assessments counts and their aggregate average values for various learning levels and ABET SO 'a' highlighted.

SOs. For each SO, the counts of total assessments and their aggregate average values are tabulated for each learning level [41]. Figure 15 also shows the overall percentage learning distribution in each learning level for all the 11 ABET SOs. The counts of assessments in various learning levels and their calculated values for all 11 ABET SOs are displayed for each learning domain [41]. The ABET SO 'a' (SO_1) is highlighted for understanding. The bottom portion of Figure 15 shows average values calculated on a 5.0 scale for the cognitive, affective and psychomotor domains, providing a good overall indication of how the program has performed in each learning domain. The pie chart indicates the EE program term 382 outcomes assessment activity percentage distribution in the 3 Bloom's learning domains. Figure 38 shows analytical results of learning distribution for 11 ABET SOs in the individual cognitive, affective and psychomotor— Bloom's domains of learning. A detailed term review report for each program was compiled with information on efforts for improvement targeting comprehensive coverage of each ABET SO to achieve curriculum delivery according to the *Ideal Learning Distribution Model*. Figure D5 (Appendix D) shows the learning domains composite and individual ABET SOs learning domain evaluations review reports for the EE program for a specific term, in which the ABET SOs coverages of the Bloom's 3 domains and their learning levels, categorized as per the 3-Skills Level Methodology, are studied and discussed. In the left column, a report of discussion and reflections for composite learning domains evaluation and learning distribution for individual SOs are indicated, where the overall percentage distribution of learning in the 3 domains, ABET SOs coverages, are analyzed and comments entered with a possible categorization of serious and other types of concerns for corrective action. In the right column, corrective actions for both composite and individual SOs learning domain evaluations are reported for follow up activity related to improvement in teaching/learning strategy, infrastructure, administrative process, or refinement of the current term's SOs assessment plan.

6) ADVISING BASED ON OUTCOMES

a: STUDENT LEVEL EVALUATION AND CQI

The Faculty of Engineering has implemented student advising systems employing the FCAR + specific/generic PIs classified per Bloom's domains and 3-Levels Skills Grouping methodology, and EvalTools® [67], [90]. A YouTube video also presents some detail of the features of this module and how individual student skills data is collected by using specific PIs, course assessments and integrated by faculty into academic advising [88]. Figure 16 illustrates a list of ABET SOs for previous (a-k) criteria calculated from PIs measurements for a typical student evaluation. The student skills SOs data is realistic and corresponds closely with actual student performances since 16 essential elements of precision assessment have been implemented to ensure outcomes data is as accurate as possible [24], [41], [67], [90].



Current Term: 392 2019

1. Choose a student: Select >>

Accreditation Criteria: current criteria previous criteria Select

Academic Standing: SENIOR

2. Choose a major: CE Select >> *There are more than one majors associated with this student...

Select	Student Outcomes	Overall Average	Term				
			382 2018	381 2017	372 2017	371 2016	362 2016
	abet_SO_1: an ability to apply knowledge of mathematics, science, and engineering	79.76	95.00	81.13	79.43	88.91	54.21
	abet_SO_2: an ability to design and conduct experiments, as well as to analyze and interpret data	85.83	75.00	92.50	90.00		
	abet_SO_3: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	95	90.00		100.00		
	abet_SO_4: an ability to function on multidisciplinary teams						
	abet_SO_5: an ability to identify, formulate, and solve engineering problems	68.9	68.40	87.68	70.67	53.56	64.20
	abet_SO_6: an understanding of professional and ethical responsibility	90		90.00			
	abet_SO_7: an ability to communicate effectively	81.51	84.52	90.00			70.00
	abet_SO_8: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	90	90.00				
	abet_SO_9: a recognition of the need for, and an ability to engage in life-long learning	80		80.00			
	abet_SO_10: a knowledge of contemporary issues	61.67		61.67			
	abet_SO_11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	75.89	81.74	85.54	69.45	81.71	61.01

FIGURE 16. **CE program's individual student's ABET SOs (a-k) composite skills cumulative data measured over multiple terms.**

Figure 16 shows how the ABET SO data is computed for each individual student. The PVT methodology of the automated FCAR facilitates the term wise collection of all (a-k or 7) SOs assessment data for each student. Appropriate WFs are applied to various assessments and skill types to obtain a high level of accuracy in the final outcomes data computations. Advisors and students can review analytical detail regarding student outcome performances and use the diagnostic features of EvalTools ® advising module to obtain precise term wise information regarding contributing courses and various types of assessments [67], [90]. Figure F1 (Appendix F) clearly indicates the type of assessments, EAMU scale and score, WF, term and overall average PI score.

b: ACADEMIC ADVISING REPORTING USING EVALTOOLS® 6

Advisors are electronically assigned advisees on the advising module of EvalTools®. Advisors create digital repositories of meetings information with their advisees using EvalTools®. The benefit of this digital system is the ease of access and quick traceability into the history of student meetings and notes. The program coordinator can upload the current degree plans for advisor access.

As shown in Figure F2 (Appendix F), advisors upload necessary documentation like academic plans, transcripts or any other pertinent information for advising or career guidance. All notes added by the advisor can be either made visible to students or strictly confidential for access by the advisor and the program coordinator [67], [90]. Advisors can very easily verify whether students actually access their advising notes so that follow up actions in future meetings are adequately planned. The Faculty of Engineering programs are intending to implement advanced features related to the evaluation of professional development and lifelong learning using the advising module provided by EvalTools®.

c: ACADEMIC ADVISING BASED ON OUTCOMES USING EVALTOOLS® 6

OBE is an educational theory that bases every component of an educational system around essential outcomes. At the conclusion of educational experiences, every student should have achieved essential or culminating outcomes. Classes, learning activities, assessments, evaluations, feedback, and advising should all help students attain the targeted outcomes. The National Academic Advising Association (NACADA) guidelines for academic advising also state that each institution must develop its own set of student learning outcomes and the methods to assess them [91]. NACADA states student learning outcomes for academic advising are "*an articulation of the knowledge and skills expected of students as well as the values they should appreciate as a result of their involvement in the academic advising experience*". These learning outcomes answer the question, "*What do we want students to learn as a result of participating in academic advising?*" [91]. Assessment of student learning should be a part of every advising program. ABET Criterion 1 for accreditation specifically states "Student performance must be evaluated. Student progress must be monitored to foster success in attaining student outcomes, thereby enabling graduates to attain program educational objectives. Students must be advised regarding curriculum and career matters" [11]. So individual student skills data or results would be both a fundamental requirement and pivotal base for the entire academic advising process to initiate and continue successfully. In fact, the ongoing and continual assessment of individual student skills would actually be the litmus test for a successful academic advising process. Figure F3 (Appendix F) shows how an elementary form of academic advising based on outcomes was initiated by engineering programs in the term 381 (Fall 2017). Currently, advisors report the failing ABET SOs and have a general discussion of the composite results with students. Eventually, the intention is to gradually expand the scope of this advising process to interact with both students and their course instructors with valuable feedback for enhancement of target skills derived from advising meetings based on outcomes [67], [90].

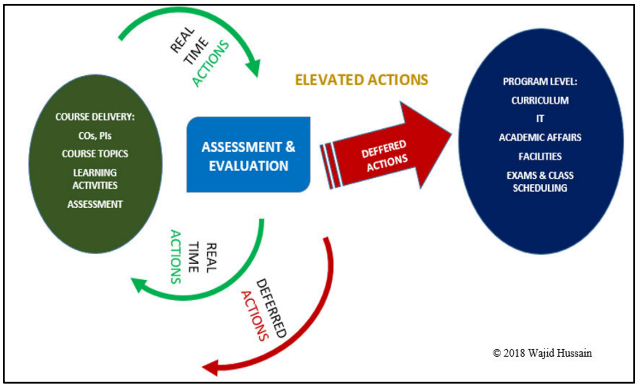


FIGURE 17. Course level actions - real time and deferred actions.

7) CIMS

a: COURSE LEVEL REAL TIME AND DEFERRED ACTIONS AND ELEVATED PROGRAM LEVEL ACTIONS

The main categories for corrective actions shown in Figure 17 for Faculty of Engineering programs' CQI process flow are program and course level actions. Faculty members perform assessment and evaluation, failure analysis of course outcomes, and write reflections, then generate real-time and deferred course level actions. The sequential content of course topics, WFs, and corresponding PIs data for assessments facilitate the application of formative corrective approaches for real-time mediation of student performance failures. Other actions related to any deficiency in culminating assessments, course topics, lecture outline etc. may necessitate deferred actions that will be applied by the instructor in the next offering of the course. As shown in Figure 17 some course actions are not the scope of the faculty and are therefore elevated in program term reviews as program-level actions to be electronically transferred with appropriate prioritization to concerned administrative committees for closure.

b: PROGRAM AND ADMINISTRATIVE COMMITTEE ACTION ITEMS, REPORTING AND DOCUMENTATION

The Faculty of Engineering programs have implemented the CIMS of EvalTools® for seamless operations, documentation and reporting of CQI activity for 20 standing administrative committees such as *Academic Advising, Examinations and Scheduling, Capstone Design, Vocational Training, Strategic Planning, Quality and Accreditation, Academic Affairs, Course and Curriculum Development, Graduate Studies, Human Resources, Alumni, External Advisory, Research and Community Service* etc. Meeting minutes, AIs and any necessary documents are all reported electronically. Hundreds of thousands of documents collected from the year 2014 to date, related to CQI activity for the EE, CE and ME programs are available in digital format on a cloud-based environment.

The Program and Administrative actions are either elevated or transferred to the concerned committee or are generated by the committee itself. As shown in Figure G1 (Appendix G), meeting minutes consist of items such as brainstorming, selected agenda items and included or generated AIs. Attendance sheets and any other documentation related to meetings are uploaded in meeting minutes' folders. Each meeting is assigned a unique electronic ID and is closed once finalized by the chair of the Program. AIs are either generated or transferred electronically. AIs are prioritized as Urgent (2 weeks closing time), High (3 weeks closing time), Normal (1-month closing time), Medium (2-month closing time), Low (3 months closing time). Each AI is assigned a unique electronic ID, consists of a time stamp, assignee and assigner information. The status of AI is either open or closed and relevant remarks are entered by the assignee/assigner at the time of change of status. Figure G2 (Appendix G) shows a sample window of AIs in the tasks list for the ME program committee in CIMS module of EvalTools ®. As shown in Figure G3 (Appendix G) below, multiple folders have been created for EE, ME and CE program committees to maintain digital information corresponding to program-level CQI activity relating to various categories such as ABET, ME Committee, Course Folders, NCAAA, Program Term Reviews etc.

The ME program's *ABET folder,* as shown in Figure G4 (Appendix G) consists of the following subfolders:

- Advising (Q_1)
- Course Delivery Process (Q_1)
- Course_Exit_Survey_Schedule (Q_1)
- Degree Plans (Program Curricular Information)
- EOT Program Assessment (Q_2)
- FCAR_Checklist (Q_2)
- ME Dept. Budget (Fiscal And Budget Planning)
- Midterm Report (Q_2)
- PDCA Cycles (Quality Cycles Flow Charts)
- Rubrics Development (Q_1)
- Rubrics Implementation Process (Q_1)
- Student_Graded_Work_Checklist (Q_2)
- Syllabus_Completion_Form (Q_2)
- Term_Wise_SO_Assessment_Plan (Q_2)

Objective evidence for CQI activity related to the PDCA quality cycles Q_1 and Q_2 is also indicated in parentheses for the subfolders above. Figure G5 (Appendix G) shows the data collected as objective evidence for several terms for CQI activity related to PDCA quality cycle Q_2: Course evaluation, feedback, and improvement for the EE program. Committee meetings folders as shown in Figure G6 (Appendix G) have been created for CE program meetings based on the month and their electronic ID.

Meetings minutes and associated documentation are uploaded accordingly in corresponding folders. NCAAA folders contain any documentation related to the Saudi Arabian National Accreditation Agency NCAAA [13]. Reviews folders shown in Figure G7 (Appendix G) consist of evidential documentation related to PDCA quality cycle Q_3: Program Term Review such as executive summary, SO/PI PVT, Course reflections/actions reports for SOs, PIs and Learning Domain Evaluations related to the CE program term reviews which are conducted every term

E. PRACTICAL FRAMEWORK – SUMMARY OF DIGITAL TECHNOLOGY AND ASSESSMENT METHODOLOGY

The Faculty of Engineering has studied various options for developing its assessment methodology and systems [19], [20], [22], [28], [29], [32], [34], [36], [37], [43]–[45], [47], [80] to establish actual CQI and not just to fulfill ABET accreditation requirements [11]. The following points summarize the essential elements chosen by the faculty to implement state-of-the-art assessment systems for achieving realistic CQI in engineering education [24], [41], [90]:

1. OBE assessment model
2. ABET, EAC outcomes assessment model employing PEOs, 11/7 ABET EAC SOs and PIs to measure COs.
3. Measurement of outcomes information in all course levels of a program curriculum: *Introductory, Reinforced* and *Mastery*.
4. The FCAR utilizing the EAMU performance vector methodology
5. Well-defined performance criteria for course and program levels.
6. A digital database of specific PIs and their hybrid rubrics classified as per Bloom's revised 3 domains of learning and their associated levels (according to the *3-Level Skills Grouping Methodology*).
7. Unique Assessment mapping to one specific PI.
8. Scientific Constructive Alignment for designing assessments to obtain realistic outcomes data representing information for one specific PI per assessment.
9. Integration of direct, indirect, formative, and summative outcomes assessments for course and program evaluations.
10. Calculation of program and course level ABET SOs, COs data based upon weights assigned to type of assessments, PIs and course levels.
11. Program as well as student performance evaluations considering their respective measured ABET SOs and associated PIs as a relevant indicator scheme.
12. The Program Term Review module of EvalTools® consisting of 3 parts a) Learning Domains Evaluation b) PIs Evaluation and c) ABET SOs Evaluation
13. A student academic advising module based on measured learning outcomes data
14. Electronic integration of the Administrative Assistant System (AAS), the Learning Management System (LMS), the Outcomes Assessment System (OAS) and the Continuous Improvement Management System (CIMS), facilitating faculty involvement for realistic CQI.
15. Electronic integration of AIs generated from program outcomes term reviews with the Faculty of Engineering standing committees' meetings, tasks, lists and overall CQI processes (CIMS feature)
16. Customized web-based software EvalTools® facilitating all of the above.

V. DESCRIPTION OF ASSESSMENT PROCESS AND ACTIVITY

According to the process flow for FCAR + Generic/Specific PIs model, which implements OBE principles and ABET accreditation criteria, the PEOs, SOs, COs, PIs and hybrid rubrics have to be developed, implemented, assessed, evaluated for deficiencies and improved based on subsequent actions for CQI. Therefore, elaborate CQI processes embedded in quality (Plan, Do, Check and Act) PDCA cycles proposed by Deming and Shewart [65] have been implemented at the CE, EE and ME programs at IU. Table 11 shows some detail regarding the process, participants, and frequency of assessment and evaluation activity implemented in various PDCA quality cycles to establish an IQMS for achieving holistic learning. A list of major assessment and evaluation activity related to the various PDCA quality cycles is provided below for a better understanding of Table 11:

1. Develop, Implement and Review PEOS with External Advisory Committee (EAC) - PDCA Q_6 (5-year cycle):
2. Develop/Adopt program SOs, multi-term review with EAC - Q_5 (3-year cycle)
3. Develop and Review performance criteria that define all SOs in a course - Q_1 (every term)
4. Review performance criteria and perform any major modification of program PIs database - Q_4 (3-year cycle)
5. Develop educational strategies, assessments aligned to performance criteria Q_1 (every term)
6. Develop, implement and review rubrics and assessment methods used to assess performance criteria - Q_1 (every term)
7. Collect and evaluate course level direct/indirect SOs assessment data, report finding and create actions - Q_1 (real-time throughout the term)
8. Implement course actions - Q_2 (termwise)
9. Evaluate program SOs data, report finding and create actions - Q_3 (termwise)
10. Implement program actions - Q_6 (termwise)

VI. INTEGRATED QUALITY MANAGEMENT SYSTEMS – 6 PDCA QUALITY CYCLES

Deming championed the work of Walter Shewhart, including statistical process control, operational definitions, and what Deming called the "*Shewhart Cycle*," which had evolved into PDCA for CQI [65]. The four phases of a typical

TABLE 11. Time-line of assessment and evaluation activity for CE, ME and EE programs Fall 2014 to Fall 2019.

Assessment and Evaluation Activity	Fall 14 (SOs a-k)	Spring 15	Fall 15	Spring 16	Fall 16	Spring 17	Fall 17	Spring 18	Summer 18 (SOs 1-7)	Fall 18	Spring 19	Fall 19
Q6: Develop, Implement and Review PEOS with EAC (5 year cycle)	Develop the program PEOs with faculty, stakeholders and publish	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**Align PEOs to REVISED ABET SOs 1-7 with Faculty and stakeholders**	N/A	EAC Major review in lieu of ABET revised accreditation criteria 2019-20	N/A
Q5: Develop/Adopt program SOs, multi-term (3 year cycle) review with EAC	Adopt the ABET SOs (a-k) with faculty, stakeholders and publish	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**Adopt revised ABET SOs 1-7 (2019/20 CRITERIA)**	Conduct multi term SOs (a-k) review	Present multi term data to EAC committee	N/A
Q1: Develop and Review performance criteria that define all SOs in a course (termwise)	Develop & Implement QIYAS & faculty COs, PIs								**Course Instructor & QA office every term**			
Q4: Review and major modification performance criteria of program database (3 year cycle)	Initial QIYAS nationalized outcomes implementation	Initial review and approval	N/A	N/A	N/A	N/A	N/A	3 Year major review completed	**Transition PIs to revised ABET SOs 1-7**	N/A	N/A	N/A
Q1: Develop educational strategies, assessments aligned to performance criteria (termwise)									**Faculty develop & implement for every course**			
Q1: Develop, implement and review rubrics and assessment methods used to assess performance criteria (termwise)									**Course Instructor & QA office every term**			
Q1: Collect and evaluate course level SOs data, surveys then report finding and create actions (real time throughout term)									**Course Instructor every term**			
Q2: Implement course actions (termwise)									**Real time and deferred to next term offering**			
Q3: Evaluate program SOs data, report finding and create actions (termwise)									**Program faculty every term**			
Q6: Implement program actions (termwise)									**Program and administrative committees follow corrective actions as per assigned prioritization**			

CQI cycle are 1) PLAN: developing the educational plan 2) DO: implementing the plan 3) CHECK: monitoring processes/results, conducting failure analysis, implementation of a plan to identify any variations to required processes or deficiencies in intermediate or final results and 4) ACT: Generate and implement appropriate corrective actions to remediate the observed deficiencies or mitigate projected failures. The Faculty of Engineering implemented state of the art IQMS consisting of 6 PDCA quality cycles based on authentic OBE principles using a web-based digital platform EvalTools® to achieve holistic engineering education for all students. The PDCA quality cycles are designed to employ digital automation wherever necessary for integrating various comprehensive quality monitoring, feedback and improvement processes to establish effective CQI. The PDCA cycles aid in the fulfillment of required ABET accreditation criteria for CQI. Specifically, they establish CQI processes related to the development, implementation, monitoring, feedback and improvement of programs' PEOs, SOs, COs, PIs and hybrid rubrics.

A comprehensive CQI process flow consisting of six PDCA quality cycles is shown in Figure 18, is explained in the following sections and listed below:

Q_1: COs, PIs and hybrid rubrics development

Q_2: Syllabi Checklist, FCAR Checklist and End of Term (EOT) Checklist

Q_3: Program term review

Q_4: PIs 3-year multi-term review

Q_5: SOs multi-term review

Q_6: PEOs 5-year review

A. PDCA QUALITY CYCLE Q_1: COs, PIs, RUBRICS DEVELOPMENT

Courses measure specific ABET SOs based on the course topics and target student learning activity. However, the Program Committee can assign relevant affective domain ABET SOs related to contemporary issues, the impact of engineering solutions, communication, teamwork, etc. for assessment in certain courses that contain appropriate content or project activity. *Sections IV.C.2 Design rules COs and PIs* and *IV.C 3 Hybrid Rubrics* provide a detailed explanation of the process related to the development of COs, PIs and rubrics. The process flowchart shown in Figure 19 lists learning activities, course topics and assessments as course inputs. The course inputs provide a fundamental guiding framework for the development of COs, PIs and their hybrid rubrics. Based on evaluation results, faculty members may decide to modify any aspect of the course inputs to reme-

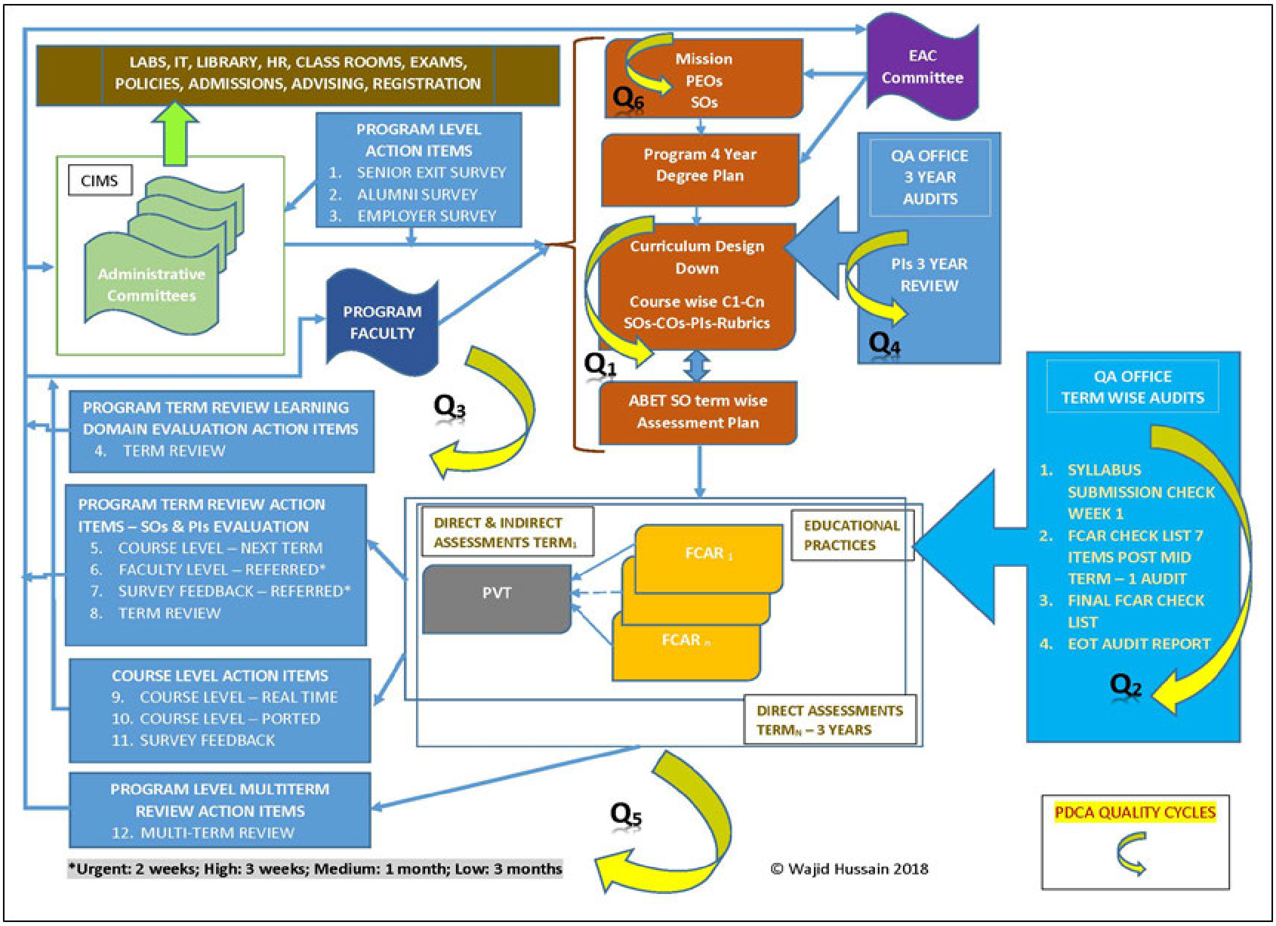


FIGURE 18. **CQI process flow for Faculty of Engineering programs.**

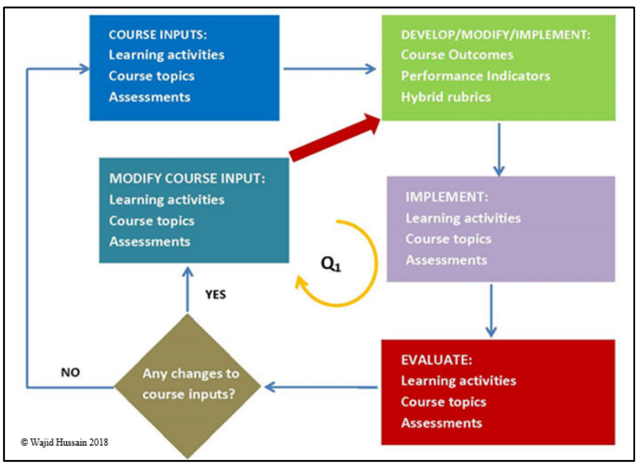


FIGURE 19. **PDCA quality cycle Q_1 COs, PIs and hybrid rubrics process development flow chart.**

diate observed failures. Any modification to course inputs could subsequently lead to a modification in the COs, PIs and their hybrid rubrics. In the first iteration of the rubrics implementation plan shown in Figure 13, three rubrics were implemented for corresponding PIs, one in each major assessment (Mid Term 1, Mid Term 2 and Final Exam), for all core courses excluding electives during the 2018-19 academic year. Upon completion of the first iteration, CE, EE and ME program committees reviewed subsequent improvement in the quality of teaching/learning and reported their recommendations for any modifications to the implemented rubrics.

In some cases, an additional set of rubrics was developed from a select group of PIs remaining in the database that targeted other major learning activities in core courses to enhance the overall quality of student learning. The improvement activities in the current 2019-2020 academic cycle involve the application of some modifications to existing rubrics and development of select additional rubrics. An example of the development of COs, PIs and hybrid rubrics for a mechanical engineering course, *ME_323*, *Theory of Machines* is explained in *Section 1* of Appendix J. Table J1 shows a list of COs, their PIs corresponding to revised ABET SOs (1-7) for course ME_323. The sequential order of COs, PIs target major learning activities corresponding to main course topics and comprehensively cover Bloom's 3 learning domains and their learning levels, achieve an *Ideal Course Learning Distribution* and fulfill required standards of engineering knowledge and skills. Samples of application of rubrics to various learning activities such as Capstone design and experimental work are also shown in *Section 1* of Appendix J.

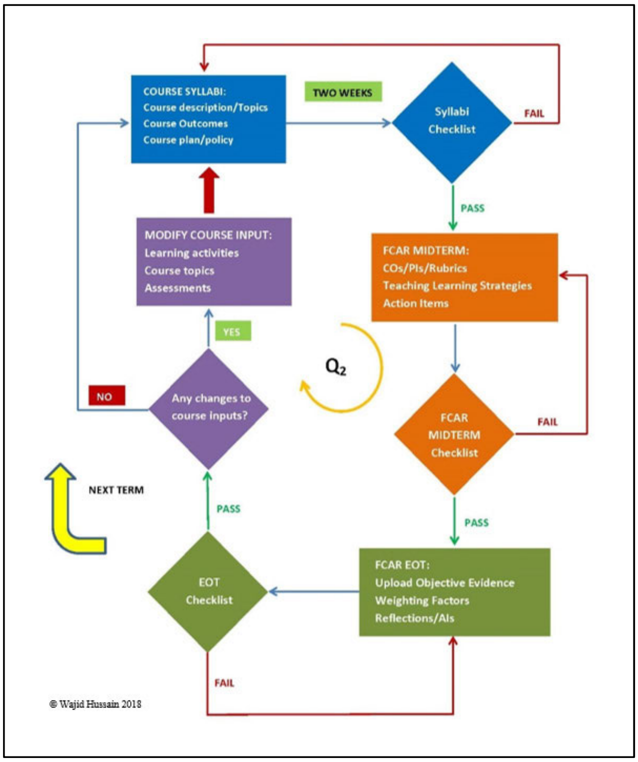


FIGURE 20. PDCA quality cycle Q_2 syllabi, FCAR mid term and EOT checklists.

B. PDCA QUALITY CYCLE Q_2: SYLLABI CHECKLIST, FCAR CHECKLIST, END OF TERM (EOT) CHECKLIST

The PDCA Quality Cycle Q_2, shown in Figure 20, consists of processes that ensure proper completion of all course work each term. Firstly, it ensures the course syllabi contain accurate information and is provided to students in the first week of the term, followed by a mid-term audit (FCAR midterm checklist) of COs, PIs, teaching/learning strategies, etc. and final End of Term (EOT) check for completion of all course assessment, evaluation and feedback for improvement processes.

Any deficiency uncovered during any stage of this quality cycle is communicated to the concerned faculty members for corrections. The Quality and Accreditation (QA) office works in coordination with the ABET coordinator of the engineering program to effectively manage all activities in this cycle. Once the EOT is approved by the QA office, it is presented to the supervisor, Quality Development (QD) for authentication and subsequent reporting in EvalTools® 6. The final authentication clears the way for the program to proceed to program term review evaluations. *Section 2* of Appendix J shows samples of syllabi audit, FCAR midterm and EOT checklists.

C. PDCA QUALITY CYCLE Q_3: PROGRAM TERM REVIEW – LEARNING DOMAINS, PIs AND SOs EVALUATION

Details of various administrative committees with their respective members are setup electronically employing the EvalTools® 6 CIMS module. Each committee maintains a schedule of action items with details on their assignment and priority level, discussions, brainstorming, creation/closure dates, and status information. Any committee can add new action items or review existing ones for status updates and closure. The advanced features of the CIMS module provide each committee the functionality to categorize an action item as per the given selection range of priority levels: *low, normal, medium, high* or *urgent*. The action items are sorted electronically according to their priority levels. Transfer or elevate features allow committees to move those action items which are beyond their scope or responsibility to another appropriate department or committee within the Faculty of Engineering or University for completion. Appendix G elaborates on the CIMS by providing relevant screenshots that present the module's essential features.

1) PROGRAM TERM REVIEW COMMITTEE

A specific program term review committee reviews the measured ABET SOs, related PIs information while considering this as a good indicator scheme and concludes its report with significant analysis and discussions as to whether a certain ABET SO is *Below, Meeting* or *Exceeding* expectations for the program in a designated term [24], [35], [41], [67]. *Section 3* of Appendix J provides samples of the program term review process.

2) PROGRAM LEVEL EVALUATION AND CQI

The Program Term Review module of EvalTools® 6 consists of three parts i) Learning Domains Evaluation ii) PIs Evaluation and iii) ABET SOs Evaluation. The PIs and SOs evaluations are focused on failing SOs and PIs for analysis and discussions relating to improvement. Weighted average values of ABET SOs and PIs with a scientific color coding scheme as per PVT heuristic rules shown in Table 6 indicate failures for investigation. Courses contributing to failing PIs and SOs are examined. The Faculty of Engineering has presented elaborate YouTube video presentations that detail the automation of outcomes assessment, showing some CIMS features such as action items elevation from the FCAR to task lists of standing committees for actual CQI [87], [88]

D. PDCA QUALITY CYCLE Q_4: PIs 3 YEAR MULTI-TERM REVIEW

As shown in Figure 22, the Faculty of Engineering programs conduct a PIs multi-term review every 3 years to check the validity of PIs in regards to technical content, learning level classification, relevancy to industry, alignment to program SOs, COs, curriculum and student learning activity. Any recommendations for modification to the PIs database is approved by a program council meeting. Issues related to redundancy, futuristic content or basic inaccuracies have been uncovered in the last multi-term PIs review conducted in term 382 (Spring 2018). Multiple examples of major types of modifications to the CE, EE and ME PIs database with their justifications are reported in Table J17 (Appendix J).

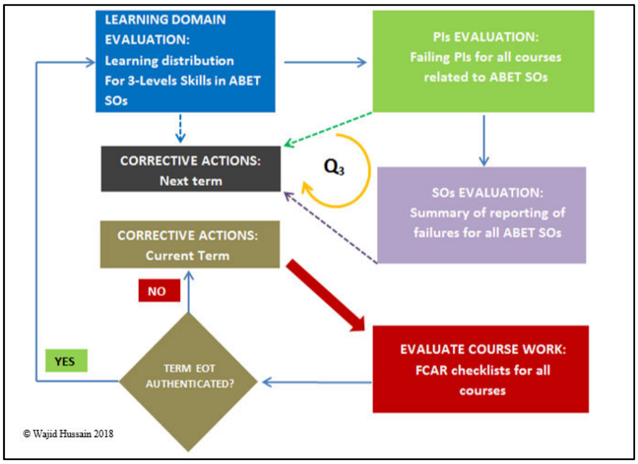


FIGURE 21. PDCA quality cycle Q_3 learning domain, PIs and SOs evaluation.

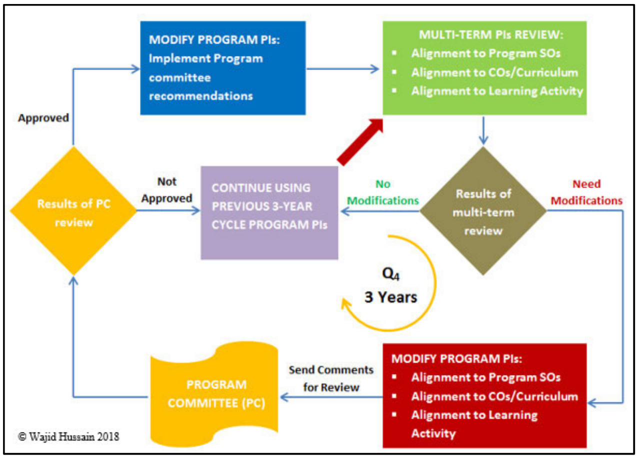


FIGURE 22. PDCA quality cycle Q_4: PIs 3 year multi-term review.

E. PDCA QUALITY CYCLE Q_5: SOs MULTI-TERM REVIEW

The Faculty of Engineering programs' assessment model includes a culminating PDCA Quality Cycle Q_5, a multi-term program SOs review which is conducted every three years (see Figure 23). This review entails a thorough trend analysis of all program SOs by the program faculty. Almost 6 terms of outcomes data are collected and reviewed for overall improving trends of performance. If more than 80% of the SOs displays a positive trend, then the program multi-term SO review results in an *Exceeding Expectations* decision. If 60% to 80% of the program SOs display an improving trend, then the decision is *Meeting Expectations*. When more than 60% of program SOs display a negative trend in overall performance, then the multi-term SO review results in a *Below Expectations* decision. The *Below Expectations* decision necessitates an examination of language, content and scope of the failing SOs besides several other corrective actions. A detailed report of recommendations for improvement, including any modifications to SOs is sent to the EAC for review and approval (*Sections 5.i, ii, iii, iv* and *v* of

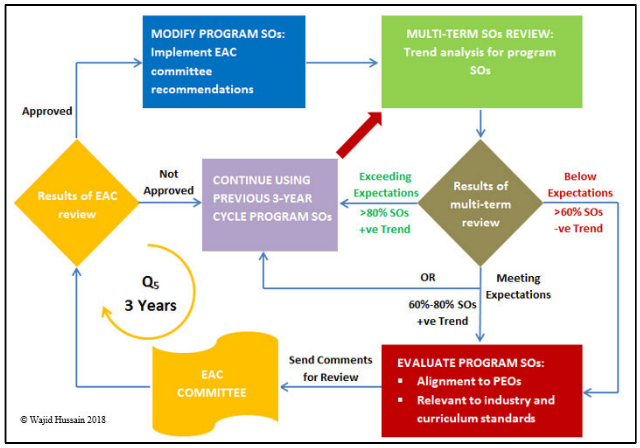


FIGURE 23. PDCA quality Cycle Q_5: SOs multi-term review process flow for ME program.

Appendix J provide 5 years multi-term SOs executive summary, performance criteria and trend analysis reports). The Faculty of Engineering programs' multi-term outcomes data is a summary of aggregation of thousands of outcomes assessment data points collected over 5 years from the termwise program and course evaluation results. They comprise reflections, actions, discussions, decisions based on a detailed review of information from FCARs, COs, PIs, SOs program evaluations.

In summary, the [2014-18] multi-term SOs (a-k) trend analyses resulted in a *Meeting/Exceeding Expectations* decision for the three engineering programs (*Section 5.v* of Appendix J). The results of these reports have had a strong multi-dimensional impact on the opinions of all stakeholders of the engineering programs (students, alumni, faculty, employers) to stimulate their response, involvement and eventual contribution to several types of corrective actions (refer *EAC committee review meeting*, *Section 6.iii* of Appendix J). These actions have improved multiple aspects of the Faculty's education process at different levels ranging from teaching/learning strategies, enhancement of direct/indirect assessments, quality of advising, curriculum standards, infrastructure and facilities, sustainability of CQI processes, and expanded institutional support.

F. PDCA QUALITY CYCLE Q_6: PEOs 5-YEARS REVIEW PROCESS

The PEOs review, revision and improvement process is mainly adopted from Sundaram's work (2013) [92]. Several programs across the US have adopted this process and achieved successful results with ABET over multiple accreditation cycles. The PEOs review and improvement process consists of internal and external components. The various phases of this process are shown in Figure 24 and listed below in chronological order:

1. *Definition and Development of PEOs* – by program faculty members in coordination with the QA office (Internal Review).

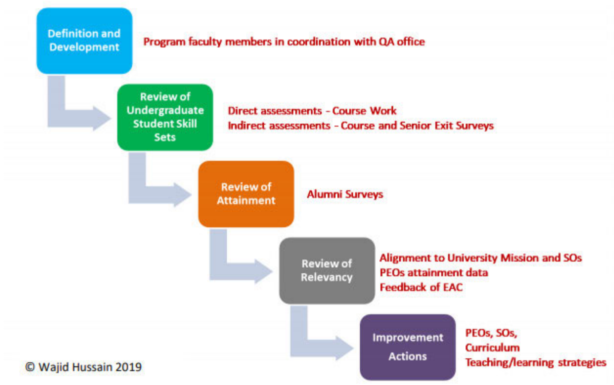


FIGURE 24. Phases of the PEOs review process.

2. *Review of Undergraduate Student Skill Sets* - necessary for achieving the PEOs, using direct assessments from course work and indirect assessments using course and senior exit surveys (Internal Review).
3. *Review of Attainment of PEOs* - using Alumni Surveys (External Review).
4. *Review of Relevancy of PEOs* - using a) alignment to University Mission and SOs mapping tables, b) PEOs attainment data based on well-established rubrics and c) feedback of EAC and Faculty members (a combination of Internal and External Review processes).
5. *Generate Corrective Actions* - for improvement of PEOs, SOs, curriculum, teaching and learning strategies (combination of Internal and External Review processes).

1) DEFINITION AND DEVELOPMENT OF PEOs

The *Definition and Development of PEOs* as shown in Figure 25 are completed by program faculty members (Internal Review) and comprises of the following essential elements:

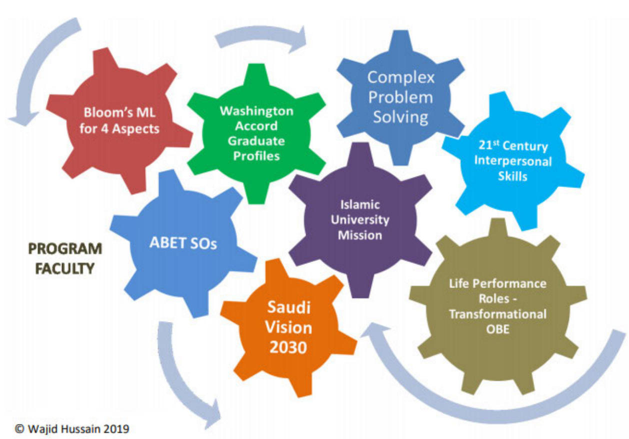


FIGURE 25. Essential elements for Definition and Development of PEOs.

1. Define 4 aspects based on *Bloom's Mastery Learning Model* [99] and adopt a chronological approach of low order to high order attributes culminating in life performance roles for developing the PEOs (application of theory to complex problem solving, soft skills, lifelong learning and community service with values) – in this area, we shift moderately from Sundaram's theory of not focusing on attributes that are not targeted within 3 years of graduation [92]. We incorporate life performance roles in graduate attributes as suggested by Spady's *Transformational OBE Model* (1994) [4], [95].
2. Select key phrases to represent complex problem solving in real engineering problems.
3. Incorporate comprehensiveness for application of engineering principles with reference to Washington Accord graduate attributes and competencies [66].
4. Incorporate key aspects of all the ABET SOs which are derived from Washington Accord graduate profiles [11], [66].
5. Incorporate key elements such as entrepreneurship from the National Saudi 2030 Vision Plan [93].
6. Incorporate key components of the Islamic University Mission such as Islamic values
7. Incorporate key elements of 21st century interpersonal skills as required by the engineering industry and global society [94].
8. Incorporate some key aspects of life performance roles, such as global contributors [95].

Once the PEOs are developed, mapping tables are created clearly aligning them to essential components of the University Mission. Figure J34 (Appendix J) shows The Islamic University Mission Statement with key phrases highlighted. The phrases underlined in Figure J34 are those that relate directly to the EE, CE and ME PEOs. Table J29 (Appendix J) shows the PEOs statements for the ME, CE and EE programs. Table J28 (Appendix J) shows the relationship between the PEOs and various parts of the University mission statement.

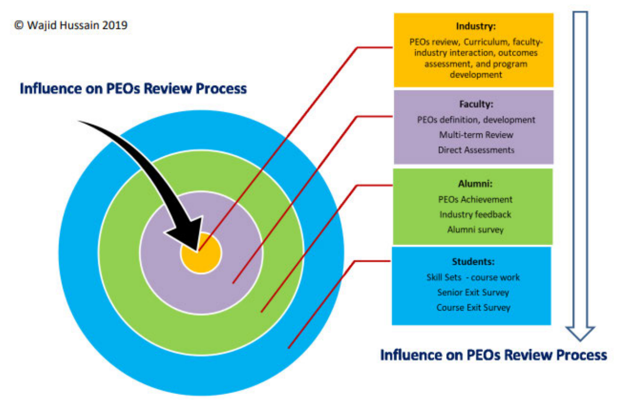


FIGURE 26. Influence and inputs of constituencies on PEO review process.

2) PROGRAM CONSTITUENCIES

As shown in Figure 26, the constituencies of the CE, ME and EE programs are: undergraduate students, alumni, faculty and Industry. The influence and inputs of the constituencies on the PEOs review process are mentioned below:

Industry inputs: The EAC represents industry for the engineering programs. The EAC consists of engineers, engineering managers, and business leaders from the local industry as well as educators from academia in CE, ME and EE program-related disciplines. It is an advisory committee that serves the engineering programs. The primary charter of this group is to:

1. Provide advice and counsel on curriculum, faculty-industry interaction, outcomes assessment, and program development
2. Identify technical needs of the regional industry in general and/or individual companies in particular for research, development, and continuing education.
3. As part of the objectives, the EAC is also to promote joint research and development projects and grants.

Student inputs: Undergraduate academic work is assessed in every one of the core courses and their comments on the course-exit survey are reviewed each term, providing input for program improvement. Faculty use EvalTools® as their Learning Management Toolset for posting their course materials and assignments. Course outcomes are automatically displayed to students whenever students access their course materials or assignments from EvalTools®. Students are also well-informed of the key assignments for each course that are collected as objective evidence in the course portfolio.

Alumni inputs: Alumni input is sought one-three years after graduation from the program to judge whether what they learned from the program allowed them to perform as expected.

Faculty inputs: The faculty, who are at the heart of the assessment process, not only plan the learning process and deliver courses and labs, but also assess effectiveness at the course level at the end of each term. Faculty members are required to write reflections on each course they teach, review and close action items accordingly, and also suggest any new action items if appropriate. Utilizing EvalTools®, Program Term Review Committees review course portfolios along with new action items suggested by faculty each term to determine if the action items are appropriate for the next cycle of course offerings. As described above, all program constituents are included in the program assessment process and provide feedback on the program.

3) REVIEW PROCESS OF PEOs

The PEOs assessment process is conducted in an iterative cycle; beginning with the University mission, which in turn influences the departments' PEOs. The departments used the ABET SOs (a-k) as the student outcomes in the first PEO review which is conducted every 5 years. With these in mind, each course outcome and assessment method is carefully examined for better coordination among courses, and setup in order to reach a complete coverage of the student outcomes for achieving the PEOs.

ABET recently changed their criteria regarding the assessment of PEOs attainment, they currently just require a review of relevancy [11], [35]. ABET also removed their requirement for employer surveys due to difficulties programs faced with obtaining alumni employment information. As such, even though the attainment of PEOs and incorporation of employer surveys are crucial, the programs focus their PEOs assessment process primarily on review of their relevancy. Since the PEO looks at a timeline of three to five years after a student graduates, the review cycle for PEOs is expected to be conducted once, in a cycle, every five years to gauge the PEO relevancy to the needs of the program's constituents. Since any corrective actions are based on results of student outcomes assessment, which involve a different cycle of assessment, it is clear that SOs assessment provides a major input to gauge whether or not PEOs are eventually met. Figure 27 illustrates the review processes of EE, CE and ME PEOs based on the *Sundaram Model* (2013) [92]. The review process seeks input and insight for gauging the success of achieving the PEOs from two different avenues, the external view of meeting the PEOs as they are intended, and the internal view of meeting the PEOs for providing the necessary skill sets to prepare students.

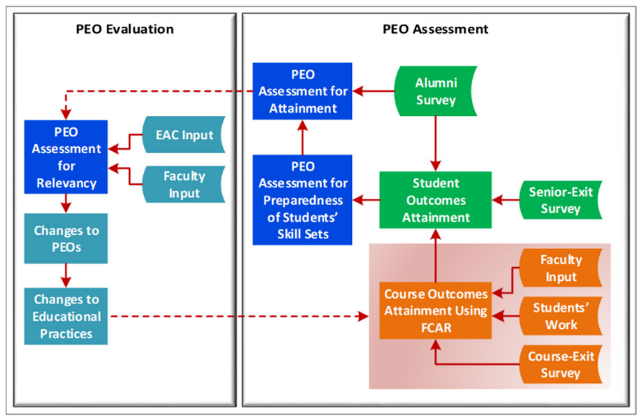


FIGURE 27. **ME, EE and CE PEOs review process (reproduced from Sundaram's model [92]).**

The focus is on addressing the following two questions:

1. *How well do the programs prepare students for the intended PEOs?*

2. *How well are the programs' graduates really doing in the workforce?*

For the PEOs assessment process, the data are rolled up and gathered primarily from these two sources:

1) External view of meeting PEOs based on alumni and employer feedback (which is not indicated in the Sundaram's model but conveniently accomplished by using EvalTools ® remote survey suite shown in *Section 6.ii, indirect assessments*, Appendix J).

2) Internal view of meeting PEOs from SOs attainment process (refer Tables J34, J35 and J36 of *Section 6.ii*, Appendix J).

However, regarding the PEOs evaluation process related to relevancy, in addition to taking the inputs from the PEO assessment process, the crucial question is: *How relevant our PEOs are, in meeting the needs of the constituents?*

TABLE 12. Breakdown of time spent in various course delivery activities (PDCA Q_1).

Course Activity	Details	Frequency	Time Spent*
COs, PIs Development	Develop COs, PIs observing specified design rules to attain *Ideal Learning Distribution.*	As per instructor requirment and discretion. Minor revision every term	*Initial design:* (6-10)-hours sessions depending on course format.
Rubrics Development	Develop hybrid rubrics for 3 major learning activities	2018-19 cycle completed (Figure 13). Minor revision once a year if required.	*Initial design:* 1 hour per rubric
Application to Exam Questions	Prepare questions for Mid-term (1&2) and Final exams aligned to hybrid rubrics	Every Term	*Initial design:* 30 mins per question. *Repeat design:* Routine exam preparation time

* Preparation times provided by the QA office.

To address the needs of the constituents, the review process seeks feedback primarily from the EAC and faculty members. The results of PEO attainment provide key direction to the discussions (see *Section 6.iii EAC review*, Appendix J). Any action items generated from the review process, such as changes to PEOs at this level (Level 1 PEO assessment) may have a substantial impact on the programs' educational practices. Action items will ultimately flow down to Level 2 SOs assessment and then Level 3 COs assessment, as indicated in Figure 27. The assessment for the attainment of SOs is based on data from senior-exit, alumni and employer surveys, and roll-up data from the embedded course assessment process that uses FCAR as the main vehicle for the assessment (refer *Section 6.ii*, Appendix J).

VII. SUSTAINABILITY OF COURSE AND PROGRAM LEVEL CQI PROCESSES

The PDCA quality cycle Q_1*: COs, PIs, Rubrics Development,* as mentioned in *Section VI.A* involves course design based on design rules for the development of COs and PIs as referred to in *Section IV.C.2* and rubrics aligned to 3 major learning activities assessed in Mid-term and Final examinations as mentioned in Section *IV.C.3 Hybrid Rubrics*. Figure 13 also indicates the hybrid rubrics development and implementation process for the 2018-19 cycle. Table 12 indicates the average time spent for COs, PIs and hybrid rubrics development activities based on inputs from the QA office while considering variations based on the type of course format and instructor expertise.

The Faculty of Engineering EE, ME, and CE programs conducted detailed surveys in coordination with the QA office to estimate additional time spent by instructors in documentation and reporting efforts for implementing online course portfolios using the *FCAR + generic/specific PIs* automated model (PDCA cycle Q_2). Several faculty and lecturer inputs were collected for various courses to determine maximum workloads related to score entry, PIs mapping, naming, scanning and uploading documentation for Low (L), Medium (M) and High (H) samples of student graded work. Figure H1 (Appendix H) shows an example of such inputs collected for an electrical engineering course, *EE 421, Wireless and Mobile Communications*. Table 13 shows a quantitative analysis of the time spent by faculty in performing various course level data reporting activities. The data reporting activities common to any assessment/evaluation system, whether automated or manual, are score entry, scanning, naming and uploading student work. Therefore, the data reporting activities taken into account for estimating any additional time spent are those which are specific to the *FCAR + generic/specific PIs model* such as score entry, mapping PIs for split questions and creating reflections and action items for failing COs and PIs. The conclusion of this finding was that faculty spent additional time ranging from 5 to 8 hours per course for an average of 15 students depending on whether the course involves lab and/or project work.

As a part of continuous improvement efforts to reduce workload for faculty to collect data, it was decided in the *Quality and Accreditation Committee* meeting on October 4th, 2016 that the EE, ME and CE programs' faculty members would scan and upload the Low, Medium and High student work samples as objective evidence. Based on academic freedom, this program-wide decision did not restrict those faculty members who wished to scan and upload assignments of all students for record-keeping or student feedback purposes. Additionally, the Islamic University policy limits a max enrollment of 25 students per course section. Additional staff currently on study leave, pursuing higher degrees, are expected to return in the coming academic years. The faculty strength is expected to increase, resulting in lesser and widely distributed workload for each instructor.

Based on these enrollment limits and favorable current and projected faculty strengths, the researchers anticipate a sustainable CQI process in the near future. The time spent by faculty members in program-level CQI activities were also considered to accurately estimate the sustainability of overall CQI processes for the automated FCAR + generic/specific PIs model using EvalTools®. The program level activities include:

1. Program term reviews which involve SOs, PIs and Learning Domains Evaluations (PDCA Cycle Q_3)
2. Multi-term PIs review conducted every 3 years (PDCA Cycle Q_4)
3. Multi-term SOs Trend Analysis conducted every 3-5 years (PDCA Cycle Q_5) and
4. PEOs Analysis and Review (PDCA Cycle Q_6)

Program term reviews SOs evaluations examine only failing PIs (20-25% of total PIs assessed in a term), involve all the program faculty and are comprehensively completed in 3 hour sessions. Multi-term PIs and SOs evaluations are completed after every 3-5 years in two or three 2 hour sessions.

TABLE 13. Quantitative analysis of time spent in various course level data reporting activities (PDCA Q_2).

H,M, L Samples	Scan & Name File	Upload File	Score Entry*	PIs Mapping
1 Quiz	5 mins × 4 QZ	2 mins × 4 QZ	No additional work	1 mins × 4 QZ
1 HW	5 mins × 4 HWs	2 mins × 4 HWs	No additional work	1 mins × 4 HWS
10 Lab Expts.	5 mins × 10 Lab Expts.	2 mins × 10 Lab Expts.	No additional work	1 mins × 10 labs
Mid Term (1 & 2) 4 Questions	15 mins × 2	2 mins × 2	10 mins × 2	1 mins × 4 Qs × 2
Final 8 Questions	15 mins	2 mins	20 mins	1 mins × 8 Qs
Project 6 Split Sections	20 mins	5 mins	30 mins	1 mins × 6 split Qs
Lab Final 3 PIs Split Sections	5 mins	2 mins	15 mins	1 mins × 3 split Qs
Lab Mid Term 2 PIs Split Sections	5 mins	2 mins	10 mins	1 mins × 2 split Qs
Time Spent	2 hrs. 45 mins.	51 mins.	1 hr. 35 mins.	45 mins.
Course Reflections & Ais			2 hrs.	
WFs			30 mins.	
Total Specific PIs Time	WFs	Course Reflections & Ais	Score Entry	PIs Mapping
4 hours 50 mins.	30 mins.	2 hrs.	1 hr. 35 mins.	45 mins.

*Class of 15 students

TABLE 14. Breakdown of time spent in various program level CQI activities.

CQI Activity	PDCA Cycle	Details	Frequency	Time Spent
Program Term Reviews	Q_3	SOs, PIs & Learning Domains Evaluations	Every Term	3-hours sessions
Multi-term PIs Review	Q_4	Review content, alignment of PIs and update database	Every 3-5 years	Two or three 2-hours sessions
Multi-term SOs Review	Q_5	Review multi-term SOs results, perform trend analysis, benchmark results and update SOs and performance criteria		Two or three 2-hours sessions
PEOs Analysis & Review	Q_6	Review direct and indirect assessment data with External Advisory Committee to verify attainment and relevance of PEOs	Every 5 years	4-hours session

Table 14 indicates the breakdown of time spent by faculty members in various program level CQI activities. The time spent for both course and program level CQI activity is practically manageable, and the current assessment and automated QA processes are seamlessly implemented at the Faculty of Engineering programs for the last 6 years (from Fall 2014). Sets of 6 years course, program level and administrative committees CQI data are available on a google cloud-based digital environment [67].

A. USE OF STATE OF THE ART DIGITAL TOOLS TO OPTIMIZE CQI TASKS RELATED TO PROGRAM MANAGEMENT, ASSESSMENT AND EVALUATION

State of the art digital technology and enhanced FCAR methodology using web-based software called EvalTools® is employed to automate the data collection, assessment, evaluation, feedback and closing the loop processes [48]. Specific features or modules of the web-based software EvalTools ® promote social distancing during COVID19 pandemic using remote operations and help achieve a significant reduction in manpower and resource expenditure with optimizations in multiple CQI tasks as listed below:

1. Embedded assessments technology coupled with a few mouse clicks for PIs mapping easily facilitates the collection of assessment information for all the PIs at the course level.
2. PIs assignment to course outcomes is linked right from the course assessment setup feature and subsequently, PI data is automatically generated for program SOs evaluations.
3. PVT feature facilitates the collection of outcomes data for all students with no additional data collection efforts besides routine course work required by instructors.
4. The development of hybrid rubrics is supported through direct derivation from the detailed language of the specific PIs statements listed in digital databases.
5. CQI documentation related to student, course and program level assessments, analytical diagnostics, curriculum maps, evaluation reports (FCAR, course action items matrix, SOs/PIs program evaluations executive summary and multi-term trend analysis), and grade books are automatically generated in standard digital formats.

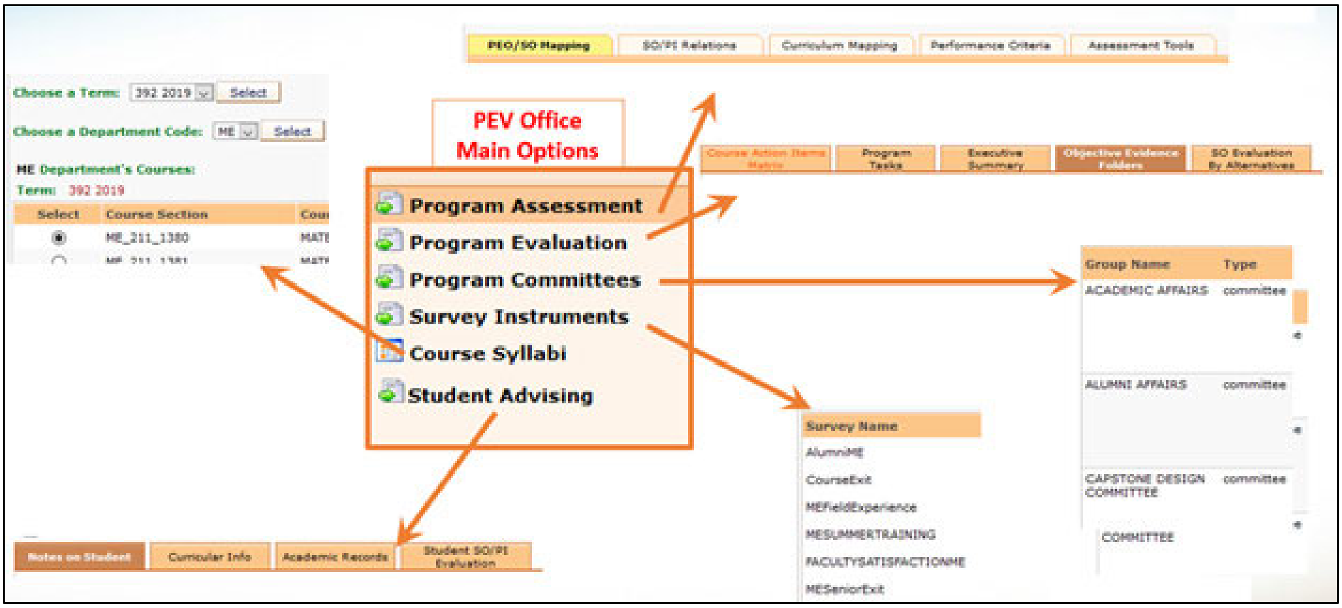


FIGURE 28. Site map EvalTools ® evaluator module.

6. Remote course exit, senior exit, employer, alumni and faculty satisfaction surveys are all conducted electronically and statistical data assimilated into necessary evaluation reports for QA purposes.
7. The CIMS module connects corrective actions generated from program term reviews' SOs based evaluations to 20 standing administrative committees. The module provides a state of the art electronic repository consisting of thousands of corrective actions and other CQI information. An enormous saving of faculty resources otherwise spent in collecting and reporting CQI information related to committee work is achieved by instant access to an exhaustive digital repository of administrative committee meetings, minutes, corrective actions tied to outcomes, the status of actions, time stamps, ownership details etc.

VIII. EVALTOOLS ® REMOTE EVALUATOR MODULE

EvalTools ® is a state of the art web-based software that employs the FCAR embedded assessment methodology and effectively integrates LMS, AAS, OAS and CIMS Systems [48] into one digital platform. EvalTools ® provides seamless automation of CQI processes and its *Remote Evaluator Module* collects, organizes and reports massive amounts of CQI data for remote accreditation audits [67]. Figure 28 shows the evaluator module site map indicating menu tabs for program assessment, program evaluation, program committees, survey instruments, course syllabi and student advising. Every major aspect of ABET accreditation display data requirement is comprehensively covered and CQI information is conveniently integrated into a user-friendly dashboard. Table 15 lists all the major tabs on the dashboard, corresponding CQI information and the coverage of ABET criteria 1 to 8 [11]. Appendix I presents some samples of data and brief explanations for CQI information related to the various tabs listed in Table 15. Millions of documents of evidential CQI data for the EE, CE and ME programs are available on a cloud-based environment for remote accreditation audits. Various types of CQI data and essential aspects for achieving their high quality are derived from specific requirements of ABET accreditation criteria related to CR2: *PEOs*, CR3: *Student Outcomes* and CR4: *Continuous Improvement.* Specifically, PEOs review and attainment, SOs assessment methodology and plan, PIs alignment with assessments and application of rubrics, accurate program and course level evaluations, integration with indirect assessments, implementation of corrective actions and ability to achieve realtime and deferred improvements etc. are some of the items extracted from ABET accreditation criteria CR 2,3 and 4 for developing requirements for various types of acceptable CQI data. Table 16 shows a summary of a qualitative comparison of various types of CQI data and key aspects for manual and automated systems. Several types of CQI data such as PEOs review, SOs and PIs assessments, course materials, surveys, committee actions, course and program evaluations etc. are required display material for accreditation audits.

Digital platforms such as EvalTools ® offer seamless collection, documentation and reporting of massive amounts of reliable and valid CQI data, thereby making remote audits a convenient and practically feasible affair for both programs and evaluators. The current global pandemic conditions, coupled with the overall benefits of automated CQI systems, present compelling justification for engineering programs and accreditation bodies to shift to digital platforms and automated collection, reporting and presentation of CQI data for remote accreditation audits. Engineering programs

TABLE 15. EvalTools ® evaluator module CQI information and coverage of ABET criteria.

Tab	CQI Information	ABET Criteria
Program Assessment	1. PEOs/SOs mapping 2. SO/PI/Rubrics relations 3. Curriculum mapping 4. Performance criteria 5. Assessment tools	CR2,3,4: Mapping PEOs to SOs; database SOs, PIs and rubrics; curriculum mapping to SOs;
Program Evaluation	1. Course action items matrix 2. Program tasks	CR4: SOs, PIs and learning domains evaluations; term wise corrective actions; executive summary reports;
	3. Executive summary 4. Objective evidence folders 5. SOs by alternatives	
Program Committees	1. Meeting 2. Tasks list 3. Document 4. Members list	CR1,2,3,4,5, 6,7,8: 20 standing administrative committees meeting minutes; tasks lists; documentation; members lists;
Survey Instruments	1. Alumni 2. Course exit 3. Field training experience 4. External Advisory approval 5. Faculty satisfaction 6. Senior exit	CR4,6,7 Indirect assessments: survey setup, participants, survey response reports
Course Syllabi	1. EE courses 2. ME courses 3. CE courses	CR5: 19 terms EE, ME and CE programs' courses syllabi (30-35 courses /program every term) in ABET format (2014-20).
Student Advising	1. Academic records 2. Students' SOs/PIs evaluations 3. Outcomes based advising	CR1: Academic advising; outcomes based advising based on SOs/PIs evaluations for every student

seeking accreditation should, therefore, make insightful decisions to actively search for appropriate digital solutions that support authentic OBE assessment methodology for implementing automated CQI systems to enable remote accreditation audits. Accreditation agencies on the other hand, should seriously consider promoting digitization of CQI data and offer training programs to their evaluators for a smooth migration to remote accreditation audits in the coming years during the COVID19 pandemic and beyond.

IX. EVALUATING THE INTEGRATED QUALITY MANAGEMENT SYSTEMS (PDCA QUALITY CYCLES Q_1 – Q_6)

In this research, we applied a meta-framework for evaluating IQMS implemented at the Faculty of Engineering programs for achieving ABET accreditation. The meta-framework is based on a recent study proposing MMTBIEs [52]. The study outlined 8 phases of the meta-framework based on prior research following the general steps for evaluation. We utilize the recommended essential steps/aspects of 8 phases of the meta-framework to extract required examination criteria.

A. PHASE 1: UNDERSTAND THE LOCAL AND BROADER CONTEXT

Context refers to the social, political, economic, and cultural milieu in which the intervention, treatment, program, or policy takes place. The local and broader context of the MMTBIE has to be understood in this phase. The objective of the IQMS implemented at the Faculty of Engineering programs was to help its beneficiaries, the enrolled students, attain ABET SOs during and upon completion of the period of study and attainment of the PEOs a few years (3-5 years) after graduation during employment. The MMTBIE conducted should verify and confirm cohorts' attainment of ABET SOs during and upon completion of a period of study and attainment of PEOs a few years after graduation and during employment. Onwuegbuzie and Hitchcock (2017) adopted Bronfenbrenner's (1979) ecological systems model [96] to conduct evaluations at one or more of Bronfenbrenner's (1979) four levels:

a) *Micro-MMTBIEs, Level 1*: MMTBIEs wherein an intervention, treatment, program, or policy subjected to one or more persons or groups occur within his/her/their immediate environment[s].

b) *Meso-MMTBIEs, Level 2*: MMTBIEs wherein an intervention, treatment, program, or policy subjected to one or more persons or groups occur within other systems, and also the interaction of these systems, in which he/she/they spend time

c) *Exo-MMTBIEs, Level 3:* MMTBIEs wherein an intervention, treatment, program, or policy subjected to one or more persons or groups occur within systems by which he/she/they that might be influenced but of which he/she/they are not explicitly a member, and

TABLE 16. **Qualitative analysis - manual and digital CQI data.**

CQI Data*	Manual CQI	EvalTools® + Specific PIs
PEOs Review	Hard copy. Massive print and collate effort	Remote access. Automated collection, collation and reporting
Course and Program Evaluations	Manual computations and application of performance criteria for evaluations.	Automated evaluation reports. FCAR, SOs/PIs and learning domains evaluations
Sampling Size	Course and program evaluations use small samples which are either random or corresponding to final level of learning (e.g. Final exams in course evaluations or 400 level courses for program evaluations)	All students and course levels are assessed due to FCAR and digital PVT technology
SOs (1-7) Assessments	Hard copy. Manual reports. Multi-year cycles	Remote access. Automated collection, collation and reporting All SOs can be assessed in a single term.
PIs Assessments	Hard copy. Manual reports. 3-5 PIs per SO annually	Remote access. Can Assess 50 PIs per SO in one term
Course materials	Hard copy. Massive collect, print and collate effort	Remote access. Automated collection, collation and reporting
SOs Objective Evidence	Hard copy. Massive collect, print and collate effort	Remote access. Automated collection, collation and reporting
Surveys	Hard copy. Massive print and collate effort	Remote access. Automated collection, collation and reporting
Advising Records	Hard copy. Massive collect, print and collate effort	Remote access. Automated collection, collation and reporting
SOs CQI Cycles	Multi-year cycles	Single year cycles
Sustainability of CQI Processes	Sustainable, if small samples of students and CQI data are considered for course and program evaluations	All course level CQI actions consume 5-8 hours based on type of course format. Program level CQI activity for SOs, PIs and PEOs reviews would take single or multiple 2-3 hour sessions.
Multi-term Course Actions	Hard copy. Massive collect, print and collate effort	Remote access. Automated collection, collation and reporting
Committees CQI data	Hard copy. Difficult collection, printing, collation for reporting.	Remote access. Automated collection, collation and reporting
Follow Up of Action Items	Hard copy. Difficult to track, update and follow up to closure.	Remote access. Automated tracking and reporting of action status
Credibility of Actions	Difficult to ensure credibility of actions	Digital time stamps and automated history and status of actions ensure credibility
SOs Trend Analysis	Difficult to track manually, benchmark and apply	Remote access. Automated reports and benchmarking capability
Data Accessibility	Difficult to integrate evidence and data for comprehensive audits	High speed access and integration of evidence and data
Data Accuracy	Low accuracy due to lack of valid and reliable assessment methods as a result of using generic PIs not aligned to specific learning domains and learning levels.	High levels of accuracy with valid and reliable assessments using hybrid rubrics, tight alignment to outcomes and specific PIs classified to Bloom's 3 domains and learning levels
Data Storage	Data is stored in physical folders in accreditation evidence rooms	Electronic databases on a cloud environment.

* CQI display data usually covers 2 years

d) *Macro-MMTBIEs, Level 4:* MMTBIEs wherein an intervention, treatment, program, or policy subjected to one or more persons or groups are studied within the larger sociocultural world or society surrounding him/her/them.

Based on Bronfenbrenner's (1979) ecological systems model [96], the IQMS implemented at the Faculty of Engineering EE, CE and ME programs involve evaluations in all the four levels which are outlined in Table K1 (Appendix K).

From Table K1, it is evident that the local and broader context of the MMTBIE adequately incorporates regional and international standards for quality in education by examining attainment of the ABET SOs during and upon completion of study and attainment of PEOs a few years after graduation during employment.

B. PHASE 2: UNDERSTAND THE CONSTRUCT(S) OF INTEREST

The second phase, understanding the construct(s) of interest, is accomplished by conducting an extensive review of the literature. As part of the literature review, the evaluator should identify the relevant framework(s) that underlies the evaluation, namely: theoretical, conceptual and practical frameworks [97]. The construct(s) of interest would then help obtain either input or output variables to the evaluation. *Section IV: Theoretical, Conceptual and Practical Frameworks* presents a detailed discussion of relevant frameworks based on an exhaustive literature review and Figure 1 conveniently displays all the essential elements of the theoretical, conceptual and practical frameworks that facilitate the seamless implementation of CQI processes consisting of 6 comprehensive PDCA quality cycles.

Table K2 (Appendix K) presents details on the relevant frameworks, construct(s) of interest and variables with references to corresponding subsections of *Section IV* of this research paper. As mentioned in *Section IV*, authentic OBE theory forms the basis for theoretical frameworks that lead to the development of crucial models which act as the foundation of the IQMS implemented at the Faculty of Engineering. Several essential concepts are then induced from OBE theory, assessment best practices and ABET criterion 4, CR4 on continuous improvement. Essential techniques and methods based on this conceptual framework are then realized as a practical framework consisting of automation tools, modules and features of a state of the art digital platform, web-based software EvalTools®. EvalTools® is effectively used for the seamless implementation of the IQMS comprising of six PDCA quality cycles Q_1 to Q_6. A highly structured and systematic description of theoretical, conceptual and practical frameworks, their constructs and variables that adequately fulfill accreditation criteria and achieve required quality standards would therefore qualify the IQMS for ABET accreditation.

C. PHASE 3: MAP OUT THE CAUSAL CHAIN THAT EXPLAINS HOW THE INTERVENTION IS EXPECTED TO PRODUCE THE INTENDED OUTCOMES

We utilize a framework proposed by Onwuegbuzie and Hitchcock (2017) to validate the mapping of causal links of the IQMS implemented at the Faculty of Engineering EE, CE and ME programs [52]. The framework refers to the requirements of White's (2009) model which suggests that the causal chain be mapped to determine how the intervention is expected to produce the intended outcome(s) [61]. That is, the causal chain links inputs to outcomes and impacts [61]. Some form of theory—evaluation theory, social science theory, and/or program theory—should govern the mapping of causal links. As part of mapping out the causal chain, the potential directionality should also be assessed to ensure observed outcomes and impacts are the result of the project activities, and not vice versa [61].

A set of supplemental evaluation questions has to also be answered for rigorous analyses [55]. Table K3 (Appendix K) presents the requirements of the framework proposed by Onwuegbuzie and Hitchcock (2017) to validate the mapping of causal links of the IQMS implemented at the Faculty of Engineering EE, CE and ME programs. Brief responses with appropriate sectional references are provided for a thorough understanding of the fulfillment of required conditions of the extracted framework.

D. PHASE 4: COLLECT QUANTITATIVE AND QUALITATIVE DATA TO TEST THE UNDERLYING ASSUMPTIONS OF THE CAUSAL LINKS

Evaluators should use a mixed methodological approach to collect both qualitative and quantitative data to rigorously evaluate all the underlying assumptions of the causal links of a given program intervention. In Table K4 (Appendix K), we provide a summary of data collection activity for qualitative or quantitative evaluations occurring in each PDCA quality cycle with references to the various sections of this research paper. Extensive distribution of comprehensive qualitative and quantitative analyses are presented in Table K4 for assessing underlying assumptions in each PDCA cycle thereby qualifying the program interventions at the Faculty of Engineering as credible MMTBIEs that fulfill mixed methodological approach requirements for phase 4 of the meta framework proposed by Onwuegbuzie and Hitchcock (2017) [52].

E. PHASE 5: DETERMINE THE TYPE AND LEVEL OF GENERALIZABILITY AND TRANSFERABILITY

Onwuegbuzie and Hitchcock (2017) present several important aspects evaluators need to consider regarding statistical data related to qualitative and quantitative analyses conducted in program interventions. Specifically, they discussed aspects such as sample size, statistical power for quantitative data, reaching saturation for qualitative data and types of generalizability and transferability [52]. Their work highlighted the possibility for discrepancy to exist between the planned sample characteristics, sample size(s), and sampling scheme(s) and those that ended up being realized as a result of factors such as mortality, nonresponse, untrustworthy responses, and the like. Onwuegbuzie and Hitchcock (2017) categorically state "*Impact evaluators need to be able to select a sample size large enough and information-rich enough to assess impact heterogeneity, bearing in mind that impact can vary as a function of factors such as intervention design, participant (i.e., beneficiary) characteristics, time, and characteristics of the community (e.g., urbanicity, population size, socioeconomic setting, socio-cultural factors).*" [52] Quantitative data that are subjected to inferential statistics should achieve adequate statistical power and qualitative data should reach data and theoretical saturation to increase validity and credibility. Impact evaluators also have to determine the type and level of generalizability and transferability. Onwuegbuzie, Slate, Leech, and Collins (2009) identified five types of generalization: external statistical generalizations (making generalizations, predictions, or inferences on evaluation data and findings yielded from a representative statistical [i.e., optimally random and large] sample to the population from which the sample was drawn); internal statistical generalizations (which involve making generalizations and predictions from evaluation data and findings obtained from one or more representative or elite study participants); analytic generalizations (wherein the evaluator is striving to generalize a particular set of [case study] results to some broader theory); case-to-case transfer (i.e., making generalizations or inferences from one case to another [similar] case); and naturalistic generalization (i.e., the stakeholders make generalizations entirely or at least in part, from their personal or vicarious experiences) [98]. In this phase, we apply the main aspects mentioned by Onwuegbuzie and Hitchcock (2017) to examine the validity and credibility of qualitative and quantitative statistical data and type and level of generalizability and transferability [52].

To better understand the entries in Table K5 (Appendix K), we explain some fundamental aspects related to the sampling methodology and accuracy of outcomes evaluation employed at the Faculty of Engineering. Direct assessment outcomes data is evaluated at both the course and program level. Outcomes data is collected at the course level using embedded assessments of the FCAR and PVT technology. This facilitates collecting assessment data for all enrolled students in a class. There are two types of sampling that occur in relation to course-level assessment data. The first type is related to selecting the most appropriate assessments for measuring a specific PI and CO when the instructor has a choice of more than two assessments for each PI [35]. The second type of sampling deals with the selection of a set of students for any specific PI and CO data being assessed. It is important to note here that manual CQI systems are generally frugal in their selection of either the number of assessments or sample size of students considered for assessments due to time and resource constraints. The FCAR and PVT technology of EvalTools ® enables collecting outcomes data for several assessments and all students in the class [24], [41], [46], [67]. Therefore, the course level statistical outcomes data is comprehensive and heterogeneous as it represents the complete set of course cohorts in all classes. Other crucial aspects of the course level statistical quantitative data are validity and reliability. Since, we are dealing with outcomes assessment, several factors contribute to the attainment of a high level of accuracy for assessment data. The Faculty of engineering programs ensure quality standards for assessment and evaluation data by employing the following:

a. Implementation of *Bloom's Mastery Learning Model* [99] to develop and administer a curriculum
b. Adopt the gold standards of Mager's [83] and Adelman's [16] outcomes design principles
c. Classify COs and specific PIs as per Bloom's three domains and their learning levels and assign electronic indices for tracking and automated EAMU average computations [24].
d. Develop and implement hybrid rubrics for major course learning activities [42].
e. Implement unique assessments (where multiple PIs cannot map to a single assessment) [22], [24], [35], [38], [48], [49], [50], [62], [63], [67], [69]
f. Implement tight scientific constructive alignment of outcomes to assessments using rigorous quality assurance processes [24], [35], [67].
g. Implement course level weighting factors for aggregating outcomes data from various types of assessments [24], [35], [41], [67].

Unlike manual systems which advocate limited sampling from select courses in the final phases of the engineering curriculum [70]–[74], the program level SOs, PIs and learning domains evaluations conducted at the Faculty of Engineering programs collect data from all courses in all levels of the curriculum [24], [41], [42], [67]. Once again, FCAR and EAMU vector technology helps EvalTools ® collect and extract specific assessment information from all relevant courses for program-level outcomes evaluations. *Section IV.D.1 FCAR and PVT* discusses the HFWFS program level weighting factor scheme and the accuracy of program level skills aggregation achieved due to its application. *Section IV.E Practical Framework – Summary of Digital Technology and Assessment Methodology* presents a detailed discussion of several essential elements incorporated into the Facutly of Engineering assessment model ensuring high standards of validity and reliability. Therefore, both samples size and statistical power of quantitative data for course and program level evaluations are qualified for the MMTBIEs of the Faculty of Engineering programs.

The qualitative data was collected from surveys and program and administrative committee reviews. Samples of surveys and relevant results are provided in *Section 6.ii PEOs Assessment Data* of Appendix J. In general, the program and administrative committees reviews have maximum response rates due to mandatory attendance requirements. The surveys conducted were comprehensive, 5 points likert format, with the alignment of the questions to required knowledge and skills of students. The surveys also provided participants with the opportunity to provide feedback in the form of comments. The student surveys related to course exit, senior exit (refer to Tables J40, J41, J42, J43, and J44, J55 for the CE, ME and EE programs respectively) achieved an overall average of more than 70% as response rate for indirect assessment data collected for the last 6 years. On the other hand, the surveys pertaining to alumni (refer to Tables J47, J48 and J49 for the CE, ME and EE programs respectively), employer (Table J58 shows a 3 year summarized result for CE, ME and EE programs) and EAC (refer to Table J33) have received higher response rates as mentioned in *Section 6.i* and *6.ii PDCA Quality Cycle Q6: PEOs 5-Years Review Process* of Appendix J. The quality of responses was deemed fairly acceptable for those received from the alumni, EAC and employers based on a qualitative examination of responses and comments. The responses indicated involvement, calculated opinions and valuable comments targeting quality improvement. On the other hand, student feedback related to course exit surveys reflect a lack of understanding and involvement on the part of the majority of students. Consequently, the QA office has recorded this observation and begun implementing a series of remedial actions to improve this deficiency. Therefore, in regards to saturation of qualitative data collected from student course exit surveys we regard this as not achieved and undergoing improvement. The reasons are not related to any deficiency in underlying theory or framework but rather to the interest and involvement of the students.

F. PHASE 6: CONDUCT A RIGOROUS EVALUATION OF IMPACT

Onwuegbuzie and Hitchcock (2017) state that in Phase 6, programs should conduct a rigorous evaluation of impact, either prospectively (i.e., beginning during the design phase of the intervention) or retrospectively (i.e., usually conducted after the implementation phase) by using a credible counterfactual, which measures what would have happened to beneficiaries of the intervention in its absence, with the impact being estimated by comparing counterfactual outcomes to those observed under the intervention [52]. They state that selecting an appropriate counterfactual is a vital task in this phase and suggest using a control or comparison group to define the counterfactual outcomes. The control group has to be identified in a way that avoids selection, confounding factors, and contamination, any of which might lead to a spurious relationship between the intervention and its outcome [52]. The Faculty of Engineering had approved budgetary support and manpower to complete required tasks related to fulfillment of requirements for ABET accreditation and preparation for an audit visit at the end of 2019. The allocation of resources or manpower required for the creation and management of additional efforts with control groups for comparison of processes and outcomes for a counterfactual without any planned intervention was not institutionally recognized since it is not mandated by ABET, Washington Accord or NCAAA accreditation criteria [11], [13], [66]. Therefore, a robust and accurate alternative, multi-term SOs data evaluations [2014-2018] with trend analysis, was employed to confirm the impact of the implementation of the IQMS at the Faculty of Engineering. In our opinion, the multi-term SOs data was a better option to study the impact of the intervention since outcomes data was quantitative, valid and reliable, collected from direct assessments using state of the art digital technology, under the strict supervision of quality assurance staff, and following world-class assessment best practices.

Several issues related to the management of control groups and strict regulation of interference conditions with the intervention were totally avoided. Multi-term executive summary reports (refer *Section 5.ii ME Program Sample - Multi-term Executive Summary Report for ABET SOs [a-k],* Appendix J) showed detailed reflections, corrective actions (refer *Section IV.D.4 Practical Framework – Digital Platform EvalTools ® - SOs, PIs Evaluations*); and the CIMS system recorded achieved improvements with thousands of actions and evidentiary CQI documentation (refer *Section IV.D.7. CIMS*). Multi-term SOs trend analyses with forecasted results showing improved SOs performances reinforced the decision of program committee reviewers (refer *Section 5.vii Summary of Results of Trend Analysis for ABET SOs (a-k) ME, CE and EE programs*; Figures J31, J32 and J33, Appendix J), EAC members and other stake holders (refer *Section 6.iii EAC Review Meeting*; Figure J50 of Appendix J) to qualify the ME, CE and EE programs' implementation of IQMS as *Meeting Expectations* in regards to attainment of SOs (refer *Section 5.vii Summary of Results of Trend Analysis for ABET SOs (a-k) ME, CE and EE programs;* Tables J25, J26 and J27, Appendix J) and PEOs (refer *Section 6.ii PEOs Assessment Data;* Tables J55, J56 and J57, Appendix J).

G. PHASE 7: CONDUCT A RIGOROUS PROCESS ANALYSIS OF LINKS IN THE CAUSAL CHAIN

In phase 7, we conduct a rigorous process analysis of all the PDCA quality cycles by reviewing the frameworks, construct(s) of interest, inputs, outputs and make observations to confirm the fulfillment of intermediate and final outcomes of the intervention. PDCA quality cycle Q_1 deals with the development of the course and curriculum delivery plans and is based on authentic OBE theory. Specifically, *Bloom's Mastery Learning Model* [99] is implemented to help students progress from low order to higher-order thinking skills using the *Ideal Course Learning Distribution Model* presented earlier in *Section IV.B.3 Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology; Ideal Learning Distribution.* The QA office has thoroughly audited course work in each term for the CE, ME, and EE programs for ensuring compliance with the design rules standards for COs, PIs and Hybrid Rubrics. Several hundred thousand documents related to complete course work portfolios for the CE, EE and ME programs for fall, spring and summer terms covering the period [2014-20] are available on a cloud-based environment. The EvalTools ® *Remote Evaluator Module* was used effectively for remote audits by ABET evaluators for 6 weeks prior to the actual visit at the end of November 2019. The quality cycle Q_2 involves intensive quality management efforts to ensure monitoring and control of all course work using a FCAR checklist according to standards and models described in the Section IV.B Conceptual Framework - Models. The FCAR checklist consists of qualitative and quantitative components as noted in Table K4. The EOT checklist covers essential course activity from all the courses and is completed following comprehensive audits conducted after the final exams each term. EOT approval by the supervisor, QD clears the way for program term reviews, which consist of Learning Domains, PIs and SOs evaluations. *Section VI.C PDCA Quality Cycle Q3: Program Term Review – Learning Domains, PIs and SOs Evaluation* provides in-depth explanations of this phase of program evaluations. The course work from a given term act as inputs and are aggregated to collect SOs and PIs data from FCAR information. Learning domains evaluations help in managing curriculum delivery by monitoring counts of assessments for each SO and learning levels of the three learning domains. The outputs of this quality cycle are updated SO assessment plans, curriculum maps and evaluation reports such as the SOs executive summary, SO/PI PVT data, course action items matrix and learning domains evaluation results. The various qualitative and quantitative analyses employed in the quality cycle Q_3 are shown in Table K6 (Appendix K). Course work and CQI data for all the terms from the fall of 2014 to date are complete and uploaded to a cloud-based environment. PIs created in quality cycle Q_1 every term are stored in a digital database and are comprehensively reviewed every 3 years in the PDCA quality cycle Q_4. The last review was conducted in spring 2018. The *Section IV.D.2 Specific PIs* database elaborates on the philosophy behind the classification of PIs according to the affective, cognitive and psychomotor domains of Bloom's taxonomy. Any redundant, inaccurate, moved etc. PIs are corrected and the database with any affected rubrics is updated. Table J17 in *Section 4 PDCA Quality Cycle Q4: PIs 3 Year Multi-Term Review* of Appendix J shows samples of PIs modifications for the EE, ME and CE programs.

The multi-term SOs average values are rolled up in a multi-term SOs executive summary for program and external advisory committees review. The results of the multi-term summary for EE, ME and CE programs indicated stabilization of SOs results towards the spring of 2018 (*Section 5.i*, Appendix J). The trend and forecast analyses for most SOs indicated upcoming improvement in the following year's SOs results, thereby receiving *Meeting Expectations* result for the EE and ME programs and *Exceeding Expectations* for the CE program (*Sections 5.iii, 5.iv* and *5.v*, Appendix J). The review committees concluded that assessment instrument quality and application to teaching and learning with a follow-up to the closure of several hundreds of real-time and deferred corrective actions contributed to the overall improvement of attainment of SOs. The evidentiary improvement information obtained from multi-term SOs data coupled with thousands of CQI data points collected by rigorous qualitative and quantitative analyses in each PDCA quality cycle clearly pointed to tight alignment models connecting outcomes with teaching, learning, assessments, feedback and improvement of student learning. Therefore, from process analysis conducted in phase 7, as shown in the Table K6, we find that all elements of the causal links assiduously follow the mentioned theoretical, conceptual and practical frameworks, plus work in a tightly cascaded connection to directly contribute to an overall improvement in the attainment of EE, ME and CE program SOs.

H. PHASE 8: CONDUCT A META-EVALUATION OF THE PROCESS AND PRODUCT OF THE MMTBIE

The PDCA quality cycle Q_6: PEOs 5 year review is the meta-analyses proposed by Onwuegbuzie and Hitchcock (2017) in phase 8 since it integrates a rigorous mixed methods evaluation of both the process and product of the IQMS implemented at the Faculty of Engineering programs. The *External Advisory Committee* with adequate representation from faculty, alumni and industry, forms an integral part of the review and analyses efforts happening in the PDCA quality cycle Q_6. The process evaluation part involves a mixed methods analyses of the EE, ME and CE programs' vision, mission, PEOs, SOs, curriculum, Capstone design and industrial training courses, and CQI systems and processes. The product evaluation part comprises of a mixed methods analyses of the EE, ME and CE programs' multi-term SOs results, alumni, senior exit and employer feedback followed with trend analysis, forecasting of SOs multi-term data. From the engineering programs' perspective, the contribution to the development of the graduate attributes stops with the education process up until the course of study. Therefore, the multi-term SOs executive summary report [2014-18] is considered a comprehensive and conclusive internal representation of knowledge and skills of cohorts who are a product of a complete and full quality cycle of the education process at the Faculty of Engineering programs. For an external source of feedback on PEOs information, data is collected from graduates who are now alumni and pursuing challenging careers in the industry. Engineering programs endeavor to collect critical information from employers and alumni as regards to how engineering education offered to these cohorts actually helped them in career and future growth prospects. Key aspects of information gathered from surveys pertain to their application of theory learnt during education to real-life engineering problem-solving, design and experimentation activity; transversal skills; entrepreneurship activity, professional development and career growth; community service, research and consulting contributions; and positive cultural and societal impact through exemplary morals derived from Islamic ethics. Engineering programs usually collect this critical information by using various mechanisms and tools such as likert surveys, invited focus groups, outreach programs etc. The feedback received is reviewed carefully by both program and external advisory committees to understand the areas of weakness and strength in the education process so that appropriate remedial actions can be developed to effectively target specific improvements.

Table K7 (Appendix K) shows qualitative and quantitative process analyses employed for PDCA quality cycles Q_1 to Q_5. The last portion of Table K7 shows the PDCA quality cycle Q_6 which is the meta-analyses phase 8 of the MMTBIE of the Faculty of Engineering EE, ME and CE programs involving both process and product evaluations. The product evaluation deals with aspects related to the attainment of the PEOs a few years after graduation. The process analyses cover qualitative review of the curriculum, Capstone project design work, industrial training experience, teaching/learning process, CQI systems, lab and other infrastructure matters. The quantitative analyses involve a review of multi-term SOs executive summary reports and trend analyses along with COs, PIs and SOs data for capstone design and industrial training courses. The qualitative and quantitative analyses conducted for the process and product evaluations in the PDCA quality cycle Q_6 involve multiple levels of audits that include the program committee, QA office, QD supervisor and finally, the External Advisory Committee. The rigorous QA procedures based on authentic frameworks and coupled with an exhaustive array of qualitative and quantitative analyses for both the process and product evaluations of the Faculty of Engineering IQMS qualify the MMTBIE in phase 8 as credible since they adequately fulfill the criteria presented by Onwuegbuzie and Hitchcock (2017) [52].

X. DISCUSSION

The driving force behind this research is to examine the benefits and limitations of the application of essential theory of an authentic OBE model for the implementation of a holistic and comprehensive educational process that maximizes opportunities for the attainment of successful student learning. The objective is to be able to remotely conduct during global pandemic conditions, a MMTBIE of state of the art IQMS implemented at the Faculty of Engineering's EE, CE and ME programs (2014-20) using digital technology and OBE methodology to achieve ABET accreditation.

A. RESEARCH QUESTION 1: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS ADEQUATELY FULFILL ESSENTIAL ELEMENTS OF THE PHILOSOPHY, PARADIGM, PREMISE AND PRINCIPLES OF AUTHENTIC OBE?

Yes. As per the literature review of this research and the *Section IV.D Practical Framework – Digital Platform EvalTools ®*, the IQMS is based on authentic OBE theoretical frameworks and induced conceptual models, techniques and methods.

B. RESEARCH QUESTION 2: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS COMPREHENSIVELY COVER ALL ASPECTS OF ABET'S OUTCOMES ASSESSMENT MODEL?

Yes. The OAS of EvalTools® implements the ABET assessment model by aligning COs, with PIs and eventually with the program SOs. Additionally, the PIs are also classified as per affective, cognitive and psychomotor domains of Bloom's learning model which is adopted by both Washington Accord and ABET. The Sections *IV.D.1 FCAR and PVT* and *IV.D.4 SOs and PIs Evaluations* and *IV.D.5 Learning Domains Evaluations* elaborate on several aspects of the course and program evaluations which fulfill essential criteria of the ABET assessment model.

C. RESEARCH QUESTION 3: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS INCLUDE SUSTAINABLE INSTRUMENTS OR PROCESSES FOR DATA COLLECTION AND REPORTING OF LEARNING OUTCOMES INFORMATION?

Yes. The outcomes data collection and reporting processes are sustainable and have been implemented systematically and seamlessly since Fall 2014. A couple of million documents of evidentiary data in the form of course materials, student work and CQI information is available on a cloud-based environment. ABET evaluators were provided access to this display material using the EvalTools® *Remote Evaluator Module*. *Section VII Sustainability of Course and Program Level CQI Processes* provides a detailed explanation of the sustainability of data collection and reporting processes.

D. RESEARCH QUESTION 4: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS PROVIDE A LISTING AND DESCRIPTION OF THE ASSESSMENT PROCESSES USED TO GATHER THE DATA UPON WHICH THE EVALUATION OF EACH STUDENT OUTCOME IS BASED? (ABET, 2019 EAC CRITERIA, SELF-STUDY TEMPLATE, CR4: SECTION A.1)

Yes. Table 11 in Section *V. Description of Assessment Process and Activity* lists the assessment and evaluation activity, timeline and ownership for all the six PDCA quality cycles Q_1 to Q_6.

E. RESEARCH QUESTION 5: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS ACHIEVE A PRACTICAL AND MANAGEABLE FREQUENCY OF CARRYING OUT ASSESSMENT PROCESSES? (ABET, 2019 EAC CRITERIA, SELF-STUDY TEMPLATE, CR4: SECTION A.2)

Yes. Table 11 in *Section V. Description of Assessment Process and Activity* lists the frequency of assessment and evaluation activity in all the six PDCA quality cycles Q_1 to Q_6. The CQI activity is managed by IQMS using EvalTools® which integrates AAS, LMS, OAS and CIMS. CIMS feature provides significant savings in terms of CQI activity documentation, tracking and history. *Section IV.D.7 CIMS* provides a detailed explanation of its features and capabilities.

F. RESEARCH QUESTION 6: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS PROVIDE PERFORMANCE CRITERIA AND HEURISTIC RULES TO CLEARLY INDICATE THE EXPECTED LEVEL OF ATTAINMENT FOR EACH OF THE STUDENT OUTCOMES? (ABET, 2019 EAC CRITERIA, SELF-STUDY TEMPLATE, CR4: SECTION A.3)

Yes. Table 6 in *Section IV.D.1 FCAR and PVT* provides an elaborate explanation of the performance criteria and heuristic rules which clearly indicate the expected level of attainment for all the SOs. However, any hybrid rubrics implemented by instructors can define additional performance criteria for specific assessments.

G. RESEARCH QUESTION 7: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS PROVIDE SUMMARIES OF THE RESULTS OF THE EVALUATION PROCESS AND AN ANALYSIS ILLUSTRATING THE EXTENT TO WHICH EACH OF THE STUDENT OUTCOMES IS BEING ATTAINED? (ABET, 2019 EAC CRITERIA, SELF-STUDY TEMPLATE, SECTION A.4)

Yes. The EvalTools ® *Executive Summary* tab under the program evaluation module provides a summary and detailed reports of results of the evaluation process and an analysis which illustrates the level of attainment of SOs. *Section IV.D.4 SOs and PIs Evaluations* and *Section IV.D.5 Learning Domains Evaluations* provide in-depth details of the assessment and evaluation diagnostic tools and reports offered by EvalTools ®.

H. RESEARCH QUESTION 8: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS PROVIDE TOOLS, RESOURCES TO EFFECTIVELY DOCUMENT AND MAINTAIN THE RESULTS OF EVALUATIONS? (ABET, 2019 EAC CRITERIA, SELF-STUDY TEMPLATE, SECTION A.5)

Yes. EvalTools® provides the following program term review evaluation reports in printable word or pdf format:

a) SO executive summary
b) Detailed SO/PI executive summary
c) SO/PI Performance Vector Table PVT summary
d) Course reflections/action items
e) Learning domains evaluation

EvalTools® also provides multi-term SOs executive summary, detailed executive summary and trend analysis reports. The CIMS feature facilitates storage of documentation related to CQI activity under ABET folders in the program committee drive (Refer to Figures G3,G4,G5,G6 and G7, Appendix G *CIMS*).

I. RESEARCH QUESTION 9: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS CLEARLY INDICATE GENERATED CORRECTIVE ACTIONS AND FOLLOW-UP SEQUENCE TO CLOSURE? (ABET, 2019 EAC CRITERIA, SELF-STUDY TEMPLATE, SECTION B)

Yes. The CIMS feature provides tasks lists for both program and administrative committees that show generated action items, history, remarks, status, ownership, time stamps, etc. This feature presents significant savings of manpower and resources, which is otherwise spent in tracking, extraction, and preparation of hard copies in organized formats as display material by manual CQI systems (refer Appendix G: *CIMS*).

J. RESEARCH QUESTION 10: DO THE IQMS IMPLEMENTED AT THE EE, CE AND ME PROGRAMS PROVIDE A PRACTICAL EXAMPLE TO SUPPORT ENGINEERING PROGRAMS AND ACCREDITATION AGENCIES FOR SEAMLESS IMPLEMENTATION AND REMOTE EVALUATION OF QUALITY STANDARDS IN ENGINEERING EDUCATION USING DIGITAL TECHNOLOGY DURING THE COVID19 PANDEMIC AND BEYOND?

Yes. The EE, CE and ME programs' successful attainment of ABET accreditation in 2020 for a full six years period up to 2026, with a majority of strengths, and without any deficiency, concern or weakness, is a credible testimony of the practicality and global quality standards of the digital IQMS [11]. The theoretical, conceptual and practical frameworks discussed in this research paper present to engineering programs a perfectly viable methodology and practical digital technology based on OBE models that fully satisfy IEA's Washington Accord accreditation criteria, graduate attributes and competency profiles [10]. The meta-analyses, sustainability evaluation, and EvalTools ® *Remote Evaluator Module,* presented in this study prove that digital technology based on authentic OBE methodology can indeed be the panacea to the challenges faced by both engineering programs and accreditation agencies to implement IQMS and conduct their credible remote audits in an unchartered digital age during and after the COVID19 global pandemic.

XI. LIMITATIONS

With a majority of positive aspects, one limitation of our system, the allocation of resources to scan paper documents, is currently performed by either the lecturers or teaching assistants. Future research can target the development of state-of-the-art digital systems that automate outcomes assessment development and scoring processes. This technology would integrate with and enhance existing digital systems to significantly reduce the overhead related to the overall time spent by faculty in the outcomes assessment process and scanning work done by lecturers. Specifically, the Faculty of Engineering, QA office intends to pursue ground-breaking automation technology to push the frontiers in outcomes assessment by including optical character recognition features in remote online marking and scoring tools to assess digital versions of hard copies of student exam sheets fed into high-end large scale scanners with barcode reading capability. The bar coding on digital copies of students' exams would help align with corresponding exam templates that automatically map to the COs, specific PIs, rubrics and SOs. This technology would automate the outcomes mapping, manual score entry, file scan and upload efforts, thereby resulting in enormous savings of manpower and other resources. Additionally, Zoom video conferencing shall be integrated in version 7 of EvalTools ® to roll out early 2021, supporting virtual tours of lab facilities, and faculty/student interviews, thereby significantly enhancing remote audit capabilities. The cutting edge innovations in digital technology can dramatically revolutionize the implementation of OBE quality systems for higher education and accreditation, especially during the COVID19 global pandemic and beyond.

XII. CONCLUSION

According to Eaton (2015), retired president of the CHEA, accreditation is the primary means by which colleges, universities and programs assure quality to students and the public. Accredited status is a signal to students and the public that an institution or program meets at least threshold standards for its faculty, curriculum, student services and libraries [100]. The two top standards of the CHEA's recognition criteria (Eaton, 2012) are 1) *Advance academic quality*: accreditors have a clear description of academic quality and clear expectations that the institutions or programs they accredit have processes to determine whether quality standards are being met and 2) *Demonstrate accountability*: accreditors have standards that call for institutions and programs to provide consistent, reliable information about academic quality and student achievement to foster continuing public confidence and investment. Unanimously, student achievement and accountability pose the biggest challenges to improving the quality of higher education in the world today [38]. In order to meet these challenges, an OBE model for student learning, along with several quality standards in higher education, have been adopted by accreditation agencies and educational institutions globally over the past two decades [10]–[13], [18], [51]. Washington Accord lays down international quality standards based on learning outcomes for engineering accreditation. Graduate attributes, knowledge and problem-solving profiles specify technical and transversal knowledge and skills which students should attain during and after completion of engineering education [66].

Accreditation standards require engineering programs to demonstrate student learning outcomes with established and sustainable CQI processes based on clearly defined performance criteria. ABET's criterion 4, is regarded by many educators as the most challenging for engineering programs to fulfill. To drive the point home, instead of citing several sources, we quote Fergus (2012), chair of ABET's Engineering Accreditation Commission, ABET fellow and chairperson of accreditation committee at the Minerals, Metals and Materials Society (TMS), "*Establishing, implementing and documenting processes to determine if graduates are meeting expectations and if students are attaining student outcomes is a significant challenge, For a continuous improvement process to be effective, it must be sustainable. Collecting assessment data at a rate that cannot be maintained and in amounts that cannot be properly evaluated is counterproductive. Data should be collected continuously at rates that do not detract from educating students and in amounts that can be evaluated to provide useful information on the effectiveness of the program. If data is being collected that is not providing useful information, then the process should be modified to obtain useful data—improvement of the process is part of continuous quality improvement.*" [39] Two essential points arise from this statement as confirmed through findings of this research and more than a decade of intensive consultation and accreditation experiences of the authors. Firstly, continuous improvement based on outcomes assessment is, by far, the most challenging aspect of accreditation. Secondly, both accreditation agencies and programs have to decide on how to proceed when precariously balancing the need for data quality and the type and amount of data, sampling models, frequency and methods of collection. According to OBE, assessment and quality experts referred to in the introduction to this paper, the two aspects related to data are interchangeable. Sufficient amounts of relevant and valid data have to be sampled appropriately, collected using precision methods and evaluated accurately. Without collecting data in all courses and for multiple assessments in various phases of course and curriculum delivery, programs can never attain real-time CQI, since they do not have sufficient data to be able to indicate failures for timely remedial action. Any CQI model which does not solve problems at hand, but relies on a deferment plan, does not fulfill the requirements of CQI at all. Such a CQI model does not address the urgent learning needs of enrolled cohorts but is rather based on a program centered model. Another major challenge for accreditation agencies is to substantiate the claims of "OBE", if all student outcomes data is not included. Washington Accord and ABET have announced student-centered education systems employing Bloom's Mastery Learning Model [99] and Taxonomy [27], but they do not seem to fulfill the gold standard of OBE viz. to establish educational systems, in which "*all students can learn and succeed*". Students cannot learn and succeed, especially if, they cannot access basic information relating to their attainment of outcomes, which is an essential requirement for gauging student achievement and establishing accountability for engineering programs. Obviously, and as per the literature cited in the introductory sections of this research, most accredited programs using manual CQI systems and processes do not assess all students due to the massive amounts of data involved and the huge costs in terms of time and other resources needed for data collection and reporting.

The literature review of this research highlighted several issues with manual CQI systems and also cited references to digital solutions adopted by several programs. ABET has also been show-casing digital solutions in their symposia for almost a decade. But, probably due to commercial and practical reasons, there has not been a mandate for digital platforms since thousands of programs in the US and across the globe are still using manual CQI systems. Additionally, the looming international crisis due to the COVID19 global pandemic, which seems like it will be a prolonged affair, with severely limited regional and international movement and travel, has resulted in drastic changes to the format of education delivery globally. The COVID19 global pandemic conditions, by force majeure, have also affected the normal protocol for onsite accreditation visits. Many accreditation bodies, including ABET, have either deferred or announced virtual audits for upcoming accreditation cycles. The limitations of manual CQI systems coupled with the global crisis conditions caused by the COVID19 pandemic have forced both accreditation agencies and engineering programs to rethink about the role of digital solutions as a panacea for remote and virtual audits. The key question is whether digital solutions would be the necessary or preferred choice for engineering programs pursuing renewal or initial accreditation. Obviously, the answer to this question would unfold in the coming years based upon the spontaneity of engineering programs in collectively responding to accreditation requirements with digital solutions.

Unfortunately, the global COVID19 pandemic does not absolve programs from accountability to the students and the public for meeting required standards of engineering education. Virtual accreditation audits will need to place a greater focus on the quality of digital CQI display data so that programs can establish credibility and meet accreditation requirements. Contrary to some uninformed opinions, there are no simplistic quantitative metrics that can be recommended to accreditation agencies and programs for verifying the accuracy and credibility of rigorous program evaluations. In fact, engineering programs may also ingeniously review some aspects of the assessment methodology and technology presented in this research and creatively produce enhanced authentic OBE assessment models or digital tools. As suggested by Onwuegbuzie and Hitchcock (2017), credibility and rigor of evaluation rest on many aspects such as using mixed methods for analyses, accurate theoretical and conceptual frameworks, appropriate context for evaluations, constructs of interest, well defined causal links, meta-analyses of processes and products, and quality of outcomes data [52]. The evaluation results and K tables reported in this study thoroughly examine all these aspects using 8 phases of a comprehensive meta-framework and provide detailed guidelines for a multi-dimensional mixed methods approach to achieve credible MMTBIEs. Essential elements that ensure the quality of CQI data such as sampling schemes, data and theoretical saturation for qualitative analyses, statistical power of quantitative data, generalizability and transferability, sustainability, data collection and reporting methods etc. have been adequately discussed in this research. We also show how embedded assessment methodology using the FCAR and PVT with specific PIs and hybrid rubrics presents significant savings to instructors and helps ensure outcomes data is valid, reliable and tightly aligned to learning activities. The documentation and reporting features of EvalTools® could help programs actively facilitate social distancing norms since both faculty and students can interact remotely and exchange digital versions of necessary educational information such as outcomes results, advising notes, syllabi, lessons, online assessments, assignments, gradebook results etc. The most arduous task of maintaining a trail of CQI history, all the way up to closed corrective actions, is transformed into a seamless and totally manageable digital affair with the help of the *CIMS Module*. The *Remote Evaluator Module* provides accreditation auditors with an all-in-one remote display dashboard with tabs to conveniently access a wealth of evidential information such as course portfolios, curriculum maps; performance criteria and heuristics rules; course and program evaluations results; PEOs, SOs, PIs and rubrics databases; single term and multi-term SOs, executive summary reports; SOs based objective evidence; complete CQI history including detailed committee activity; and advising records [90]. The discussions on the limitations of current digital technology and proposed solutions present an exciting new frontier of research dealing with the automation of development of outcomes based assessments and their remote marking capabilities. Detailed theoretical and practical frameworks presented in this research provide comprehensive information for the implementation of IQMS. The results of evaluation and discussions provide valuable insights on conducting credible program interventions by showing how various phases of a novel meta-framework help to qualify comprehensive digital CQI systems. In conclusion, the findings of this study offer both accreditation agencies and engineering programs significant exposure to the overwhelming benefits of an outcome-based digital IQMS for seamless management of automated data collection and reporting to enable credible remote accreditation audits during the COVID19 global pandemic and beyond.

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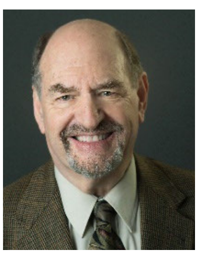

WILLIAM G. SPADY received the Ph.D. degree from the University of Chicago, in 1967. He began his academic career as a Professor with the Graduate School of Education, Harvard University. This was followed by major national leadership positions in education and the founding of his own national consulting company in 1991. Since then, he has lectured at major educational conferences throughout the world on cutting-edge approaches to a range of topics related to OBE, leadership , human potential, paradigm change, and learner empowerment. He is recognized across the world as a dynamic and compelling consultant and presenter. He has published nine highly acclaimed professional books, scores of journal articles, and many solicited chapters in the books of others. A list of his books can be found on his website. He has been the subject of three doctoral dissertations, and has been honored with a Center on Transformational Leadership and Learning in the Philippines bearing his name. His experience and expertise in Outcome-Based Education are unmatched globally. Known internationally as "The Father of OBE," he has earned the reputation as the recognized worldwide authority on future-focused, paradigm-shifting, personally-empowering approaches to Transformational OBE. For over four decades, he has spearheaded major OBE initiatives throughout North America, South Africa, Australia, The Philippines, Saudi Arabia, and the United Arab Emirates on expanding the vision, shifting the paradigm, and improving the performance of learners, educators, and educational systems. This work has bolstered his recognized expertise in organizational change, transformational leadership development, strategic organizational design, and elevated models of learning and living.

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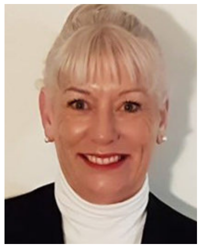
SOHAIB ZIA KHAN received the B.Eng. degree in mechanical engineering from NED University, Pakistan, the M.Phil. degree in mechanical engineering, and the Ph.D. degree in materials engineering from The University of Manchester, U.K., in 2002, 2006, and 2010, respectively. He got years of industrial experience before proceeding for higher education. He worked at the National University of Sciences and Technology (NUST), Pakistan, as a Faculty Member and Swinburne University of Technology, Australia, as a Research fellow of Endeavour Fellowship in 2016. He is currently an Associate Professor with the Islamic University of Madinah (IUM), Saudi Arabia. His research and teaching interests are materials characterization, mechanics of materials, and engineering education. He is the lead person for ABET accreditation in the Mechanical Engineering Department at IUM and plays a pivotal role in implementing quality in education and outcome-based education.

BILAL A. KHAWAJA (Senior Member, IEEE) received the B.S. degree in computer engineering from Sir Syed University of Engineering and Technology, Karachi, Pakistan, in 2002, the M.Sc. degree in communication engineering and signal processing from the University of Plymouth, Plymouth, U.K., in 2005, and the Ph.D. degree in electrical engineering from the University of Bristol, Bristol, U.K., in 2010. From 2003 to 2004, he was a Software Engineer with Simcon International (Pvt.) Ltd., Pakistan. From 2010 to 2016, he was working as an Assistant Professor with the Electronics and Power Engineering Department, PN-Engineering College, National University of Science and Technology (NUST), Karachi, Pakistan. In 2015, he was a Visiting Postdoctoral Researcher with the Lightwave Systems Research Laboratory, Queens University, Kingston, Canada, involved in the Natural Sciences and Engineering Research Council (NSERC) - Canada CREATE Next Generation Optical Network (NGON) project on the characterization and measurements of 25GHz RF signal generation optical comb sources. He is currently an Associate Professor with the Department of Electrical Engineering (EE), Faculty of Engineering, Islamic University of Madina (IUM), Saudi Arabia. He is the lead person for ABET Accreditation at the EE Department, IUM, and his efforts in implementing continuous improvement and quality in outcome-based education led to successful ABET Accreditation of the EE program in 2020. He has also authored and coauthored several journals and IEEE proceeding publications. His current research interests include next-generation of millimeter-wave (mm-wave) radio-over-fiber systems and mm-wave/THz signal generation mode-locked lasers, and antennas design/characterization for the Wi-Fi/IoT/UAVs/FANETs/5G systems and millimeter-wave frequency bands. He is an active reviewer for many reputed IEEE journals and letters.



LINDSEY CONNER is an internationally renowned education expert who is known for her research on innovation in Education and teaching. Her commitment to social justice and prioritization of specific actions underpins her philosophy and leadership to empower people to stretch their potential for social mobility. She was previously the Deputy Pro-Vice-Chancellor (Education), and the Associate Dean Postgraduate Research and Dean (Education) at the University of Canterbury, New Zealand. Her leadership in Education is drawn from nearly 26 years as a Researcher and Teacher Educator in science education, including research on the application of technologies within disciplines and in cross-disciplinary contexts. She has also led an international partnership project on implementing ICT in schools and was the Director of the Science and Technology Education Research Hub which has had international acclaim. She has a strong international profile and led the seven country Pacific Circle Consortium research project on Teacher Education for the Future. In 2013, she was an invited consultant to NIER (Japan) working with the Ministry of Education Japan on infusing competencies across curriculum. She was also a funded visiting fellow at SEAMEO RECSAM, Penang (2013) and a consultant in developing science teaching standards for the South East Asian Ministries of Education (2014), which have been implemented in 11 Countries. She has developed courses and supported researchers from universities in Bangladesh, China, Malaysia, and South Korea. Previously, she was the New Zealand's Coordinator for the OECD Innovative Learning Environments Project and Commissioner for the New Zealand Olympic Education Committee.

APPENDIX A: *FCAR*

Figure A1:

1. *Course Description:* Pre-requisites, Co-requisites, Faculty name, Term, Response Rate for Course exit surveys.
2. *Course Outcomes Indirect Assessment:* A summary of student responses from the course exit survey corresponding to COs and faculty self-evaluation results. A histogram plot conveniently displays the mentioned COs indirect assessment information.
3. *Grade Distribution:* Summary of class grades distribution.

Figure A2:

4. *Old Action Items:* Any pending AIs related to a current course offering are ported electronically into this section of the FCAR from the recent offering of the same course.
5. *Reflections:* Program faculty report failing COs, their associated PIs, ABET SOs, comments on student indirect assessments and other general issues of concern in the respective *course reflections* section of the FCAR. The course reflections maintain headings related to format CO_*N1*; PI_*N2*_*N3*; SO_*N2*; where *N1*: CO index; *N2*: ABET SO index (1 being 'a' and 11 being 'k'); and *N3*: PI index. Additionally, course reflections have to also mention the failing assessments in abbreviated form
6. *New Actions:* Based upon these course reflections, new action items are proposed by the faculty. The new action items maintain headings related to format CO_*N1*; PI_*N2*_*N3*; SO_*N2*; where *N1*: CO index; *N2*: ABET SO index (1 being 'a' and 11 being 'k'); and *N3*: PI index.

Figures A3 and A4:

7. *Course Outcomes Assessment:* This section presents a detailed evaluation of each CO. The CO evaluation consists of EAMU calculations for each assessment corresponding to specific PIs related to this CO. Each CO is comprehensively evaluated by using theoretical, practical, project/term paper based assessments corresponding to Bloom's three domains (Cognitive, Psychomotor and Affective) and their learning levels. Weighted averaging is performed to obtain summative EAMU results from various types of assessments for evaluation of a specific CO. A summarized histogram plot conveniently displays all the COs assessed in the course. A scientific color coding scheme indicates the performance criteria for summative evaluation of all COs in the course.
8. *Assignment List:* The assignment list table displays all the Assignment / Activities / Events conducted in the course and their corresponding performance measurement standards (CO/PI/SO).

Figure A5:

9. *Summary of Assignment Distributions:* Two Pie charts clearly illustrate the learning domain distribution for the Bloom's three domains (Cognitive, Psychomotor and Affective) and their learning levels as indicated by the 3-Levels Skills Grouping Methodology. The pie charts display learning domains distribution information extracted real time from the course assessment and learning activity. Therefore, they provide an excellent source of formative information for improving pedagogy to achieve holistic learning.
10. *Student Outcomes Assessment:* A summary of Student Outcomes (SOs) assessment is conveniently displayed in tabulated format with the following sections: Item, Student Outcomes, Correlated Course Outcomes, Key Assignments, EAMU and Average. A summarized histogram plot conveniently displays all the SOs assessed in the course. A scientific color coding scheme indicates the performance criteria for the summative evaluation of all SOs in the course.

Figure A6:

11. *Performance Indicators Assessment:* A summary of PIs assessment is conveniently displayed in a tabulated format with the following sections: Item, Performance Indicators, Correlated Student Outcomes, Key Assignments, EAMU and Average. A summarized histogram plot conveniently displays all the PIs assessed in the course. A scientific color coding scheme indicates the performance criteria for the summative evaluation of all PIs in the course.
12. *Student Outcomes - Performance Indicators Assessment Charts:* A summarized histogram plot conveniently displays all the PIs corresponding to an individual SO. A scientific color coding scheme indicates the performance criteria for summative evaluation of all PIs in the course

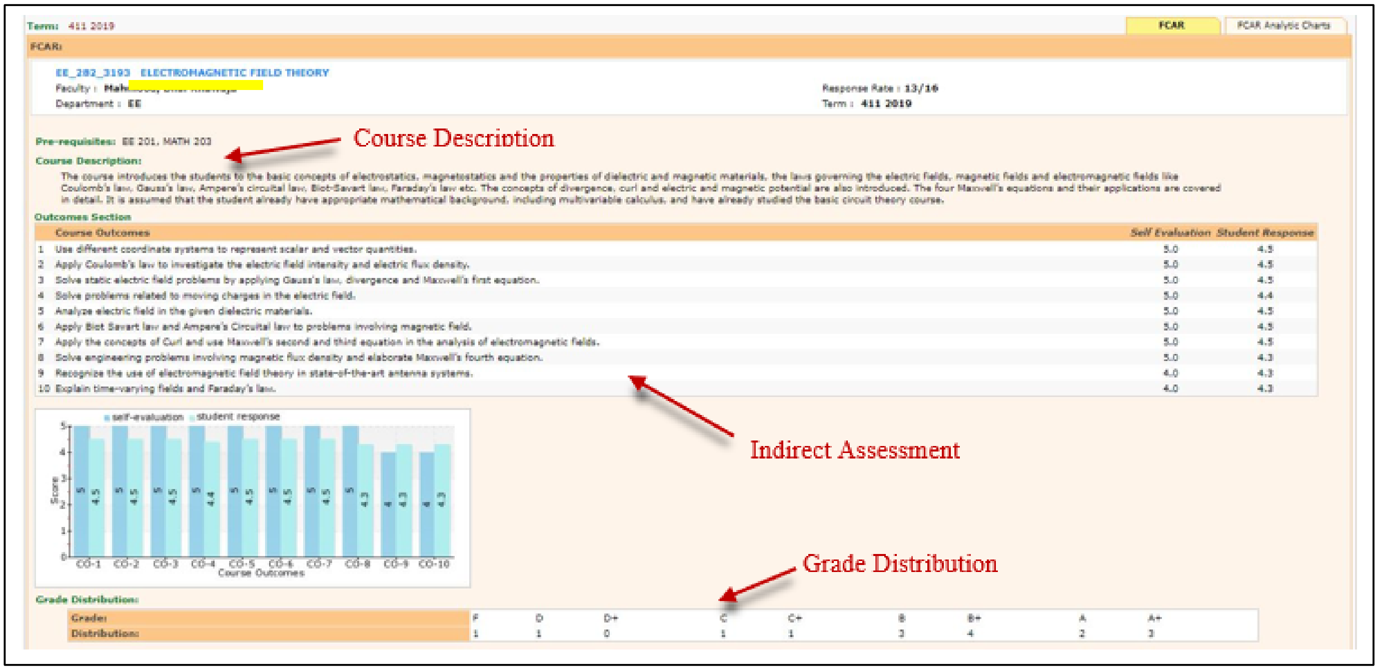


Figure A1. FCAR – course description, indirect assessments and grade distribution

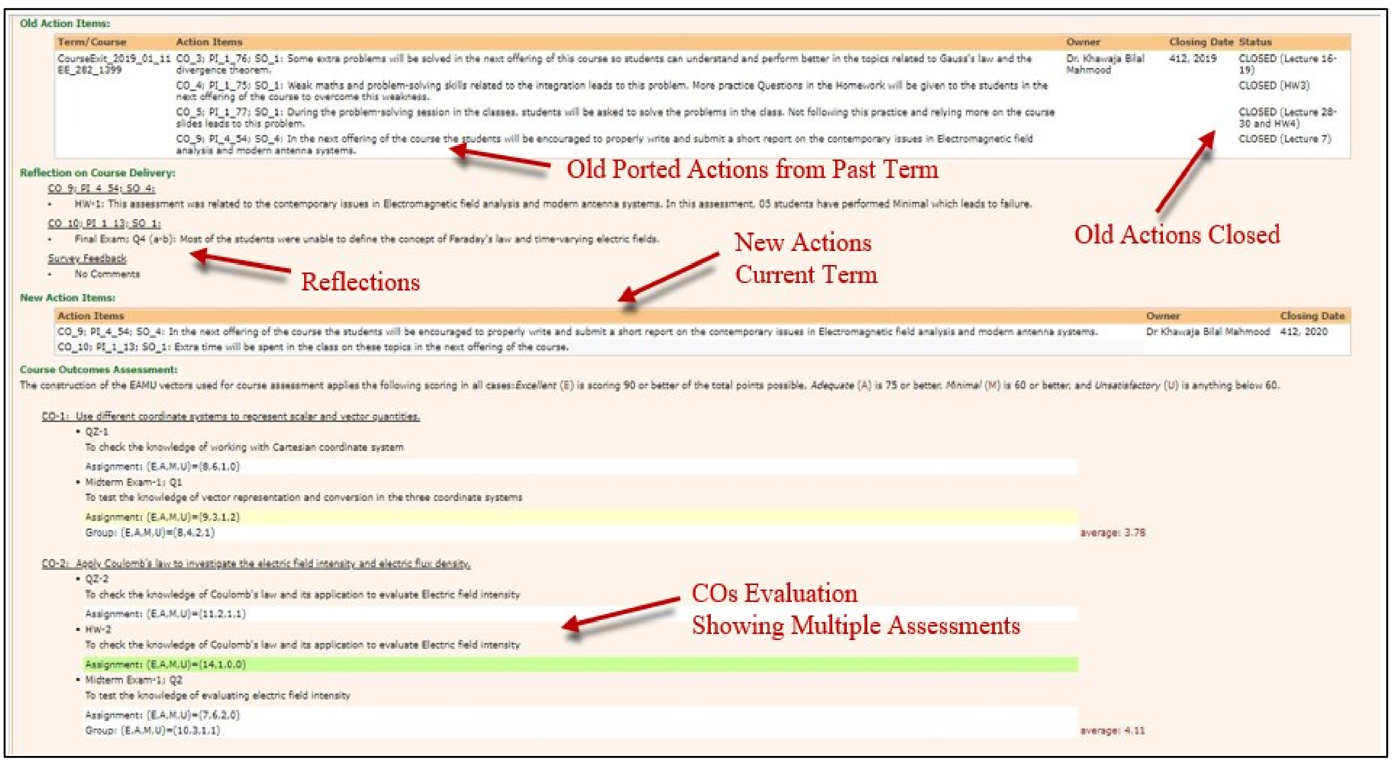


Figure A2. FCAR – actions, reflections and COs evaluation

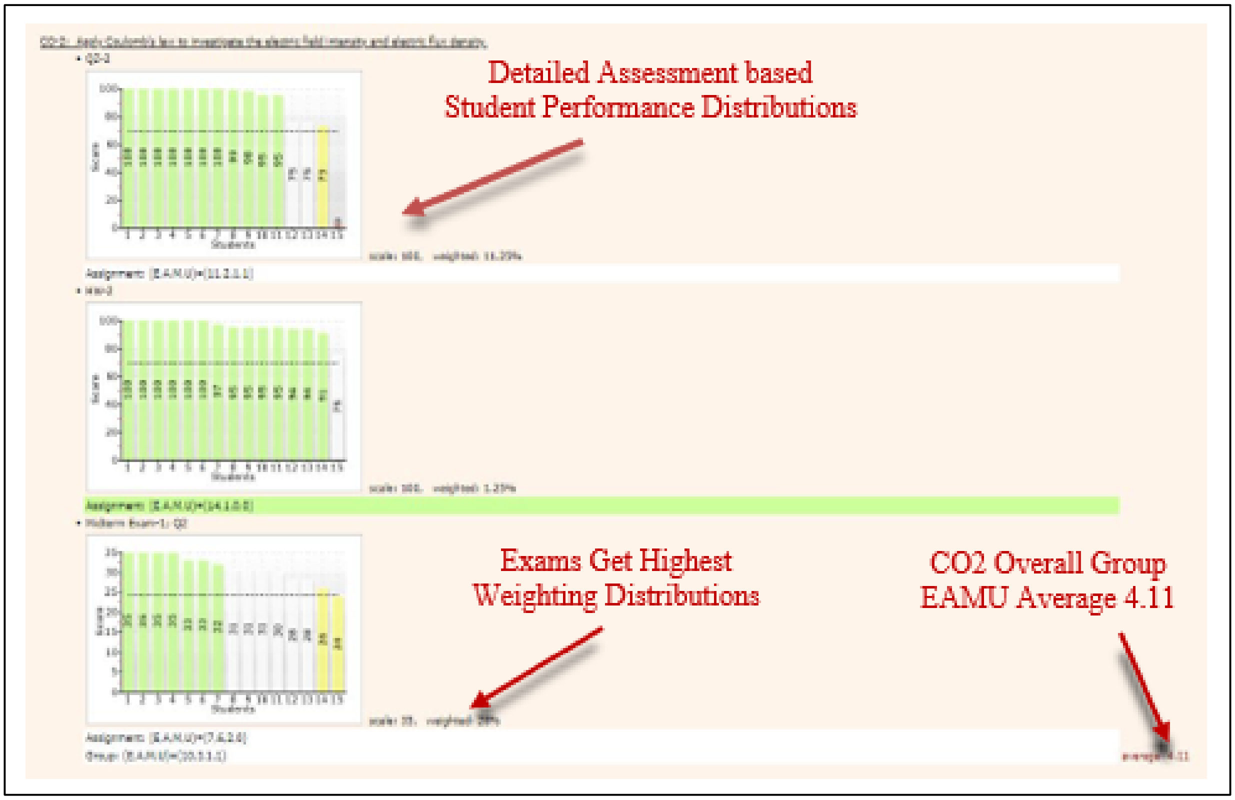


Figure A3. FCAR – detailed analytical view of student performances

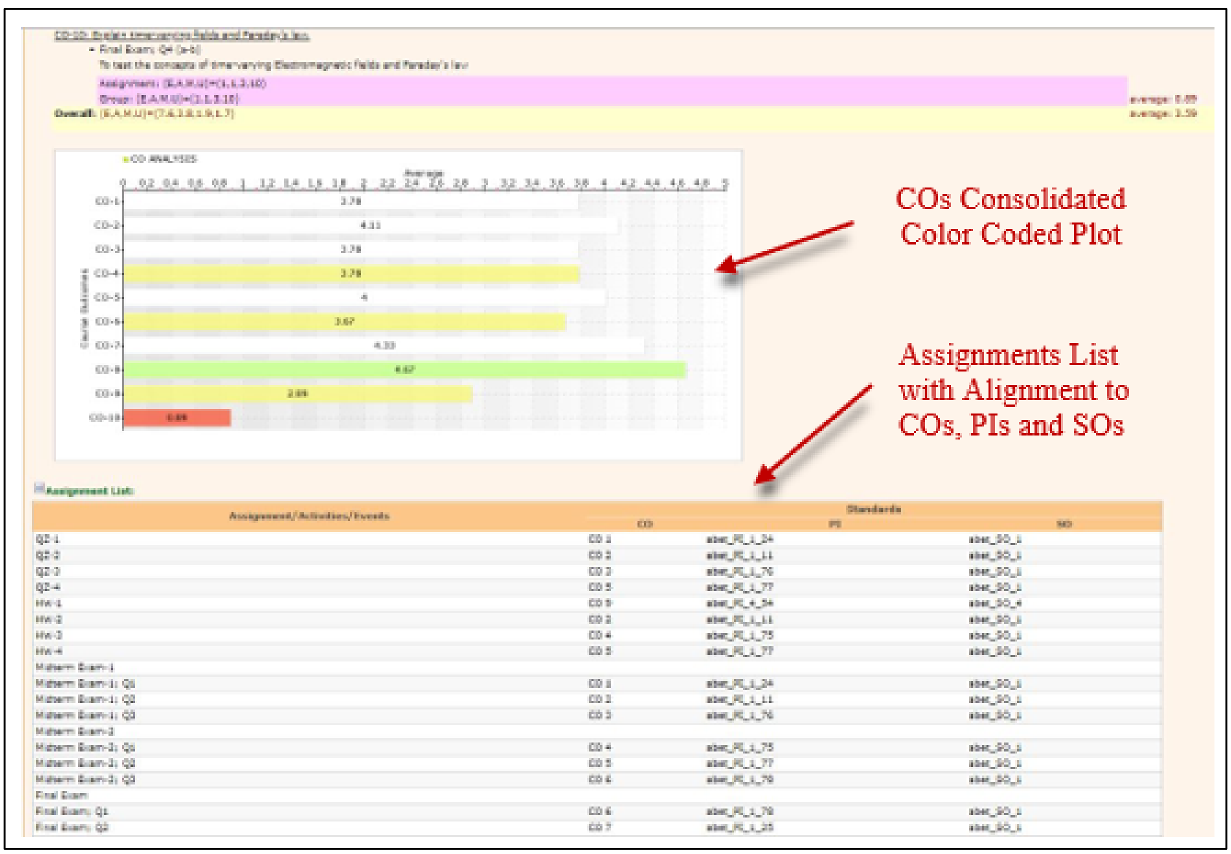


Figure A4. FCAR – COs plot and assignment list

Figure A5. FCAR – course learning distribution and SOs evaluation

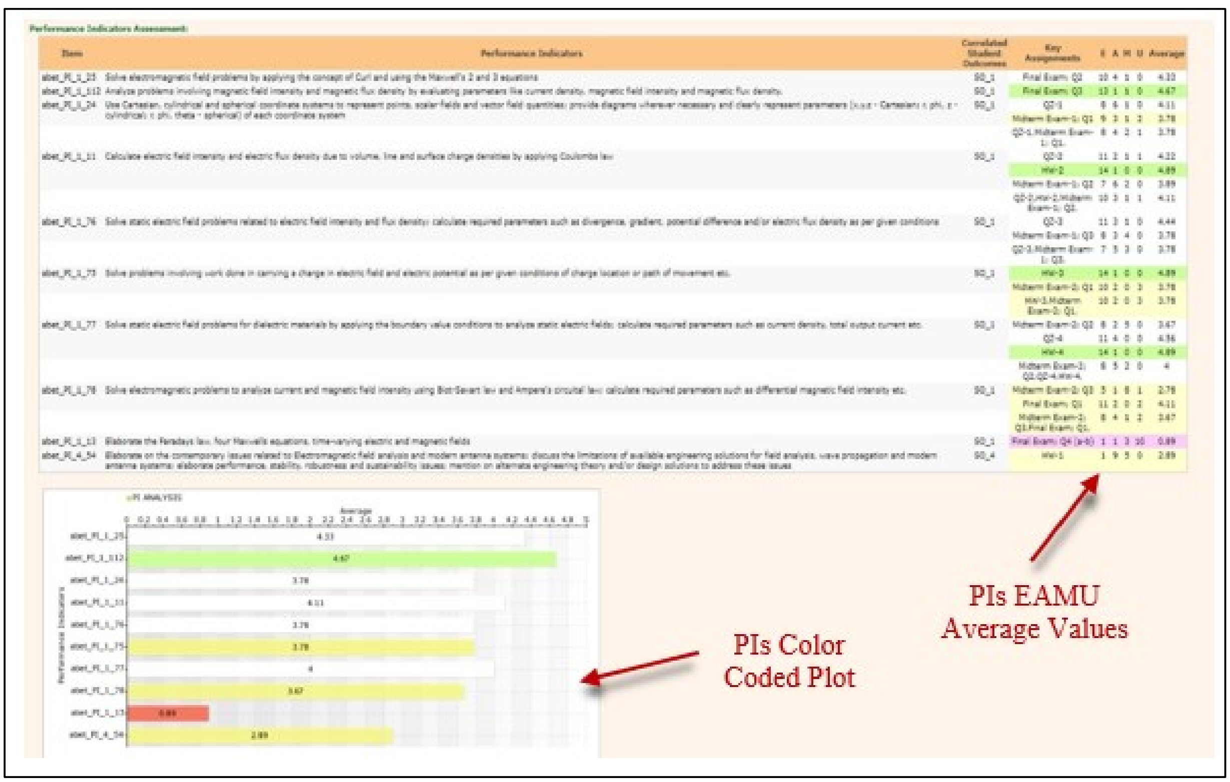


Figure A6. FCAR – PIs evaluation

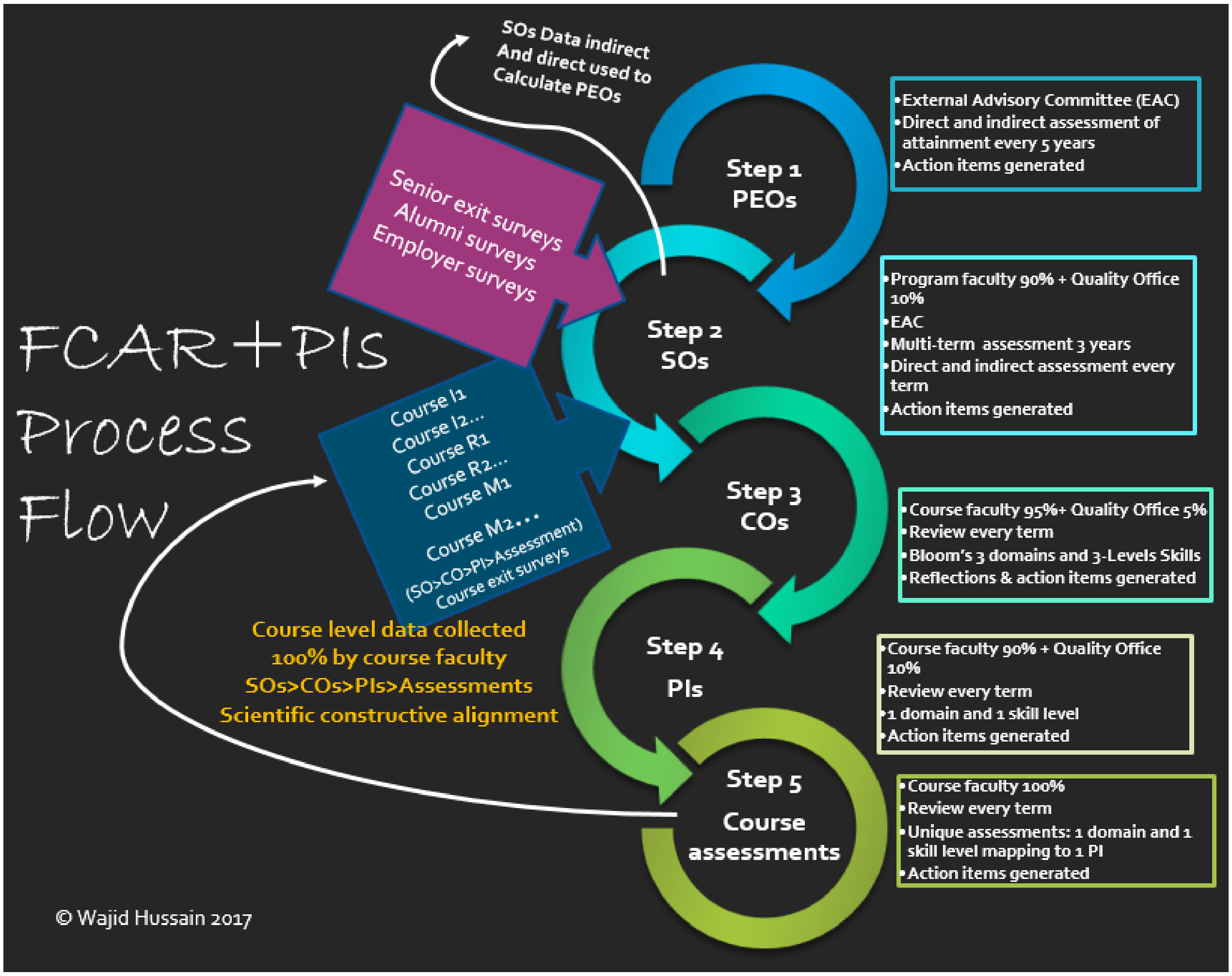


Figure A7. FCAR + PIs assessment model process flow indicating course faculty involvement in almost all phases of CQI cycle Course faculty is directly

APPENDIX B: *PVT and Course and Program Level WFs*

Performance Vector
Class: CE_201_2165 STATICS
Size: 16

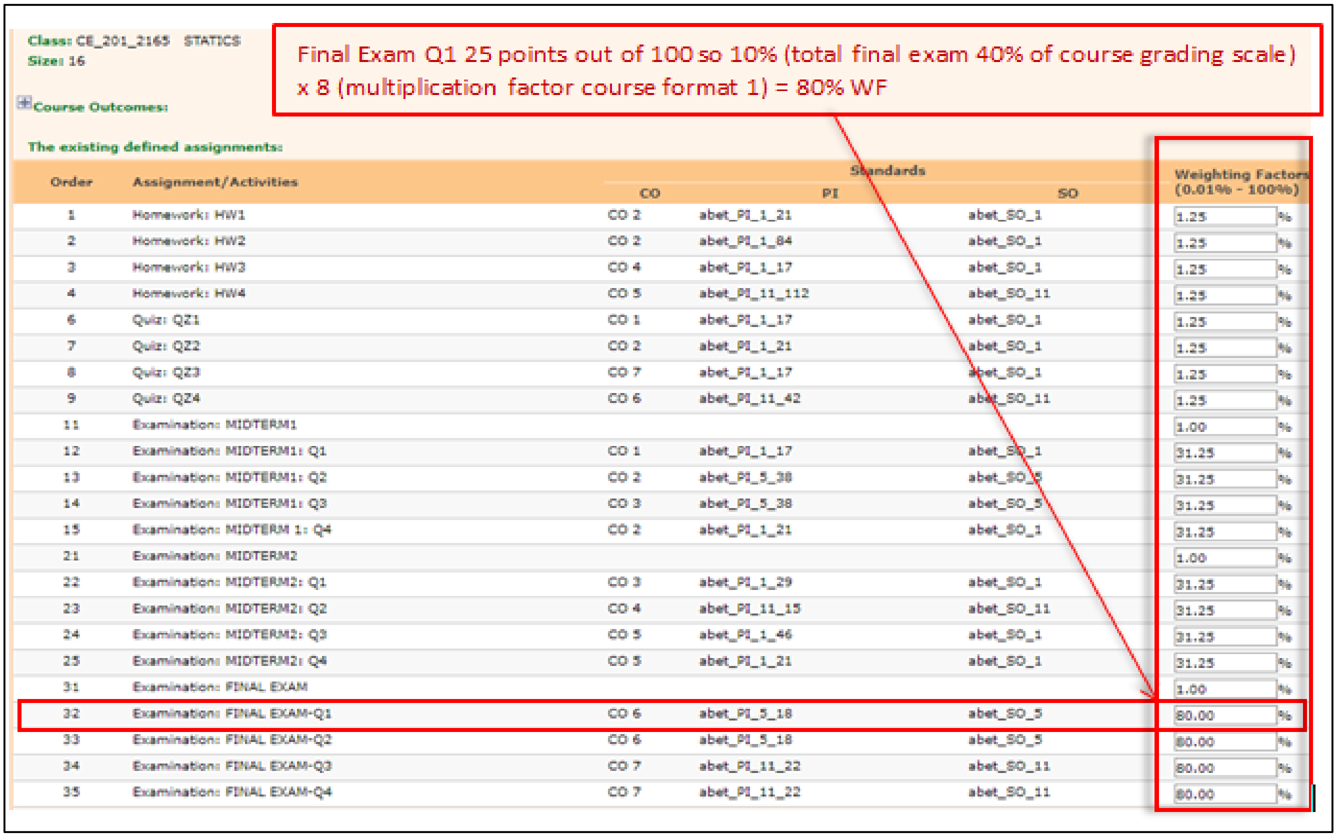
Course Outcomes:
CO 1 Define fundamental concepts of statics, system of units and perform basic unit conversions
CO 2 Define, explain the concept of resolution of forces and calculate the resultant force, couple and moment
CO 3 Solve engineering mechanics problems by utilizing equilibrium equations
CO 4 Define free body diagram and Draw free body diagrams of various structures
CO 5 Describe various types of trusses and their applications and Analyze trusses by method of joints and method of section
CO 6 Define and calculate the center of gravity of a body or any arbitrary shape and moment of inertia
CO 7 Define shear force and bending moment and calculate them for simple beams

Student	CO 1 (100%)		QZ1 (100)	MIDTERM 1: Q1 (25)	CO 2 (100%)		HW1 (100)	HW2 (100)	QZ2 (100)	MIDTERM 1: Q2 (25)	MIDTERM 1: Q4 (25)	CO 3 (100%)		MIDTERM 1: Q3 (25)
	0	U	0	0	0	U	0	0	0	0	0	0	U	0
	96	E	96	24	92.09	E	92	95	94	25	21	62	M	6
	92.15	E	96	23	56.34	U	92	96	98	22	5	76	A	18
	92.12	E	95	23	75.09	A	90	94	96	23	14	46	U	8
	95.96	E	95	24	59.96	U	89	94	95	14	15	46	U	7
	95.85	E	92	24	97.68	E	94	92	91	25	24	98	E	24
	57.54	U	96	14	75.04	A	90	92	95	23	14	62	M	8
	96.08	E	98	24	88.06	A	90	92	85	24	20	90	E	21
	96.08	E	98	24	88.25	A	94	92	91	24	20	82	A	22
	92.19	E	97	23	92.08	E	90	94	96	24	22	92	E	21
	95.96	E	95	24	89.7	A	94	80	80	25	20	96	E	24
	95.96	E	95	24	61.23	M	94	86	65	15	15	96	E	23
	92.19	E	97	23	97.66	E	92	92	92	25	24	86	A	24
	95.96	E	95	24	97.62	E	92	92	90	25	24	96	E	24
	88.35	A	97	22	90.09	E	94	91	90	24	21	94	E	23
	96	E	96	24	85.94	A	95	95	65	23	20	86	A	20

Figure B1. Performance vector table (PVT) for CE_201 statics course

Course Outcomes	E	A	M	U
CO 1	13	1	0	2
CO 2	6	6	1	3
CO 3	7	4	2	3
CO 4	3	6	3	4
CO 5	7	4	3	2
CO 6	13	2	0	1
CO 7	6	4	4	2
Overall	7.86	3.86	1.86	2.43

Figure B2. COs and EAMU summary for CE_201 statics course



Class: CE_201_2165 STATICS
Size: 16

Final Exam Q1 25 points out of 100 so 10% (total final exam 40% of course grading scale) x 8 (multiplication factor course format 1) = 80% WF

Course Outcomes:

The existing defined assignments:

Order	Assignment/Activities	Standards CO	Standards PI	Standards SO	Weighting Factors (0.01% - 100%)
1	Homework: HW1	CO 2	abet_PI_1_21	abet_SO_1	1.25 %
2	Homework: HW2	CO 2	abet_PI_1_84	abet_SO_1	1.25 %
3	Homework: HW3	CO 4	abet_PI_1_17	abet_SO_1	1.25 %
4	Homework: HW4	CO 5	abet_PI_11_112	abet_SO_11	1.25 %
6	Quiz: QZ1	CO 1	abet_PI_1_17	abet_SO_1	1.25 %
7	Quiz: QZ2	CO 2	abet_PI_1_21	abet_SO_1	1.25 %
8	Quiz: QZ3	CO 7	abet_PI_1_17	abet_SO_1	1.25 %
9	Quiz: QZ4	CO 6	abet_PI_11_42	abet_SO_11	1.25 %
11	Examination: MIDTERM1				1.00 %
12	Examination: MIDTERM1: Q1	CO 1	abet_PI_1_17	abet_SO_1	31.25 %
13	Examination: MIDTERM1: Q2	CO 2	abet_PI_5_38	abet_SO_5	31.25 %
14	Examination: MIDTERM1: Q3	CO 3	abet_PI_5_38	abet_SO_5	31.25 %
15	Examination: MIDTERM 1: Q4	CO 2	abet_PI_1_21	abet_SO_1	31.25 %
21	Examination: MIDTERM2				1.00 %
22	Examination: MIDTERM2: Q1	CO 3	abet_PI_1_29	abet_SO_1	31.25 %
23	Examination: MIDTERM2: Q2	CO 4	abet_PI_11_15	abet_SO_11	31.25 %
24	Examination: MIDTERM2: Q3	CO 5	abet_PI_1_46	abet_SO_1	31.25 %
25	Examination: MIDTERM2: Q4	CO 5	abet_PI_1_21	abet_SO_1	31.25 %
31	Examination: FINAL EXAM				1.00 %
32	Examination: FINAL EXAM-Q1	CO 6	abet_PI_5_18	abet_SO_5	80.00 %
33	Examination: FINAL EXAM-Q2	CO 6	abet_PI_5_18	abet_SO_5	80.00 %
34	Examination: FINAL EXAM-Q3	CO 7	abet_PI_11_22	abet_SO_11	80.00 %
35	Examination: FINAL EXAM-Q4	CO 7	abet_PI_11_22	abet_SO_11	80.00 %

Figure B3. CE_201 statics course WF calculations for Final Exam Q1

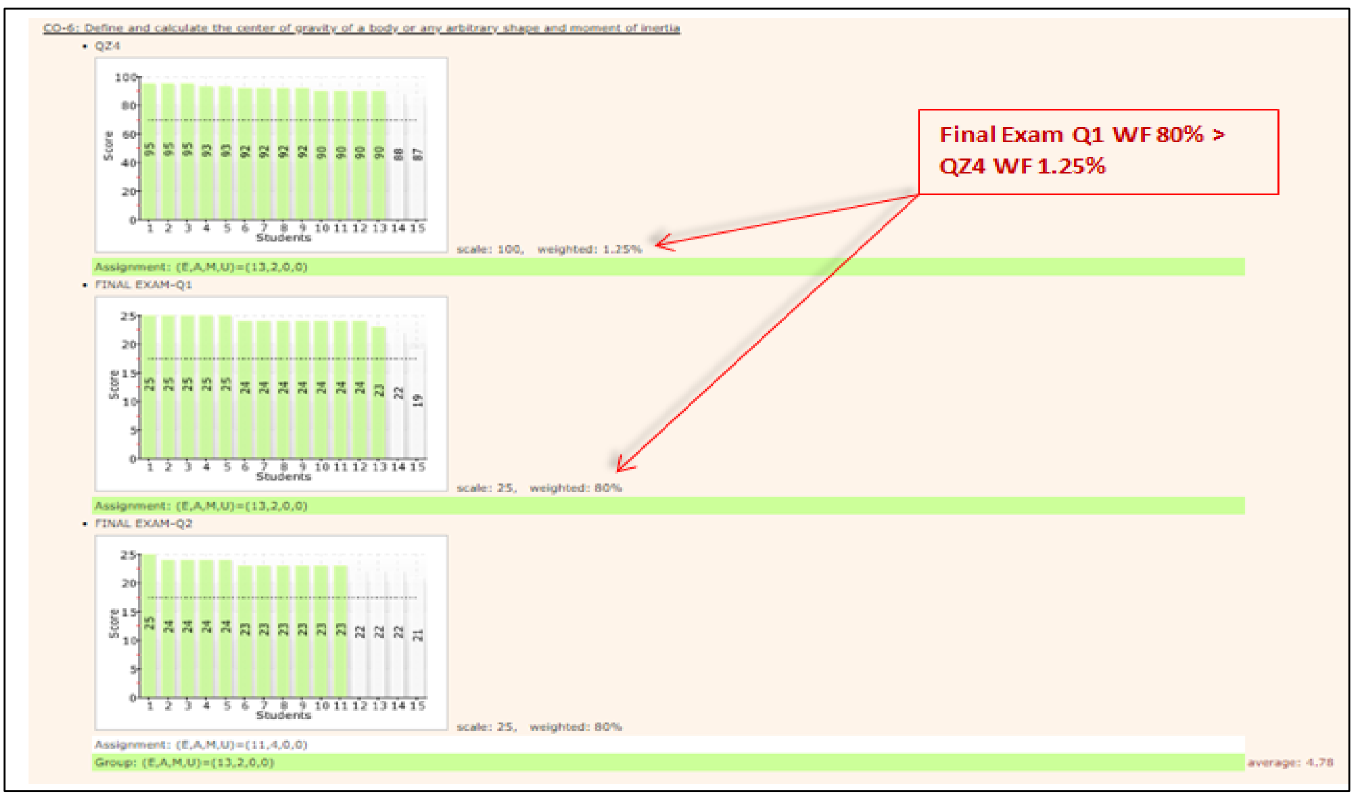


Figure B4. CE_201 statics course CO6 aggregation showing assessments QZ4, Final Exam Q1 and Q2 EAMU with WFs

abet_SO_6 : an understanding of professional and ethical responsibility

abet_PI_6_5: Identify the inherent risks of contract conditions such as delay penalty, vague process for conflict resolution, sudden death of contractor, natural disasters and other unavoidable circumstances

abet_PI_6_6: Recognize the professional and ethical responsibilities of different roles (client, consultant and contractor) in typical civil engineering project management.

abet_PI_6_26: Explain the concepts and philosophy of engineering standards and codes for structural steel design; provide reasons related to safety, health, welfare and sustainability; describe briefly ASTM, ASCE standards and policies

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_6_5	(0,0,1,0)	3.21	CE_482_2256	CONTRACTS AND CONSTRUCTION ENGINEERING	Mastery	4	4	5	0	3.21
abet_PI_6_6	(0,0,0,2)	3.12	CE_321_2217	SOIL MECHANICS	Reinforced	0	5	6	2	2.05
			CE_482_2256	CONTRACTS AND CONSTRUCTION ENGINEERING	Mastery	5	4	2	2	3.21
abet_PI_6_26	(0,1,0,0)	3.96	CE_417_2229	STEEL STRUCTURES DESIGN	Mastery	3	5	0	0	3.96

Overall SO Average: 3.42 EAMU: (0,1,1,1)

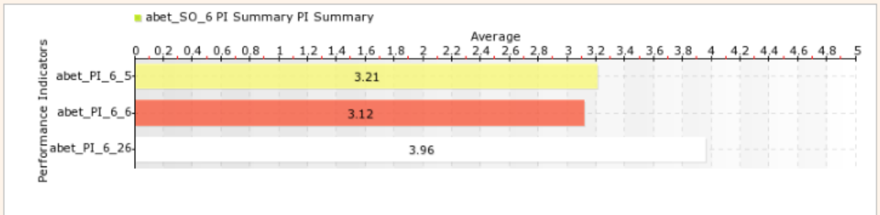


Figure B5. List of specific PIs classified as Per Bloom's 3 domains, learning levels and measured by the CE program in term 382 for ABET SO 'f' (SO_6)

Step 1: Update PI grades

PI Classification	PI Grade
Cognitive:Remembering	Elementary
Cognitive:Understanding	Elementary
Cognitive:Applying	Intermediate
Cognitive:Analyzing	Intermediate
Cognitive:Evaluating	Advanced
Cognitive:Creating	Advanced
Affective:Receiving phenomena	Elementary
Affective:Responding to phenomena	Elementary
Affective:Valuing	Intermediate
Affective:Organize values into priorities	Advanced
Affective:Internalizing values	Advanced
Psychomotor:Perception	Elementary
Psychomotor:Set	Elementary
Psychomotor:Guided response	Elementary
Psychomotor:Mechanism	Intermediate
Psychomotor:Complex overt response	Intermediate
Psychomotor:Adaptation	Advanced
Psychomotor:Origination	Advanced

Step 2: Define % learning weighting factors per SO

Term: 382 2018

SO_6: an understanding of professional and ethical responsibility

Course Level	PI Grade	% Learning WF
Mastery	Advanced	300.00 %
	Intermediate	0.01 %
	Elementary	0.01 %
Reinforced	Advanced	25.00 %
	Intermediate	0.01 %
	Elementary	0.01 %
Introductory	Advanced	0.01 %
	Intermediate	0.01 %
	Elementary	0.01 %

Figure B6. ABET SO 'f' (SO_6) WFs definition for 3-level skills in mastery, reinforced and introductory courses

APPENDIX C: *PIs and Hybrid Rubrics*

ABET Student Outcomes

[abet_SO_1] an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

- [abet_PI_1_1] Cognitive: Analyzing Derive needed unknowns for a given engineering problem by applying mathematical principles such as integral calculus or differential equations
- [abet_PI_1_2] Cognitive: Applying Use matrices manually or with MATLAB for solving systems of linear equation
- [abet_PI_1_3] Cognitive: Analyzing Define eigenvalues and eigen vectors and describe how they are used in engineering analysis.
- [abet_PI_1_4] Cognitive: Analyzing Complete a basic statistical analysis, including producing histograms, identifying probability distributions, and computing mean values, standard deviations, standard deviations of the mean, and confidence intervals
- [abet_PI_1_5] Cognitive: Evaluating Define regression analysis and correlation coefficients, and an ability to use the method of least squared error to define a best-fit curve.
- [abet_PI_1_6] Cognitive: Analyzing Implement real-world engineering applications of statistical analysis

Additional PIs for ABET SO_1 but not shown here for brevity

- [abet_PI_1_72] Cognitive: Analyzing Calculate heat, internal energy, and/or work in closed systems by applying first law of thermodynamics
- [abet_PI_1_73] Cognitive: Evaluating Apply procedures and specifications for water supply and drainage systems
- [abet_PI_1_74] Cognitive: Understanding Explain linear regression and outline the steps involved in problems related to linear regression
- [abet_PI_1_75] Cognitive: Applying Explain the process of hypothesis testing and its use in distribution fitting tests
- [abet_PI_1_76] Cognitive: Analyzing Perform statistical analysis, trigonometric calculations, matrix manipulations, uniform and Gaussian random number generation using MATLAB functions

[abet_SO_2] an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

[abet_SO_3] an ability to communicate effectively with a range of audiences

[abet_SO_4] an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

[abet_SO_5] an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

[abet_SO_6] an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

[abet_SO_7] an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

- [abet_PI_7_1] Affective: Internalizing values Utilize Library and Web resources and provide documentation of references
- [abet_PI_7_2] Affective: Internalizing values Identify what is required to solve case studies of realistic industrial problems
- [abet_PI_7_3] Affective: Internalizing values Set goals, targets and ways for improvement
- [abet_PI_7_4] Affective: Organize values into priorities Identify ways for further improving learning and performance
- [abet_PI_7_5] Affective: Internalizing values Demonstrate resume writing skills
- [abet_PI_7_6] Affective: Internalizing values Measure sustainability of projects with life cycle analysis
- [abet_PI_7_7] Affective: Internalizing values Examine overall framework for project integration management as it relates to the other PM knowledge areas and the project life cycle
- [abet_PI_7_8] Psychomotor: Adaptation Develop procedure to analyze project time variance in real time
- [abet_PI_7_9] Cognitive: Applying Discuss contemporary project management methods and discuss how project overrun are managed
- [abet_PI_7_10] Affective: Internalizing values Evaluate sustainability of projects assessing cost benefit analysis, environmental and ethical questions

Figure C1. ME program database for specific and generic PIs corresponding to revised ABET SOs (1-7)

Instructor View of Hybrid Rubrics:

Figure C2 shows an instructor view of rubrics for PI_1_83: *Solve engineering problems involving steady-state and transient heat conduction to calculate heat transfer rate, thermal conductivity, temperature difference, thickness, and area for given objects with simple geometries like cylinder, walls, sphere, plates etc.; and provide neatly labeled sketches wherever necessary;* in a mechanical engineering course, ME_346_3418, Heat Transfer.

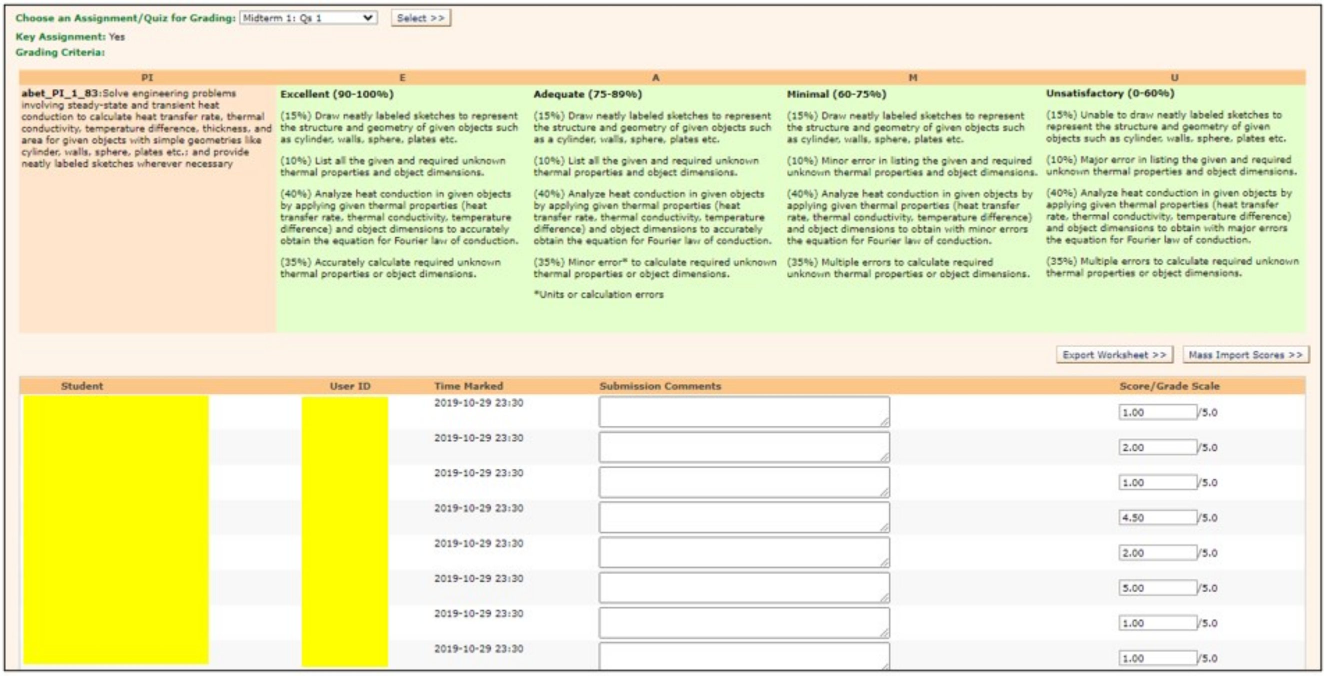


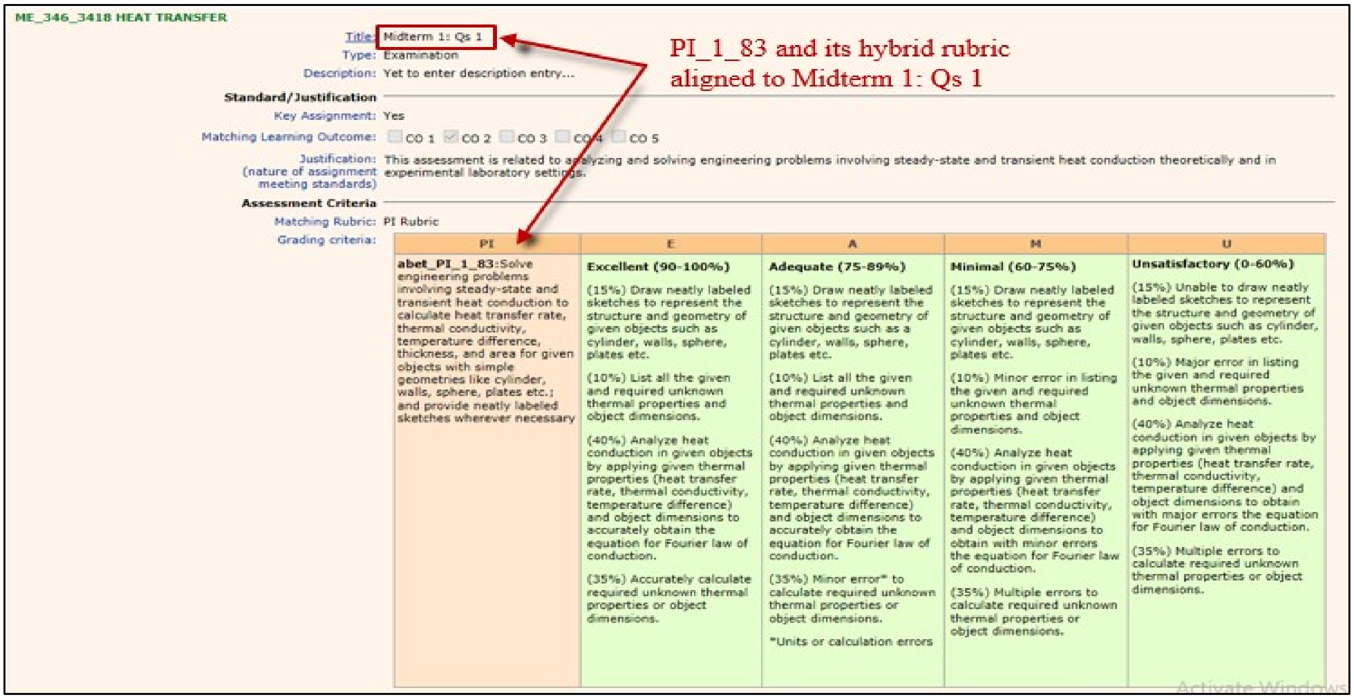
Figure C2. Instructor view for rubrics in grade assignment module

55	**Calculate the steady state voltage, current and average power in an electrical circuit by applying periodic voltage or current as an input forcing function**	**Excellent (90-100%)** **(30%)** Accurately obtain a general output of the circuit using circuit analysis techniques **(70%)** Accurately obtain distinct components of the output using individual inputs to determine steady state response of the circuit	**Adequate (75-89%)** **(30%)** Obtain a general output of the circuit using circuit analysis techniques **with minimal errors** **(70%)** Obtain distinct components of the output using individual inputs to determine steady state response of the circuit **with minimal errors*** *Calculation errors	**Minimal (60-75%)** **(30%)** Obtain a general output of the circuit using circuit analysis techniques **with multiple errors** **(70%)** Obtain distinct components of the output using individual inputs to determine a steady state response of the circuit **with multiple errors*** *Calculation and minor theoretical/conceptual errors	**Unsatisfactory (0-60%)** **(30%) Unable*** to obtain a general output of the circuit using circuit analysis techniques **(70%) Unable*** to obtain individual components of the output using individual inputs to determine a steady state response of the circuit *Theoretical/Conceptual errors
56	**Analyze AM switching, multiplier, non-linear, modulators and demodulators; draw neatly labeled block diagrams of AM modulators clearly indicating all components, input and output signals; obtain required parameters such as local oscillator frequency, image frequency, modulated or demodulated output signal amplitude etc.**	**Excellent (90-100%)** **(50%) Accurately** sketch an adequately labeled block diagram of an AM modulator / demodulator. **(25%) Accurately** describe the working of all the sections (blocks) of an AM modulator / demodulator. **(25%) Accurately** define or identify any unknown parameters.	**Adequate (75-89%)** **(50%)** Sketch an adequately labeled block diagram of an AM modulator / demodulator **with minor errors** **(25%)** Describe the working of all the sections (blocks) of an AM modulator / demodulator **with minor errors** **(25%)** Define or identify any unknown parameters **with minor errors**.	**Minimal (60-75%)** **(50%)** Sketch a labeled block diagram of an AM modulator / demodulator **with several minor errors** **(25%)** Describe the working of all the sections (blocks) of an AM modulator / demodulator **with several minor errors** **(25%)** Define or identify any unknown parameters **with several minor errors**	**Unsatisfactory (0-60%)** **(50%)** Sketch a labeled block diagram of an AM modulator / demodulator **with major errors*** **(25%)** Describe the working of all the sections (blocks) of an AM modulator / demodulator **with major errors*** **(25%)** Define or identify any unknown parameters **with major errors*** *Theoretical/conceptual errors
57	**Analyze FM direct and indirect, modulators and demodulators, PLL based demodulators; draw neatly labeled block diagrams of FM modulators clearly indicating all components, input and output signals; obtain required parameters such as local oscillator frequency, modulated or demodulated output signal frequencies etc.**	**Excellent (90-100%)** **(34%) Accurately** sketch an adequately labeled block diagram of the FM modulator. **(33%) Accurately** sketch the adequately labeled block diagram of the FM demodulator. **(33%) Accurately** derive mathematical expressions that define the modulated FM signal in the time / frequency domain and also derive its β factor.	**Adequate (75-89%)** **(34%)** Sketch an adequately labeled block diagram of the FM modulator **with minor errors** **(33%)** Sketch an adequately labeled block diagram of the FM demodulator **with minor errors** **(33%)** Derive **with minor errors** mathematical expressions that define the modulated FM signal in the time / frequency domain and also derive its β factor	**Minimal (60-75%)** **(34%)** Sketch a labeled block diagram of the FM modulator **with several minor errors** **(33%)** Sketch a labeled block diagram of the FM demodulator **with several minor errors** **(33%)** Derive **with several minor errors** mathematical expressions that define the modulated FM signal in the time / frequency domain and also derive its β factor	**Unsatisfactory (0-60%)** **(34%)** Sketch a labeled block diagram of the FM modulator **with major errors*** **(33%)** Sketch a labeled block diagram of the FM demodulator **with major errors*** **(33%)** Derive **with major errors*** mathematical expressions that define the modulated FM signal in the time / frequency domain and also derive its β factor *Theoretical/conceptual errors

Figure C3. Student view for rubrics in mycourse info – assigments/quiz module

PIs Alignment to Hybrid Rubrics:

PI_1_83 is aligned to its hybrid rubric showing the dimensions, score percentages and performance scales for the EAMU vector. These performance characteristics and corresponding scoring scales are applied to various steps of students' solved work for given engineering problems. Figure C3 shows a student view for the Midterm-1, Qs-1 in *my course info - assignments/quiz* module. Students can align the rubrics to the score marking on their graded exam sheets for verification of accuracy of instructor scoring. Auditors can easily confirm the application of rubrics and scoring system for PI_1_83 in the ME_346_3418, Heat Transfer course by downloading a soft copy of student sample for the Midterm -1.


ME_346_3418 HEAT TRANSFER

Title: Midterm 1: Qs 1
Type: Examination
Description: Yet to enter description entry...

PI_1_83 and its hybrid rubric aligned to Midterm 1: Qs 1

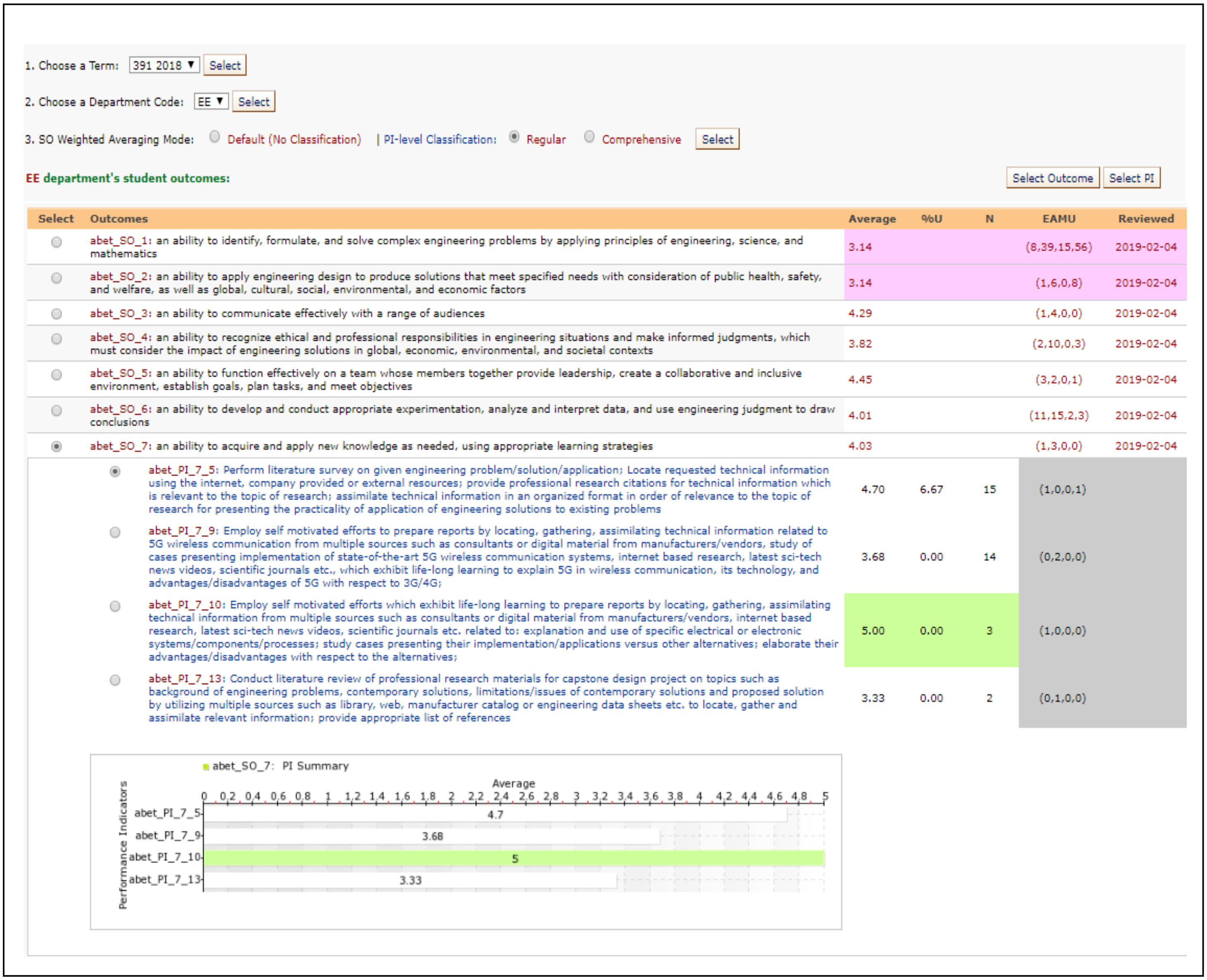
Standard/Justification
Key Assignment: Yes
Matching Learning Outcome: CO 1 CO 2 CO 3 CO 4 CO 5
Justification: (nature of assignment meeting standards) This assessment is related to analyzing and solving engineering problems involving steady-state and transient heat conduction theoretically and in experimental laboratory settings.

Assessment Criteria
Matching Rubric: PI Rubric
Grading criteria:

PI	E	A	M	U
abet_PI_1_83:Solve engineering problems involving steady-state and transient heat conduction to calculate heat transfer rate, thermal conductivity, temperature difference, thickness, and area for given objects with simple geometries like cylinder, walls, sphere, plates etc.; and provide neatly labeled sketches wherever necessary	**Excellent (90-100%)** (15%) Draw neatly labeled sketches to represent the structure and geometry of given objects such as cylinder, walls, sphere, plates etc. (10%) List all the given and required unknown thermal properties and object dimensions. (40%) Analyze heat conduction in given objects by applying given thermal properties (heat transfer rate, thermal conductivity, temperature difference) and object dimensions to accurately obtain the equation for Fourier law of conduction. (35%) Accurately calculate required unknown thermal properties or object dimensions.	**Adequate (75-89%)** (15%) Draw neatly labeled sketches to represent the structure and geometry of given objects such as a cylinder, walls, sphere, plates etc. (10%) List all the given and required unknown thermal properties and object dimensions. (40%) Analyze heat conduction in given objects by applying given thermal properties (heat transfer rate, thermal conductivity, temperature difference) and object dimensions to accurately obtain the equation for Fourier law of conduction. (35%) Minor error* to calculate required unknown thermal properties or object dimensions. *Units or calculation errors	**Minimal (60-75%)** (15%) Draw neatly labeled sketches to represent the structure and geometry of given objects such as cylinder, walls, sphere, plates etc. (10%) Minor error in listing the given and required unknown thermal properties and object dimensions. (40%) Analyze heat conduction in given objects by applying given thermal properties (heat transfer rate, thermal conductivity, temperature difference) and object dimensions to obtain with minor errors the equation for Fourier law of conduction. (35%) Multiple errors to calculate required unknown thermal properties or object dimensions.	**Unsatisfactory (0-60%)** (15%) Unable to draw neatly labeled sketches to represent the structure and geometry of given objects such as cylinder, walls, sphere, plates etc. (10%) Major error in listing the given and required unknown thermal properties and object dimensions. (40%) Analyze heat conduction in given objects by applying given thermal properties (heat transfer rate, thermal conductivity, temperature difference) and object dimensions to obtain with major errors the equation for Fourier law of conduction. (35%) Multiple errors to calculate required unknown thermal properties or object dimensions.

Figure C4. Portion of lists in a digital database showing PIs and their corresponding hybrid rubrics for ABET SO 'e' on problem solving

APPENDIX D: SOs, *PIs and Learning Domains Evaluations*



1. Choose a Term: 391 2018 Select

2. Choose a Department Code: EE Select

3. SO Weighted Averaging Mode: Default (No Classification) | PI-level Classification: Regular Comprehensive Select

EE department's student outcomes: Select Outcome Select PI

Select	Outcomes	Average	%U	N	EAMU	Reviewed
	abet_SO_1: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	3.14			(8,39,15,56)	2019-02-04
	abet_SO_2: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	3.14			(1,6,0,8)	2019-02-04
	abet_SO_3: an ability to communicate effectively with a range of audiences	4.29			(1,4,0,0)	2019-02-04
	abet_SO_4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	3.82			(2,10,0,3)	2019-02-04
	abet_SO_5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	4.45			(3,2,0,1)	2019-02-04
	abet_SO_6: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	4.01			(11,15,2,3)	2019-02-04
	abet_SO_7: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	4.03			(1,3,0,0)	2019-02-04
	abet_PI_7_5: Perform literature survey on given engineering problem/solution/application; Locate requested technical information using the internet, company provided or external resources; provide professional research citations for technical information which is relevant to the topic of research; assimilate technical information in an organized format in order of relevance to the topic of research for presenting the practicality of application of engineering solutions to existing problems	4.70	6.67	15	(1,0,0,1)	
	abet_PI_7_9: Employ self motivated efforts to prepare reports by locating, gathering, assimilating technical information related to 5G wireless communication from multiple sources such as consultants or digital material from manufacturers/vendors, study of cases presenting implementation of state-of-the-art 5G wireless communication systems, internet based research, latest sci-tech news videos, scientific journals etc., which exhibit life-long learning to explain 5G in wireless communication, its technology, and advantages/disadvantages of 5G with respect to 3G/4G;	3.68	0.00	14	(0,2,0,0)	
	abet_PI_7_10: Employ self motivated efforts which exhibit life-long learning to prepare reports by locating, gathering, assimilating technical information from multiple sources such as consultants or digital material from manufacturers/vendors, internet based research, latest sci-tech news videos, scientific journals etc. related to: explanation and use of specific electrical or electronic systems/components/processes; study cases presenting their implementation/applications versus other alternatives; elaborate their advantages/disadvantages with respect to the alternatives;	5.00	0.00	3	(1,0,0,0)	
	abet_PI_7_13: Conduct literature review of professional research materials for capstone design project on topics such as background of engineering problems, contemporary solutions, limitations/issues of contemporary solutions and proposed solution by utilizing multiple sources such as library, web, manufacturer catalog or engineering data sheets etc. to locate, gather and assimilate relevant information; provide appropriate list of references	3.33	0.00	2	(0,1,0,0)	

Figure D1. PIs evaluation snapshot for 7 revised ABET SOs EE program term 391

abet_SO_5 : an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

abet_PI_5_2: Contribute to the overall critical thinking, problem solving process for team project fulfillment

abet_PI_5_4: Complete assigned duties and provide work of high quality to promote team spirit and contribute towards excellent standards of overall fulfillment of objectives of the experimentation

abet_PI_5_8: Contribute actively to prepare the team contract with collaboration of team members and faculty; define conditions of team contract such as general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution; elaborate individual and team member strengths and weaknesses with faculty and colleagues related to definition of team roles; collect and verify CVs appropriately aligned to required roles; submit signed team contract with finalized assignment of team roles

abet_PI_5_10: Communicate effectively with assigned supervisors, team members and other stake holders; listen to given instructions; listen to others in the team and create a supportive team environment; effectively coordinate tasks with other team members; and complete assigned tasks in a timely manner

abet_PI_5_11: Develop the team meeting schedule for fulfillment of various tasks in an engineering project; meet regularly with team members as per meeting schedule; brainstorm, select agenda items, discuss project schedules, implementation, and issues; document meeting minutes; assign action items to team members and follow up for closure.

abet_PI_5_12: Attend assigned company team meetings regularly; observe and document the various aspects of the culture of corporate engineering meetings such as brainstorming, discussion of project schedules, implementation and issues, Documentation of meeting minutes, assignment of action items, their follow up and closure

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_5_2	(2,1,0,0)	4.77	EE_261_1667	DIGITAL LOGIC DESIGN	Introductory	4	2	2	0	3.75
			EE_361_1690	MICROPROCESSORS	Reinforced	3	0	0	0	5
			EE_352_1695	ELECTRICAL POWER SYSTEMS 1	Reinforced	7	2	0	0	4.63
abet_PI_5_4	(2,0,0,0)	5	EE_332_1693	CONTROLS THEORY	Reinforced	2	0	0	0	5
			EE_416_1700	POWER ELECTRONICS	Mastery	5	0	0	0	5
abet_PI_5_8	(3,4,0,0)	4.4	EE_261_1667	DIGITAL LOGIC DESIGN	Introductory	5	3	0	0	4.38
			EE_361_1690	MICROPROCESSORS	Reinforced	3	0	0	0	5
			EE_332_1693	CONTROLS THEORY	Reinforced	2	0	0	0	5
			EE_352_1695	ELECTRICAL POWER SYSTEMS 1	Reinforced	3	6	0	0	3.89
			EE_416_1700	POWER ELECTRONICS	Mastery	3	2	0	0	4.33
			EE_497_2355	SENIOR DESIGN PROJECT 1	Mastery	2	0	0	0	5
			EE_497_2356	SENIOR DESIGN PROJECT 1	Mastery	0	2	0	0	3.33
abet_PI_5_10	(4,0,0,0)	4.91	EE_361_1690	MICROPROCESSORS	Reinforced	3	0	0	0	5
			EE_332_1693	CONTROLS THEORY	Reinforced	2	0	0	0	5
			EE_352_1695	ELECTRICAL POWER SYSTEMS 1	Reinforced	7	2	0	0	4.63
			EE_416_1700	POWER ELECTRONICS	Mastery	5	0	0	0	5
abet_PI_5_11	(0,0,1,0)	1.67	EE_497_2356	SENIOR DESIGN PROJECT 1	Mastery	0	0	2	0	1.67
abet_PI_5_12	(0,1,0,0)	3.75	EE_261_1667	DIGITAL LOGIC DESIGN	Introductory	4	2	2	0	3.75

Overall SO Average: 4.45 EAMU: (3,2,0,1)

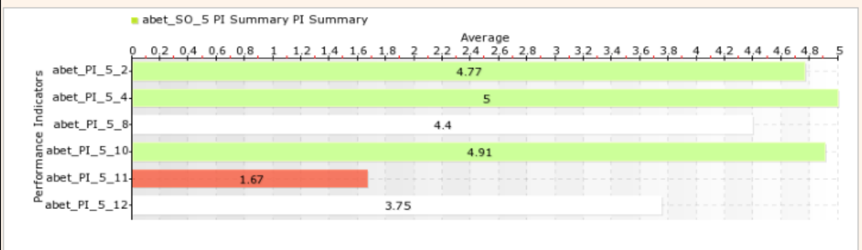


Figure D2. **PIs evaluation module showing composite PIs data collected from multiple courses for assessing EE Program ABET SOs (1-7)**

Term Selected: 391 2018

Department Code: EE

abet_SO_4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

abet_PI_4_7: Explain the professional, ethical responsibilities and safety regulations/standards for electrical engineers while using electrical machines and power system equipment (transformers/DC/AC machines/transmission line modules)

Metric: FCAR reports from the following courses will summarize the necessary evidence in meeting this specific performance indicator.

Item	Course	Title	Level	E	A	M	U	Average
1	EE_352_1695	ELECTRICAL POWER SYSTEMS 1	Reinforced	1	1	0	7	0.93

Overall PI Average: 0.93 %U: 77.78

Classification: **Below Expectations**

Discussion: **Final Exam Q2.1_f:** 6 students out of 9 have failed to explain the professional, ethical responsibilities and safety regulations/standards for electrical engineers while using electrical machines and power system equipment (transformers/DC/AC machines/transmission line modules) when analysing the reactive power compensation in a power system.

Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure

Reviewers: Dr. Hassan Chattha, Dr. Mazhar Ali, Dr. H Abdul Wajid, Dr. Abdul Rahman Al Kassem, Dr. Azzedine Draou, Dr. Amer Canaan, Dr. Khawaja Bilal Mahmood, Dr. Mohsin Jamil, Dr. Muhammed Uzair, Mr. Nathirulla Sheriff, Mr. Mohiuddin, Mr. Arshad K V, Mr. Shujaur Rahman, Mr. Wajid Hussain, Dr. Rayan Al Sisi, Mr. Mohsen Aldaadi, Mr. Naief Almatrafi, Mr. Almutasim Billa Alanazi

Review Date: 2019-02-04

Figure D3. **PIs evaluation module in term 391 (Fall 2018) showing corresponding courses, detailed failure analysis and review for PI_4_7.**

Cognitive Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		SO_8		SO_9		SO_10		SO_11		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced										8						1						11	2.99	20	6.8
	Intermediate										8												3	2.94	11	3.7
	Elementary		17																					2.97	17	5.8
Reinforced	Advanced						13				18												11	2.83	42	14.3
	Intermediate		9								23												22	3	54	18.4
	Elementary		34																					2.46	34	11.6
Introductory	Advanced				3		14				12												7	3.53	36	12.2
	Intermediate		22								52												2	2.64	76	25.9
	Elementary		4																					3.88	4	1.4
																								2.89	294	100.1

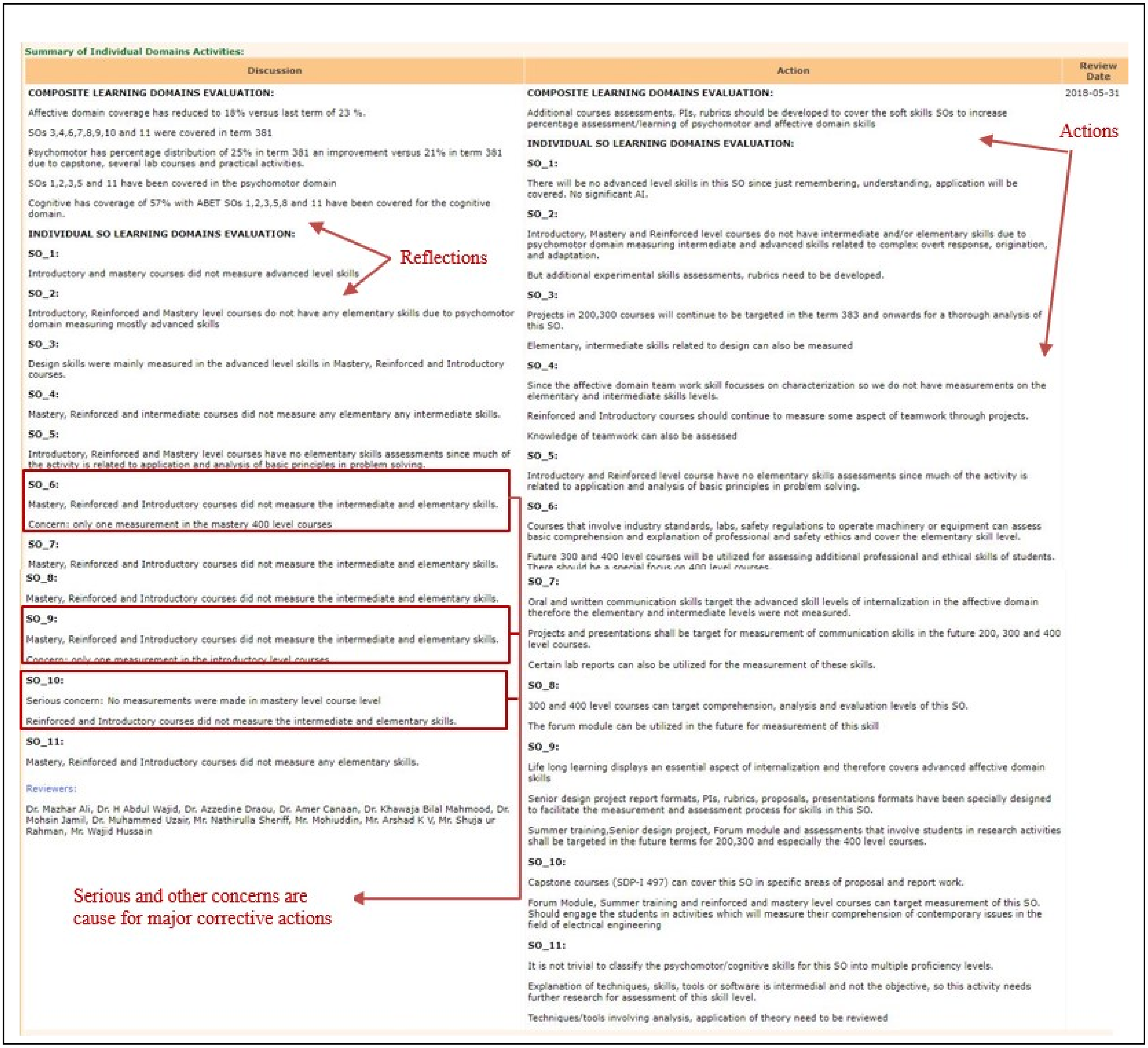
Affective Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		SO_8		SO_9		SO_10		SO_11		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced						5		10				1		8		4		6				4	4.24	38	47.5
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced						1		12				4		5		4		3		3			3.62	32	40
	Intermediate																							0	0	0
	Elementary																							0	0	0
Introductory	Advanced								3				2		2		1		1		1			3.96	10	12.5
	Intermediate																							0	0	0
	Elementary																							0	0	0
																								3.96	80	100

Psychomotor Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		SO_8		SO_9		SO_10		SO_11		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced				11		2				11												3	3.72	27	20.5
	Intermediate																							0	0	0
	Elementary																							0	0	0
Reinforced	Advanced		2		50		1																14	3.68	67	50.8
	Intermediate																							0	0	0
	Elementary																							0	0	0
Introductory	Advanced				31																		1	4.58	32	24.2
	Intermediate				6																			4.24	6	4.5
	Elementary																							0	0	0
																								3.93	132	100

Figure D4. Learning domains evaluation for EE program term 361 showing assessment counts and values for the individual cognitive, affective and psychomotor domains



Summary of Individual Domains Activities:

Discussion	Action	Review Date
COMPOSITE LEARNING DOMAINS EVALUATION:	**COMPOSITE LEARNING DOMAINS EVALUATION:**	2018-05-31
Affective domain coverage has reduced to 18% versus last term of 23 %. SOs 3,4,6,7,8,9,10 and 11 were covered in term 381 Psychomotor has percentage distribution of 25% in term 381 an improvement versus 21% in term 381 due to capstone, several lab courses and practical activities. SOs 1,2,3,5 and 11 have been covered in the psychomotor domain Cognitive has coverage of 57% with ABET SOs 1,2,3,5,8 and 11 have been covered for the cognitive domain.	Additional courses assessments, PIs, rubrics should be developed to cover the soft skills SOs to increase percentage assessment/learning of psychomotor and affective domain skills	
INDIVIDUAL SO LEARNING DOMAINS EVALUATION:	**INDIVIDUAL SO LEARNING DOMAINS EVALUATION:**	
SO_1: Introductory and mastery courses did not measure advanced level skills	**SO_1:** There will be no advanced level skills in this SO since just remembering, understanding, application will be covered. No significant AI.	
SO_2: Introductory, Reinforced and Mastery level courses do not have any elementary skills due to psychomotor domain measuring mostly advanced skills	**SO_2:** Introductory, Mastery and Reinforced level courses do not have intermediate and/or elementary skills due to psychomotor domain measuring intermediate and advanced skills related to complex overt response, origination, and adaptation. But additional experimental skills assessments, rubrics need to be developed.	
SO_3: Design skills were mainly measured in the advanced level skills in Mastery, Reinforced and Introductory courses.	**SO_3:** Projects in 200,300 courses will continue to be targeted in the term 383 and onwards for a thorough analysis of this SO. Elementary, intermediate skills related to design can also be measured	
SO_4: Mastery, Reinforced and intermediate courses did not measure any elementary any intermediate skills.	**SO_4:** Since the affective domain team work skill focusses on characterization so we do not have measurements on the elementary and intermediate skills levels. Reinforced and Introductory courses should continue to measure some aspect of teamwork through projects. Knowledge of teamwork can also be assessed	
SO_5: Introductory, Reinforced and Mastery level courses have no elementary skills assessments since much of the activity is related to application and analysis of basic principles in problem solving.	**SO_5:** Introductory and Reinforced level course have no elementary skills assessments since much of the activity is related to application and analysis of basic principles in problem solving.	
SO_6: Mastery, Reinforced and Introductory courses did not measure the intermediate and elementary skills. Concern: only one measurement in the mastery 400 level courses	**SO_6:** Courses that involve industry standards, labs, safety regulations to operate machinery or equipment can assess basic comprehension and explanation of professional and safety ethics and cover the elementary skill level. Future 300 and 400 level courses will be utilized for assessing additional professional and ethical skills of students. There should be a special focus on 400 level courses.	
SO_7: Mastery, Reinforced and Introductory courses did not measure the intermediate and elementary skills.	**SO_7:** Oral and written communication skills target the advanced skill levels of internalization in the affective domain therefore the elementary and intermediate levels were not measured. Projects and presentations shall be target for measurement of communication skills in the future 200, 300 and 400 level courses. Certain lab reports can also be utilized for the measurement of these skills.	
SO_8: Mastery, Reinforced and Introductory courses did not measure the intermediate and elementary skills.	**SO_8:** 300 and 400 level courses can target comprehension, analysis and evaluation levels of this SO. The forum module can be utilized in the future for measurement of this skill	
SO_9: Mastery, Reinforced and Introductory courses did not measure the intermediate and elementary skills. Concern: only one measurement in the introductory level courses	**SO_9:** Life long learning displays an essential aspect of internalization and therefore covers advanced affective domain skills Senior design project report formats, PIs, rubrics, proposals, presentations formats have been specially designed to facilitate the measurement and assessment process for skills in this SO. Summer training,Senior design project, Forum module and assessments that involve students in research activities shall be targeted in the future terms for 200,300 and especially the 400 level courses.	
SO_10: Serious concern: No measurements were made in mastery level course level Reinforced and Introductory courses did not measure the intermediate and elementary skills.	**SO_10:** Capstone courses (SDP-I 497) can cover this SO in specific areas of proposal and report work. Forum Module, Summer training and reinforced and mastery level courses can target measurement of this SO. Should engage the students in activities which will measure their comprehension of contemporary issues in the field of electrical engineering	
SO_11: Mastery, Reinforced and Introductory courses did not measure any elementary skills.	**SO_11:** It is not trivial to classify the psychomotor/cognitive skills for this SO into multiple proficiency levels. Explanation of techniques, skills, tools or software is intermedial and not the objective, so this activity needs further research for assessment of this skill level. Techniques/tools involving analysis, application of theory need to be reviewed	

Reviewers:

Dr. Mazhar Ali, Dr. H Abdul Wajid, Dr. Azzedine Draou, Dr. Amer Canaan, Dr. Khawaja Bilal Mahmood, Dr. Mohsin Jamil, Dr. Muhammed Uzair, Mr. Nathirulla Sheriff, Mr. Mohiuddin, Mr. Arshad K V, Mr. Shuja ur Rahman, Mr. Wajid Hussain

Figure D5. **Learning domains evaluation 382 term review report showing reflections and actions with concerns for SOs 6, 9 and 10**

APPENDIX E: *SOs, PIs Executive Summary Reports*

Direct Assessment of SOs – A Sample from a Single Term 382 Analysis

In this section, we present the results of direct assessments for a single term as a sample. The section below presents program evaluation conducted in term 382 (Spring 2018) refers to outcomes assessment evaluations for ABET SOs (a-k). Table E1 shows a summary of EE program committee decisions Exceeding, Meeting or Below Expectations for an overall review of ABET SOs (a-k) score results in a program term review term 382 (Spring 2018). Figure E1 shows a composite plot for ABET SOs (a-k) obtained from a EE program term review term 382. The Red, Yellow, Green and White flags have already been explained in Table 5 of *Section IV.D.1* of this paper listing performance criteria.

Table E1. Executive summary report for Term 382 (Spring 2018)

Department: EE

Executive Summary Report for 382 2018

SO	Associated Student Outcomes	Average	Classification
abet_SO_1	an ability to apply knowledge of mathematics, science, and engineering	2.71	Below Expectations
abet_SO_2	an ability to design and conduct experiments, as well as to analyze and interpret data	4.40	Meeting Expectations
abet_SO_3	an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	3.47	Meeting Expectations
abet_SO_4	an ability to function on multidisciplinary teams	4.69	Meeting Expectations
abet_SO_5	an ability to identify, formulate, and solve engineering problems	2.97	Below Expectations
abet_SO_6	an understanding of professional and ethical responsibility	4.29	Meeting Expectations
abet_SO_7	an ability to communicate effectively	4.12	Meeting Expectations
abet_SO_8	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	3.46	Meeting Expectations
abet_SO_9	a recognition of the need for, and an ability to engage in life-long learning	4.23	Meeting Expectations
abet_SO_10	a knowledge of contemporary issues	2.88	Below Expectations
abet_SO_11	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	3.58	Meeting Expectations

Figure 1E. ABET SOs (a-k) composite plot EE program term review term 382 (Spring 2018)*Single-Term 382 Executive Summary Report for ABET SOs (a-k)*

For the sake of brevity, a portion of the single term executive summary report for term 382 is shown below in Table E2 for just SO 'a' (SO_1) on "problem solving". The executive summary report shows summarized notes and actions by attending program faculty members for deficiencies reviewed during the program term review. The overall summary includes a program level decision of whether the ABET SO is Exceeding, Meeting or Below Expectations. Table 5 shown earlier in the *Section IV.D.1* of this paper describes the performance criteria and heuristic rules for resulting final decisions.

Table E2. EE program detailed SO/PI executive summary report for Term 382 (Spring 2018)

Department: EE

Detailed SO/PI Executive Summary Report for 382 2018

SO	Detailed Executive Summary	Average	Classification/ Review Date
abet_SO_1	**abet_SO_1 : Overall Summary** Discussion: 1) Final Exam_Q1; Quiz_1: The students were unable to explain the meaning, symbols and notations associated with various control systems engineering terms and quantities. This is mainly due to the fact that students have weak ability in English language. 2) Final Exam_Q4b: The students were not able to find the steady state error for specific input such as step, ramp and parabolic. This was mainly due to lack of practice. 3) Final Exam_Q3_d: 7 out of 9 students failed to describe the effect of Locational Marginal Price (LMP) in power systems; elaborate on the cost of generation, the incremental losses of the transmission system and the limiting transmission lines; 4) QZ_1; Final Exam_Q1a: The students were unable to explain and implement per unit system properly. 5) Midterm Exam-2 Q2, QZ-3, Final Exam Q3 Some of the student are unable to explain construction of different memories and their port address decoding 6) Midterm Exam2_Q2: The students were unable to describe the construction and operation of the induction motor. This is mainly due to less focus This is mainly due to less focus and week technical explanation skills on the subject topics.	2.71	Below Expectations

	on the subject topics. 7) Midterm Exam-2: Q3-Q4: Some of the students were unable to answer the questions related to the characterization of the given FM signals/system in the time and frequency domains. Some of them were unable to either draw the labelled block diagram or calculate the FM signal bandwidth using the normal method and Bessel table method. 8) QZ-1, Final Exam_Q1(b): Students are unable to Represent diagrammatically complex exponential and sinusoidal forms of continuous-time and discrete-time signals. 9) Midterm Exam 2, Q3: Most of the students could not explain the reason for the use of transformer based switch mode power converters. Reviewers: Dr. HC, Dr. M, Dr. HAW, Dr. AD, Dr. AC, Dr. KBM, Dr. MU, Dr. AWM, Mr. NS, Mr. M, Mr. AKV, Mr. SR, Mr. WH		
	abet_PI_1_103: Discussion: Final Exam_Q1; Quiz_1: The students were unable to explain the meaning, symbols and notations associated with various control systems engineering terms and quantities. This is mainly due to the fact that students have weak ability in English language. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	2.00	Below Expectations
	abet_PI_1_104: Discussion: Final Exam_Q4b: The students were not able to find the steady state error for specific input such as step, ramp and parabolic. This was mainly due to lack of practice. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	1.33	Below Expectations
	abet_PI_1_109: Discussion: QZ-4: Only 2 out of 9 students failed to describe (using bus and branch graph) solutions to potential generation unit failure and compensation using spinning reserve Final_Exam_Q3_b: Only 1 out of 9 students failed to describe (using bus and branch graph) solutions to potential generation unit failure and compensation using spinning reserve Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	2.22	Below Expectations
	abet_PI_1_110: Discussion: Final Exam_Q3_d: 7 out of 9 students failed to describe the effect of Locational Marginal Price (LMP) in power systems; elaborate on the cost of generation, the incremental losses of the transmission system and the limiting transmission lines; Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	0.74	Below Expectations
	abet_PI_1_13: Discussion: QZ_1; Final Exam_Q1a: The students were unable to explain and implement per unit system properly. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this	0.83	Below Expectations

	failure Review Date: 2018-05-31		
	abet_PI_1_29: Discussion: Midterm Exam-2 Q2, QZ-3, Final Exam Q3 Some of the student are unable to explain construction of different memories and their port address decoding Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	1.39	Below Expectations
	abet_PI_1_53: Discussion: Midterm QZ1 Some of the students are not able to describe the architecture of 8086 processor, its internal units and their functionality. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	2.92	Below Expectations
	abet_PI_1_60: Discussion: Midterm Exam-1_Q-3: The students were unable to describe construction and operation of synchronous motor/generators properly. This is mainly due to less focus on the subject topics. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	2.17	Below Expectations
	abet_PI_1_61: Discussion: Midterm Exam2_Q2 :The students were unable to describe the construction and operation of the induction motor. This is mainly due to less focus This is mainly due to less focus and week technical explanation skills on the subject topics. on the subject topics. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	1.50	Below Expectations
	abet_PI_1_63: Discussion: Final Exam; Q3: Some students were unable to apply the concepts of curl in the analysis of electromagnetic fields. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	2.78	Below Expectations
	abet_PI_1_78: Discussion: Midterm Exam-2: Q3-Q4: Some of the students were unable to answer the questions related to the characterization of the given FM signals/system in the time and frequency domains. Some of them were unable to either draw the labelled block diagram or calculate the FM signal bandwidth using the normal method and Bessel table method. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this	2.08	Below Expectations

	failure Review Date: 2018-05-31		
	abet_PI_1_80: Discussion: QZ-1, Final Exam_Q1(b): Students are unable to Represent diagrammatically complex exponential and sinusoidal forms of continuous-time and discrete-time signals. Action: FCAR AIs were reviewed for examining the possible solutions for improvement of this failure Review Date: 2018-05-31	1.67	Below Expectations

SO/PI PVT ABET SOs (a-k) Summary Report for Term 382 (SS 2018)

The SO/PI PVT Summary Report shown in Table E3 shows a sample portion of a complete report for just one ABET SO ‘h’ (SO_8). A list of PIs assessed for the SO ‘h’ are shown along with the corresponding courses, EAMU scales and scores. Figure E2 shows a composite plot for all PIs assessed for ABET SO ‘h’ (SO_8) term 382.

Table E3. SO/PI PVT summary report for ABET SO ‘H’ (SO_8) Term 382

abet_SO_8: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

abet_PI_8_4: Examine environmental/economic tradeoffs, health and safety/economic tradeoffs of an engineering design of prototype

abet_PI_8_10: Explain the application of state space and digital control in modern control systems; elaborate on the advantages and limitations of state space applications with perspective of their impact in societal, health and safety, economic, environmental and sustainability context.

abet_PI_8_15: Study the impact of various engineering solutions to minimize environmental pollution caused by contemporary power generation system/plants

abet_PI_8_16: Examine the impact of communication systems to environment and society

abet_PI_8_19: Compare the types of services and functionality, level of infrastructure, hardware cost, carrier frequency, and complexity required for the subscriber segment and base station segment of given mobile communication systems.

abet_PI_8_21: Explain first (1G), second (2G), third (3G) generations of wireless networks, the modifications in technology, supporting standards, advantages and applications

abet_PI_8_23: Describe equalization, diversity, and channel coding; provide the reasons how these techniques improve signal quality; their supporting systems, advantages and applications

abet_PI_8_24: Evaluate the economic feasibility of manufacturing, implementation, operation and commercialization of the final design; detail the development costs, operational costs (operation and maintenance), non-recurring capital investment costs (site and facility, hardware purchase, software purchase), recurring costs (raw materials, utilities, skilled and non-skilled labor, consumables); show cost reduction (one-time purchase of less expensive hardware, lower one-time license fee), value enhancement (reduction of resource requirements, improved storage and retrieval techniques; improved resource utilization, reduced error rates), labor cost reduction, decreased overhead costs; present total benefit over estimated lifetime and the payback period

abet_PI_8_25: Evaluate the environmental impact of the manufacturing/implementation/operation phases of the final design related to toxic emissions into the atmosphere, nuclear radiations, emission of high power electromagnetic radiations, exposure to RF and microwave signals, biological contaminations, deforestation, disposal/reuse of hazardous waste material, pollution of natural resources contributing towards global warming, ozone layer depletion and ecological disturbance etc.; to conform to the minimum acceptable limits set by the national/international codes/standards and regulations.

abet_PI_8_26: Evaluate the societal impact of manufacturing/implementation/operation phases of the final design on cultural: sites/monuments of archeological/religious significance; economic: effect on employment conditions; political: societal divisions based on public interest due to harms or benefits of engineering solutions; and living conditions: shift in regional demographics, change in living and behavioral conditions due to technological influence

abet_PI_8_27: Evaluate the final design for sustainability related to (a) environment: preserve biodiversity, maintain and preserve ecosystem with respect to resource development and waste assimilation; implement pollution control; integrate environmental impact assessment tools; prioritize renewable energy sources over non renewable energy sources; employ green technology; Ensure all input, output resources, fuels, materials and consumables are safe and benign to environment and life; (b) society: offer equal opportunity to all sections of community; involve stakeholder respecting local culture and religious sentiment; (c) economy: implement value enhancement, cost reduction; allocate benefits and costs of economic activity equitably; implement shorter payback period with higher benefit to cost ratio in the life time of the project

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_8_4	(1,1,0,0)	4.99	EE_201_2232	CIRCUIT THEORY 1	Introductory	8	4	0	0	4.44
			EE_416_2266	POWER ELECTRONICS	Mastery	4	0	0	0	5
abet_PI_8_10	(0,0,0,1)	2.33	EE_332_2264	CONTROLS THEORY	Reinforced	1	1	2	1	2.33
abet_PI_8_15	(1,0,0,0)	4.72	EE_352_2245	ELECTRICAL POWER SYSTEMS 1	Reinforced	5	1	0	0	4.72
abet_PI_8_16	(0,0,1,0)	1.67	EE_322_2247	COMMUNICATIONS THEORY	Reinforced	0	0	4	0	1.67
abet_PI_8_19	(0,0,0,1)	2.22	EE_421_2250	WIRELESS AND MOBILE COMMUNICATIONS	Mastery	2	3	0	4	2.22
abet_PI_8_21	(0,0,0,1)	0.74	EE_421_2250	WIRELESS AND MOBILE COMMUNICATIONS	Mastery	0	0	4	5	0.74
abet_PI_8_23	(0,0,0,1)	2.22	EE_421_2250	WIRELESS AND MOBILE COMMUNICATIONS	Mastery	2	1	4	2	2.22
abet_PI_8_24	(1,0,0,0)	4.87	EE_498_2459	SENIOR DESIGN PROJECT II	Mastery	12	1	0	0	4.87
abet_PI_8_25	(0,1,0,0)	4.1	EE_498_2459	SENIOR DESIGN PROJECT II	Mastery	6	7	0	0	4.1
abet_PI_8_26	(0,1,0,0)	4.1	EE_498_2459	SENIOR DESIGN PROJECT II	Mastery	7	5	1	0	4.1
abet_PI_8_27	(1,0,0,0)	4.74	EE_498_2459	SENIOR DESIGN PROJECT II	Mastery	11	2	0	0	4.74

Overall SO Average: 3.46 EAMU: (4,2,0,5)

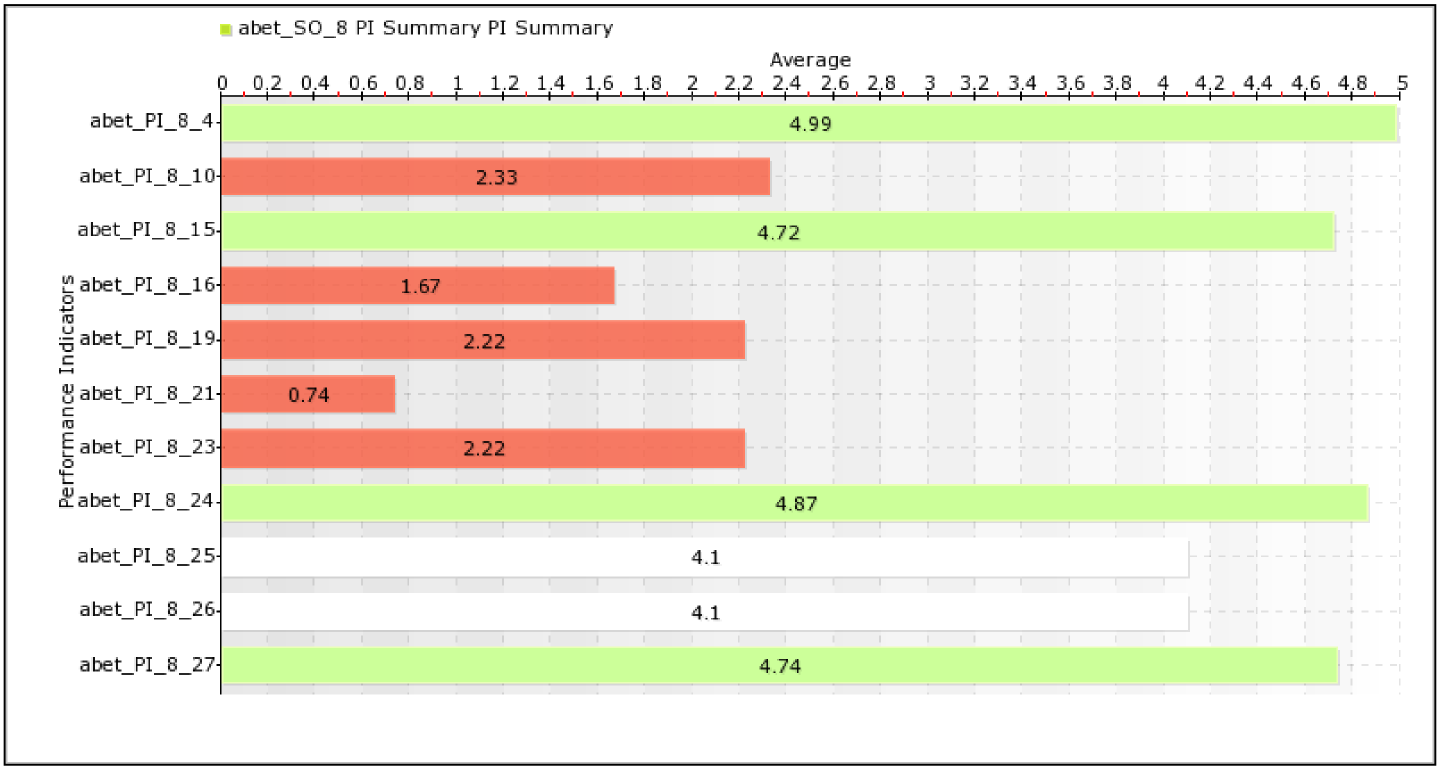


Figure E2. PIs Plot for ABET SO 'h' (SO_8) Term 382 (SS 2018)

Course Reflections/Action Items Summary Report for Term 382 (Spring 2018)

In this section, as shown in Table E4, we provide samples of course reflections and AIs for EE_447_2265 Power Systems Operation and Control and EE_201_2232 Circuit Theory 1. Faculty members document reflections for failures followed with AIs for remediation and CQI. The key point to note is that the course reflections and action items maintain headings related to format CO_N1; PI_N2_N3; SO_N2; where N1: CO index; N2: ABET SO index (1 being 'a' and 11 being 'k'); and N3: PI index. Additionally, course reflections have to also mention the failing assessments in abbreviated form. Faculty members document reflections and AIs related to valid course exit survey feedback collected from students at the end of every term.

Table E4. Course reflections/AIs summary report for EE_447 Power Systems Operation and Control and EE_201 Circuit Theory 1, TERM 382 (SS 2018)

Department: EE

Course Reflections/Action Items Summary Report for 382 2018

Course	Reflection	Action Items
EE_447_2265 Power Systems Operation And Control	CO 1 ;PI 1 107:SO 1 Final Exam_Q1: Only 1 out of 9 students failed to describe the model and characteristics of a typical thermal plant, such as steam units with the various components involved using properly labelled block diagrams; elaborate on the characteristics of steam units such as heat input to the unit (MBtu/h), Fuel cost per hour input to the unit for fuel; Draw and explain incremental heat (cost) rate, net heat rate characteristics etc.	• CO 1; PI_1_107:SO 1: The failure rate is minimal 1/9. Still, absenteeism is a real problem. Students tend to miss/skip classes at the end of the term. We recommend discouraging the students from being absent in order to grasp most of the in-class discussions.

	CO 3;PI_1_110;SO 1 Final Exam_Q3_d: 7 out of 9 students failed to describe the effect of Locational Marginal Price (LMP) in power systems; elaborate on the cost of generation, the incremental losses of the transmission system and the limiting transmission lines; CO 3;PI_11_103; SO 11 Final Exam_Q2_b: Only 2 out of 9 students failed to solve given power flow problems by using power flow algorithms to calculate real, reactive power flows and losses on a transmission network CO 4;PI_11_99; SO 11 Final Exam_Q3_e: Only 3 out of 9 students failed to solve unit commitment problems for thermal units (with or without considering network losses) by using Priority Lists; tabulate various combinations of generated power in steps; determine the total cost for each valid combination; choose the optimal operating point according to the constraints and total cost CO 6; PI_1_109; SO 1 QZ-4: Only 2 out of 9 students failed to describe (using bus and branch graph) solutions to potential generation unit failure and compensation using spinning reserve Final_Exam_Q3_b: Only 1 out of 9 students failed to describe (using bus and branch graph) solutions to potential generation unit failure and compensation using spinning reserve CO 7;PI_11_44; SO 11 Final Exam_Q3_f: 6 out of 9 students failed to solve given power flow problems by using power flow algorithms to calculate real, reactive power flows and losses on a transmission network. CO 8;PI_7_18: SO 7 Term paper: Only 3 out of 9 students failed to write complete technical course project reports following appropriate standards, format and style with: title, front matter, list of tables and contents; details of overall organization of the report; proper English(grammar/spelling/sentence structure); neatly labeled sketches/diagrams; abstract/introduction; adequate technical content of problem definition; properly assimilated and relevant literature review; design specifications: customer requirements or constraints; design methodology: concepts development, concepts selection and evaluation; manufacturability: scope, planning, budget, deliverables; detailed design analysis: fulfillment of constraints; conclusion, references, appendices etc. Survey feedback The impression of the students was positive about this course as indicated by the results of the exit survey. No special remarks were noted.	• CO 3; PI_1_110; SO 1: Absenteeism is a real problem. Students tend to miss/skip classes at the end of the term. We recommend discouraging the students from being absent in order to grasp most of the in-class discussions. • CO 3;PI_11_103; SO 11 Students are discouraged to be absent during the last quarter of the term in order not to miss some important knowledge about the topic of this assessment. • CO 4;PI_11_99; SO 11 Students are discouraged to be absent during the last quarter of the term in order not to miss some important knowledge about the topic of this assessment. • CO 6; PI_1_109; SO 1 Though the failure rate is minimal, absenteeism is a real problem. Students tend to miss/skip classes at the end of the term. We recommend discouraging the students from being absent in order to grasp most of the in-class discussions. • CO 7;PI_11_44; SO 11 Students are encouraged to review the prerequisite material of power systems I. • CO 8;PI_7_18: SO 7 A discussion session about the correct formatting and contents of a term paper may be helpful to the students. Owner: , Closing date: 391, 2018
EE_201_2232 Circuit Theory 1	CO_1; PI_1_92; SO_1: Final Exam_Q1: Students performance was not	• CO_1; PI_1_92; SO_1: Extra focus should be given to students in the prerequisite course of

	satisfactory and failed to calculate the power for a given system CO_6; PI_5_5; SO_5: Final Exam_Q2: Students failed to analyze the circuit using node voltage method CO_7; PI_5_39; SO_5: Quiz-3: Students failed to explain and analyze the operational amplifier CO_8; PI_5_7; SO_5: Midterm Exam-2_Q1: Students were not able to define the time constants, and measure its value. CO_9;PI_5_7; SO_5: Quiz 4; Midterm Exam-2_Q3; Final Exam_Q4: Students were not able to analyse first-order (RL and RC) & second-order (RLC) circuits to determine the natural & step responses, i.e., current and voltages inside the circuit. CO_9; PI_6_2; SO_6: Final Exam_Q5: Students were not able to find out the natural response of RL circuit CO_10;PI_5_7; SO_5: Final Exam_Q3;Midterm Exam-2_Q2: Students were not able to find analyse first-order (RL and RC) circuits containing self and mutual inductance using mesh current methods. Survey Feed Back The students' comments are not precise and specific, i.e. It takes too much effort; Material is too much. It is difficult to extract any meaningful action from the comments.	physics, i.e., examples of charge, current, voltage, and power • CO_6; PI_5_5; SO_5: More examples should be solved in the class room. Students must be encouraged to do the homework by themselves and practice problems. • CO_7; PI_5_39; SO_5: Extra tutorials should be arranged, and more problems must be solve in the class. • CO_8; PI_5_7; SO_5: More examples should be solved in the class room, and extra tutorials should be arranged. Students must be encouraged to read theory. • CO_9; PI_5_7; SO_5: Students must be encouraged to read theory, practice problems, and to solve homework by themselves. More examples should be solved in the class rooms • CO_10; PI_5_7; SO_5: More examples should be solved in the class room. Students must be encouraged to do the homework by themselves and practice problems • CO_9; PI_6_2; SO_6: Students must be encouraged to attend classes regularly at the end of the semester, and practice more problems. More examples should be solved in the class rooms • Survey Feed Back: Students should be advised that how to write a well-focused, and precise feedback. Owner: Closing date: 391, 2018

APPENDIX F: *Academic Advising Based on Outcomes*

Current Term: 383 2018
Department: CE
Student: 331000673: WAEL, SULTAN
Student Outcome: abet_SO_8: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

PI List:

abet_PI_8_12: Identify the rights and obligations of concerned parties
abet_PI_8_13: Compare the different stages involved in project construction, planning, management and bidding processes
abet_PI_8_15: Explain bridge engineering: its impact on Transportation Systems (people factor) and their various types such as Stone Arch Bridges Wooden Bridges, Metal Truss Bridges Suspension Bridges Metal Arch Bridges Reinforced Concrete Bridges, Girder Bridges: explain their brief history, their advantages and disadvantages
abet_PI_8_16: Summarize the need for effective large scale inland transport specifically mentioning factors such as customer, operator, overall planning, route requirements, environmental etc. discuss historical background of inland transport whenever necessary.
abet_PI_8_18: Discuss the various types of rails (double headed, bull headed and flat footed rail): discuss their merits and de merits; the requirements for an ideal rail section; rail wear and tear (deformation); provide diagrams when necessary
abet_PI_8_20: Explain functions and requirements of sleepers; types of sleepers (timber, concrete prestressed, twin block, steel); discuss their merits and demerits
abet_PI_8_21: Discuss importance of railway signalling; modern signalling principles; point operation, locking and detection; interlocking; minimum headways; home and distant signals; subsidiary signals; two, three and four aspect signalling;
abet_PI_8_25: Relate the use of Bernoulli Equation and the Continuity Equation to real life situations.
abet_PI_8_30: Explain various lateral load resisting systems (Moment resisting frames, concentric, eccentric and chevron bracing etc.), detailing the application and benefits of each type with the help of sketches wherever necessary
abet_PI_8_32: Evaluate the environmental impact of the manufacturing/implementation/operation phases of the final design related to toxic emissions into the atmosphere, nuclear radiations, biological contaminations, deforestation, disposal/reuse of hazardous waste material, pollution of natural resources contributing towards global warming, ozone layer depletion and ecological disturbance etc.; to conform to the minimum acceptable limits set by the national/international codes/standards and regulations
abet_PI_8_33: Evaluate the societal impact of manufacturing/implementation/operation phases of the final design on cultural: sites/monuments of archeological/religious significance; economic: effect on employment conditions; political: societal divisions based on public interest due to harms or benefits of engineering solutions; and living conditions: shift in regional demographics, change in living and behavioral conditions due to technological influence
abet_PI_8_34: Evaluate the final design for sustainability related to (a) environment: preserve biodiversity, maintain and preserve ecosystem with respect to resource development and waste assimilation; implement pollution control; integrate environmental impact assessment tools; prioritize renewable energy sources over non renewable energy sources; employ green technology; Ensure all input, output resources, fuels, materials and consumables are safe and benign to environment and life; (b) society: offer equal opportunity to all sections of community; involve stakeholder respecting local culture and religious sentiment; (c) economy: implement value enhancement, cost reduction; allocate benefits and costs of economic activity equitably; implement shorter payback period with higher benefit to cost ratio in the life time of the project

Performance Indicator	PI Average	Term	Course	EAMU	Average (%)
abet_PI_8_12	90.4	372 2017	CE 482 890 CONTRACTS AND CONSTRUCTION ENGINEERING	(2,0,0,0)	90.4
abet_PI_8_13	86	372 2017	CE 482 890 CONTRACTS AND CONSTRUCTION ENGINEERING	(0,1,0,0)	86
abet_PI_8_15	84.91	371 2016	CE 415 3031 BRIDEG ENGINEERING	(1,1,0,0)	84.91
abet_PI_8_16	45	371 2016	CE 444 3030 RAILWAY ENGINEERING	(0,0,0,1)	45
abet_PI_8_18	100	371 2016	CE 444 3030 RAILWAY ENGINEERING	(1,0,0,0)	100
abet_PI_8_20	92	371 2016	CE 444 3030 RAILWAY ENGINEERING	(1,1,0,0)	92
abet_PI_8_21	100	371 2016	CE 444 3030 RAILWAY ENGINEERING	(2,0,0,0)	100
abet_PI_8_25	50	361 2015	CE 351 378 FLUID MECHANICS	(0,0,0,1)	50
abet_PI_8_30	90	372 2017	CE 417 887 STEEL STRUCTURES DESIGN	(1,0,0,0)	90
abet_PI_8_32	90.53	372 2017	CE 498 891 SENIOR DESIGN PROJECT II	(2,0,0,0)	90.53
			Assignment: Detailed Analysis Part1 (Progress Report)- Part 2 — EAMU: E, WF: 3, Score: 36/40		
			Assignment: Detailed Analysis Part 2 (Progress Report)- Part 1- Environmental impact — EAMU: E, WF: 1.75, Score: 32/35		
abet_PI_8_33	91.43	372 2017	CE 498 891 SENIOR DESIGN PROJECT II	(1,0,0,0)	91.43
abet_PI_8_34	86.67	372 2017	CE 498 891 SENIOR DESIGN PROJECT II	(0,1,0,0)	86.67

Overall SO Average: 83.91%

Figure F1. Individual student's ABET SOs composite skills data measured in multiple courses, types of assessments, terms and applying weighting factors WFs

Student Id : [redacted]
Student Name : [redacted]
Academic Standing : JUNIOR

Existing notes/comments:

Date	Purpose	Note/Comment	Related Document
2017-12-06	Advising	✔ **Viewed by student** Student met with Advisor [redacted] in advisor's office continuously for than 2 hours and 15 minutes from 2:00 to 4: 15 PM on Wednesday December 6th 2017. He has a special case because he transferred from a different college and he has withdrawn from the university in the past for to semesters. We made a plan to try to accommodate his situations. He needs a total of 15 terms to finish. He still requires 4 semesters to graduate. We distributed the 69 credit hours he needs to graduate into the coming 4 semesters. submitted by: [redacted]	[redacted]_4Dec2017_1.pdf Download Degree_Plan_35x_dated_Oct2017.pdf Download Academic_plan[redacted]ec2017.pdf Download
2017-12-04	Advising	✔ **Viewed by student** Uploading academic transcripts as of 4 Dec 2107. From edugate.edu site submitted by: [redacted]	[redacted]transcripts_4Dec2017.pdf Download
2017-12-04	Advising	✔ **Viewed by student** Student came to [redacted] office his advisor at 11 AM on 4 December 2017. He brought a clear academic transcripts. an appointment was set for Wednesday 6 Dec 2017 to complete the full academic plan for the student. submitted by: [redacted]	
2017-11-28	Advising	✔ **Viewed by student** The student met with advisor [redacted] on Tuesday 28th November 2017 from 1 to 1:30 pm at advisor's office. The purose was to go over his academic progress and to fill in the academic form for all of his studies. He brought his academic transcripts with him but this printout does not show full code numbers. Therefore it was not possible to assess his progress and make future academic plan. [redacted] tried to access student's academic transcripts but he discovered that the academic transcripts appearing in Evaltools are totally incorrect and it has many omissions and it was useless. [redacted] requested the student to obtain academic transcripts with full course codes and return to [redacted] as soon as possible. submitted by: [redacted]	
2017-01-04	Advising	✖ **Viewed by student** Apart from the Lab work, SO2, SO4, and SO6, his performance is poor in all the SOs and PIs. He is adviced to focus on the courses which make the basis and pre-requeisite for the upcoming senior level courses. **submitted by:** [redacted]	

Figure F2. **Sample of student advising electronic documentation using advising module of EvalTools® 6**

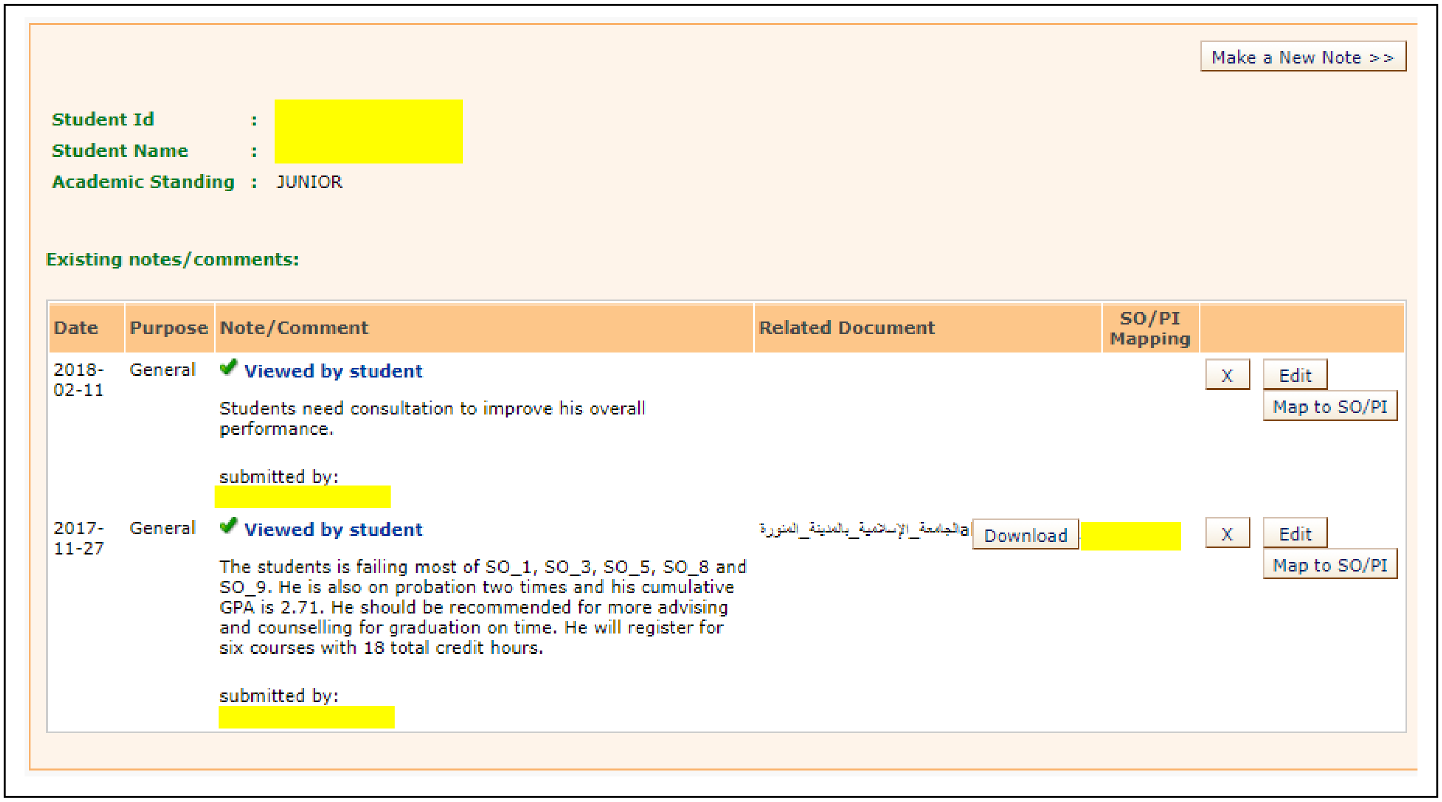


Figure F3. Sample of advising based on outcomes initiated in fall of year 2017

APPENDIX G: *CIMS*

Mechanical Engineering (ME) Committee Meeting Minutes

Meeting Code: ME:MTG:2018-01-23:V43

Location:

Meeting Schedule:

Attended:

Excused: -

Absent: -

1: Brainstorming (BRAINSTORMING)

1. Course Reflections & AIs for the last semester_381
2. Syllabus and course info as in EvalTool for the current semester (Term 381).
3. Approval and finalization of the SO assessment plant for the current semester.
4. Course Allocation in case of Dr. Suhail Kazi not reporting for the current semester (382)
5. Review of Pre-Requisites to all the ME Courses
6. Recruitment of two of best ex-students of the department
7. Renewal of contract for Two Senior non-Saudi Faculty members

2: Agenda Items (AGENDA ITEMS)

1. Course Reflections & AIs for the last semester_381
2. Syllabus and course info as p in EvalTool for the current semester (Term 381).
3. Approval and finalization of the SO assessment plant for the current semester.
4. Course Allocation in case of Dr. Suhail Kazi not reporting for the current semester (382)
5. Review of Pre-Requisites to all the ME Courses
6. Recruitment of two of best ex-students of the department
7. Renewal of contract for Two Senior non-Saudi Faculty members

3: Reflections & AIs for the last semester_381 (ABET)

Discussion:

It was discussed that Completion of all the requisites related to all the courses in EvalTool for the previous semester (Term 381), including reflection and action items to be prepared for the end of term review by 5th Feb 2018.

Proposed Solution:

All the faculty members are asked to complete all the Evaltools related activities associated to Term 381 by Thursday, 25th Jan 2018.

4: Syllabi and Course Info for Semester 382 (ABET)

Discussion:

The faculty members discussed the Syllabi, course info and lecture plans as per ABET to be completed in EvalTool for the current semester (Term 382). It was also mentioned that the course allocation and login are not ready on the evaltools for the 382 courses yet.

Proposed Solution:

The faculty members are asked to keep the Syllabi, course info and lecture plans as per ABET to be made available on EvalTool as soon as the access to allocated courses is made available on the evaltools.

5: SO assessment plant for the current semester (382). (ABET)

Discussion:

D n proposed the use of Term Papers to cover less covered SOs like SO_4,6,7 & 9. Missing SOs may be accommodated though minor reshuffles in the SO assessment structure.

6: Course Allocation in case of D i not reporting for the current semester (382) (FACULTY WORK LOAD)

Discussion:

It was informed that Dr may not report to the faculty in the current semester and the load distribution is affected by it. The possibility of withdrawing Dr. from the chairmanship of the Extra Curricular Activities committee to be able to teach three courses was discussed.

Proposed Solutions:

- A request is to be made to the Deans Office about withdrawing Dr. from the chairmanship of the Extra Curricular Activities committee for him to be able to teach three courses.
- Dr. may share the course ME 323 Mechanics of Machines with another Lecturer.

7: Review of Pre-Requistes to the ME Courses (CURRICULUM DEVELOPMENT)

Discussion:

The core courses in the ME Curriculum was discussed among the faculty members and following recommendations were made:

- Material Science ME 211: Math 102 is to be removed as a pre-requisite.
- Probability and Statistics for Engineers: ENGR 202: MATH 102 may be reviewed as a pre-requisite and a Maths course with related content (statistics) may replace it.
- Fluid Mechanics ME 375: PHYS 102 is to be reviewed as a Pre-requisite in consultation with Dr. Mazhar Ali.
- Summer Training ME 390: New Pre-requisite condition [Yet to be discussed in detail]

8: Recruitment of two of best ex students of the department

- Based on the recommendation of the recruiting committee of the University No. 22 and dated 6/4/1439 H recommending the designation of the Engine i to the post of Assistant in the Department of Mechanical Engineering, the council of the department has approved the designation of the Eng .
- Based on the recommendation of the recruiting committee of the University No. 22 and dated 6/4/1439 H recommending the designation of the Enginee to the post of Assistant in the Department of Mechanical Engineering, the council of the department has approved the designation of the Eng f.

9: Renewal of contract for Two Senior non Saudi Faculty members

Discussion:

Renewal of contract for non-Saudi Faculty members having reached the age of 60 or having gone beyond 10 years of service in IUM from the next academic year 1439/1440 H.

Decision:

The council of the Department of Mechanical Engineering gives its approval for the extension of the contract for the next academic year 2018/2019 for Prof. .

The council of the Department of Mechanical Engineering gives its approval for the extension of the contract for the next academic year 2018/2019 for Prof.

Figure G1. ME Meeting sample window in EvalTools ®

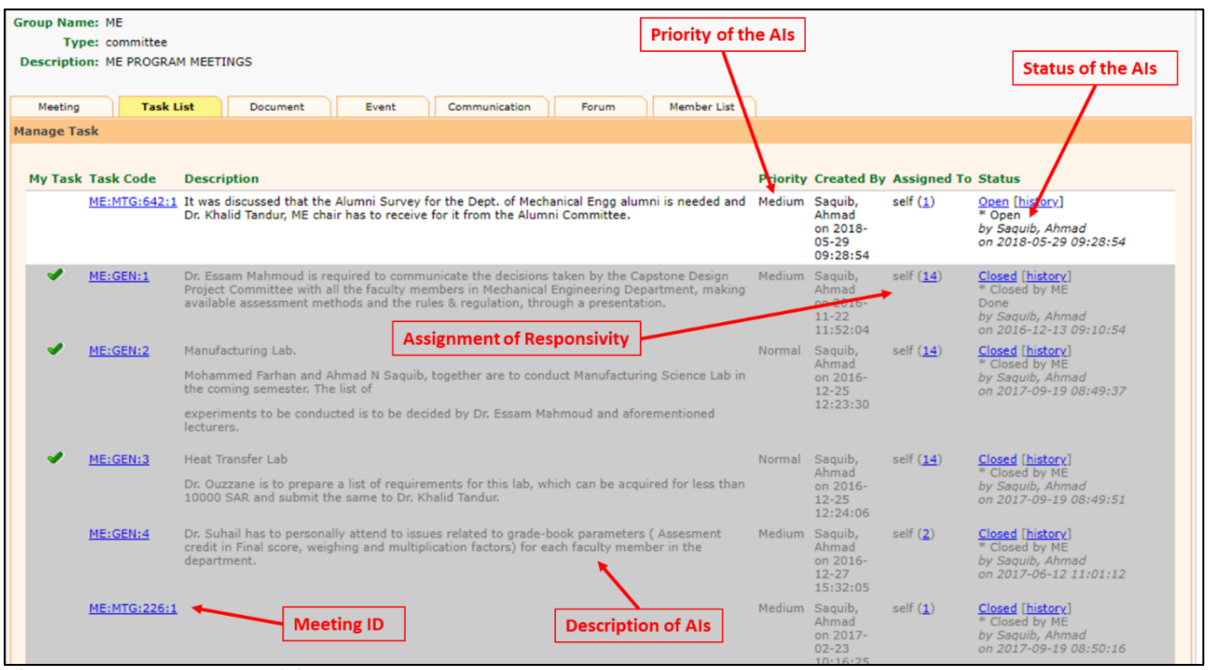


Figure G2. Sample window in EvalTools ® for ME program committee tasks' list indicating meeting ID, description, responsibility, priority and status of AIs

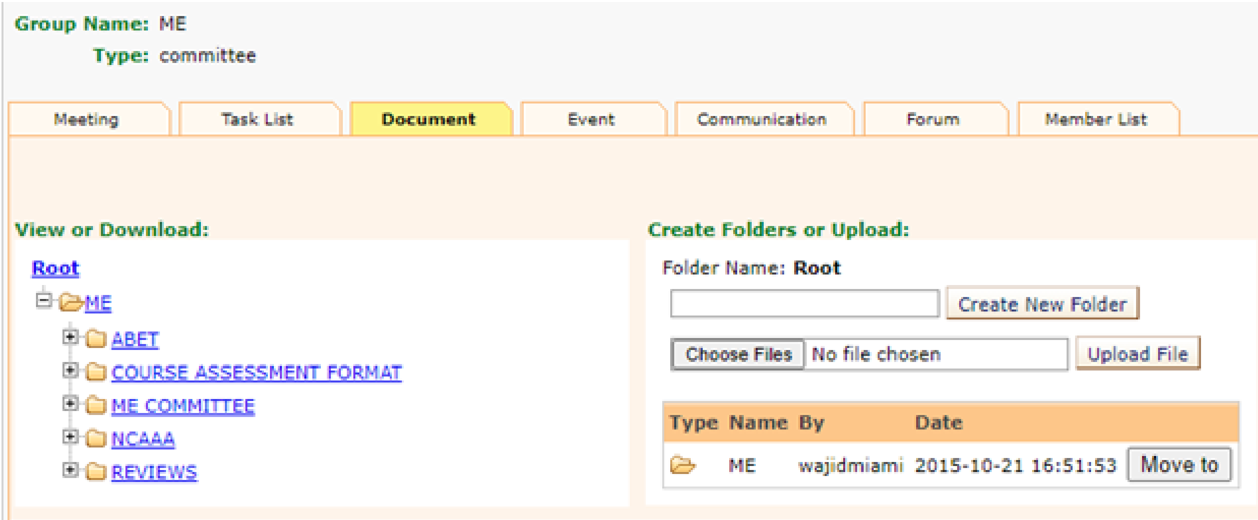


Figure G3. ME program committee folder documentation

Figure G4. ME program's ABET folder in EvalTools ®

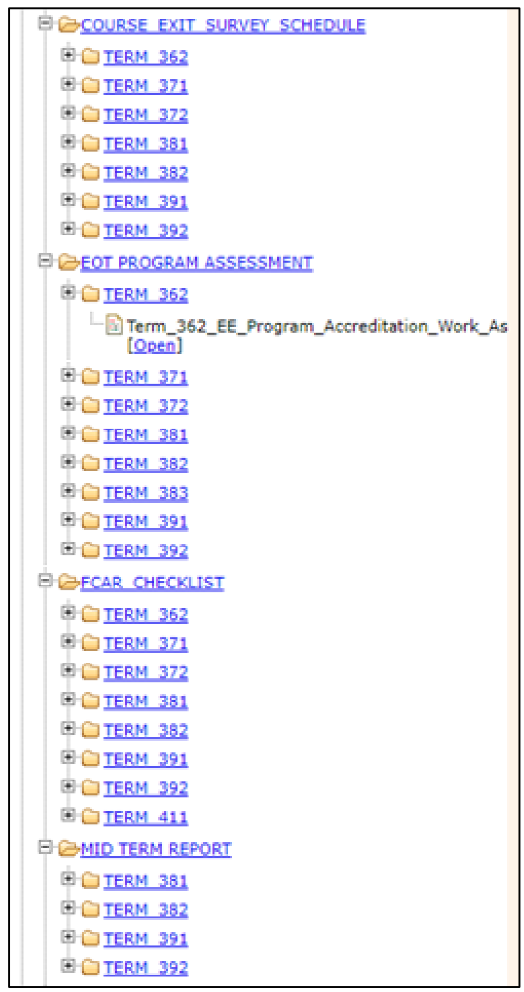


Figure G5. EE Program objective evidence for CQI activity related to quality cycle

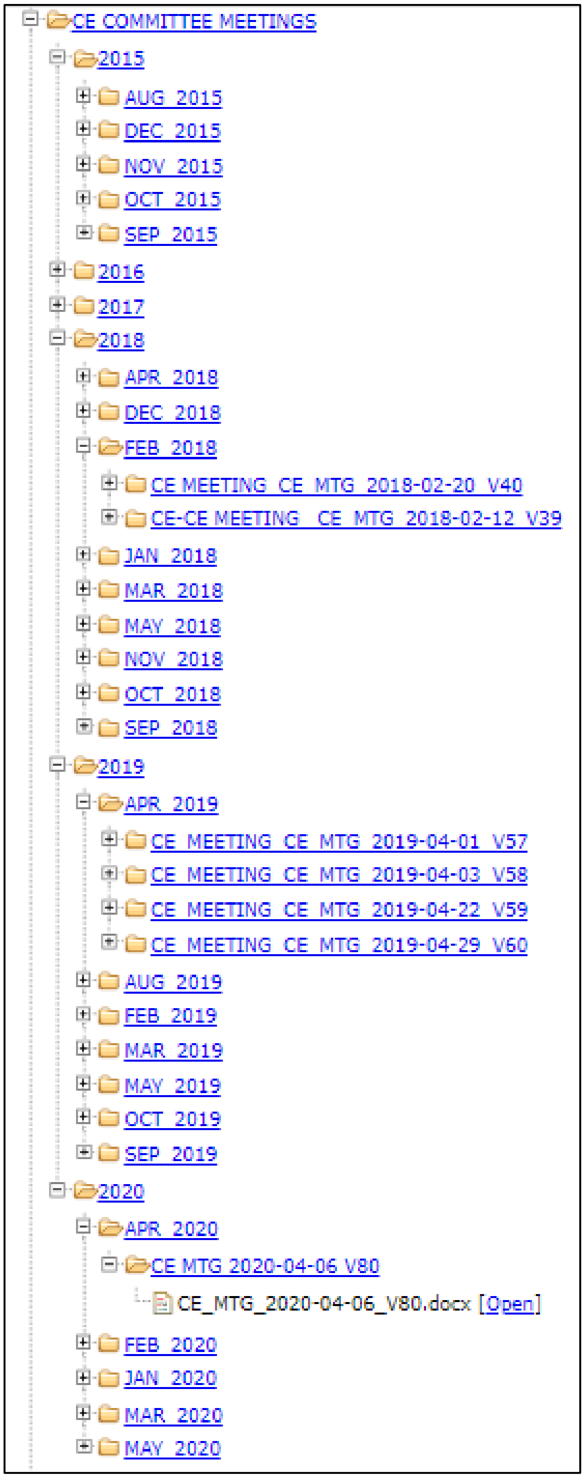


Figure G6. **CE program committee meetings folders in EvalTools®**

Figure G7. **CE program term review folders in EvalTools®**

APPENDIX H: *Sustainability and Course Workload*

Faculty Course Data Collection Work Load QA Form

Islamic University:
Faculty of Engineering

Islamic University: requests your help. Please complete the following QA form* to officially document the faculty work load for course data collection activity listed in the form below. Thank you for your time.

FACULTY: [redacted] COURSE TITLE: WIRELESS COMMUNICATIONS COURSE CODE: EE421 TERM: 381. SIGNATURE: [redacted]

ABET COORDINATOR: [redacted] DATE: TIME: SIGNATURE:

Activity↓/Categories→	SAMPLES	SCAN/FILE NAMING	UPLOAD	SCORE ENTRY	MAPPING
HW (4 HWs)	H,M,L	12 mins x 4	3 mins x4	7x4 = 28	4x4 = 16
Quiz (4 QUIZs)	H,M,L	6 mins x 4	2 mins x4	7x4 = 28	4x4 = 16
~~Lab Expt. (10 Expts.)~~	H,M,L	~~15 mins x10~~	~~3 mins x10~~		
Mid Term-1 (4 split questions)	H, M,L	20 mins	20 mins	8x4 = 32	4x4 = 16
Mid Term-2 (4 split questions)	H, M,L	20 mins	20 mins	8x4 = 32	4x4 = 16
Final Exam (8 split questions)	H, M,L	20 mins	20 mins	10x4 = 40	4x4 = 16
~~Project~~ TERM PAPER (6 split sections)	GROUP WISE			7x3 = 21	4x3 = 12.
Lab Mid (2 split questions)	H, M,L				
Lab Final (4 split questions)	H,M,L				

Comments: THERE ARE 07 STUDENTS IN THIS COURSE AND. THERE ARE NO LABS. HERE.

LECTURER: [redacted]

Program Coordinator: [redacted] Date: 3/12/2017

*Note: Please fill in approximate time in minutes or hours scale to help the Faculty of Engineering stream line faculty member course data collection activities and ensure future sustainability

QA Training Form - ____________ 1

Figure H1. Faculty course data collection workload for EE 421 wireless and mobile communications (Sustainability Report

APPENDIX I: *EvalTools ® Remote Evaluator Module*

Figure I1 shows the *Program Evaluation – Objective Evidence Folders* tab arranged according to SOs (1-7). The ABET SO_1 is examined for CE program course portfolios.

Figure I2 shows the *Program Evaluation – Executive Summary* tab with detailed information of the EE and ME programs' term 411 ABET SOs (1-7), PIs and Learning Domains evaluations aggregate results. The executive summary provides several termwise reports for each program such as SOs executive summary, detailed SO and PI executive summary, SO/PI PVT summary, course action items matrix, and learning domains evaluation. Scientifically color coded outcomes histogram plots and detailed digital diagnostic information help auditors to quickly gauge the performance of program SOs and PIs, investigate associated courses, assessments and review their remedial actions.

Figure I3 displays a portion of a list of 20 administrative committees such as *Academic Affairs, Alumni Affairs, Capstone Design, CE, Class Scheduling and Examinations, Course and Curriculum Development,* and *External Advisory.* These committees use the CIMS to maintain a comprehensive digital database of CQI information related to their meeting minutes, tasks lists and associated documentation. Samples of tasks lists, documentation folders and meeting minutes history for the ME and EE programs' committees are also shown to indicate seamless reporting and accessibility of status and history of corrective actions and associated documentation. Automation of reporting and collection of massive amounts of administrative committees' CQI data using the CIMS poses a striking contrast to the complex and labor intensive manual processes which require an exhaustive expenditure of man power and other resources to accurately collect and report a fraction of similar sets of digital CQI information.

Figure I4 shows complete lists of surveys deployed for the EE, CE and ME programs. Samples of statistical data and inferences for course exit, alumni and faculty satisfaction surveys are also displayed below. The *Survey Instruments* tab gives auditors first hand information on all indirect assessments, dates of deployment, participant details, response rates and statistical results.

Figure I5 shows the *Program Assessment- SOs-PIs relations with rubrics* tab for the CE program listing all the PIs for SO_1 and corresponding hybrid rubrics in a digital database. Also shown are samples for curriculum maps, SOs-PEOs mapping, and performance criteria and heuristics rules. The *Program Assessment* tabs provide the foundational framework for course and program level assessment and evaluation, thereby providing auditors crucial guidelines to confirm whether implemented CQI processes are aligned to defined construct and their results are accurate.

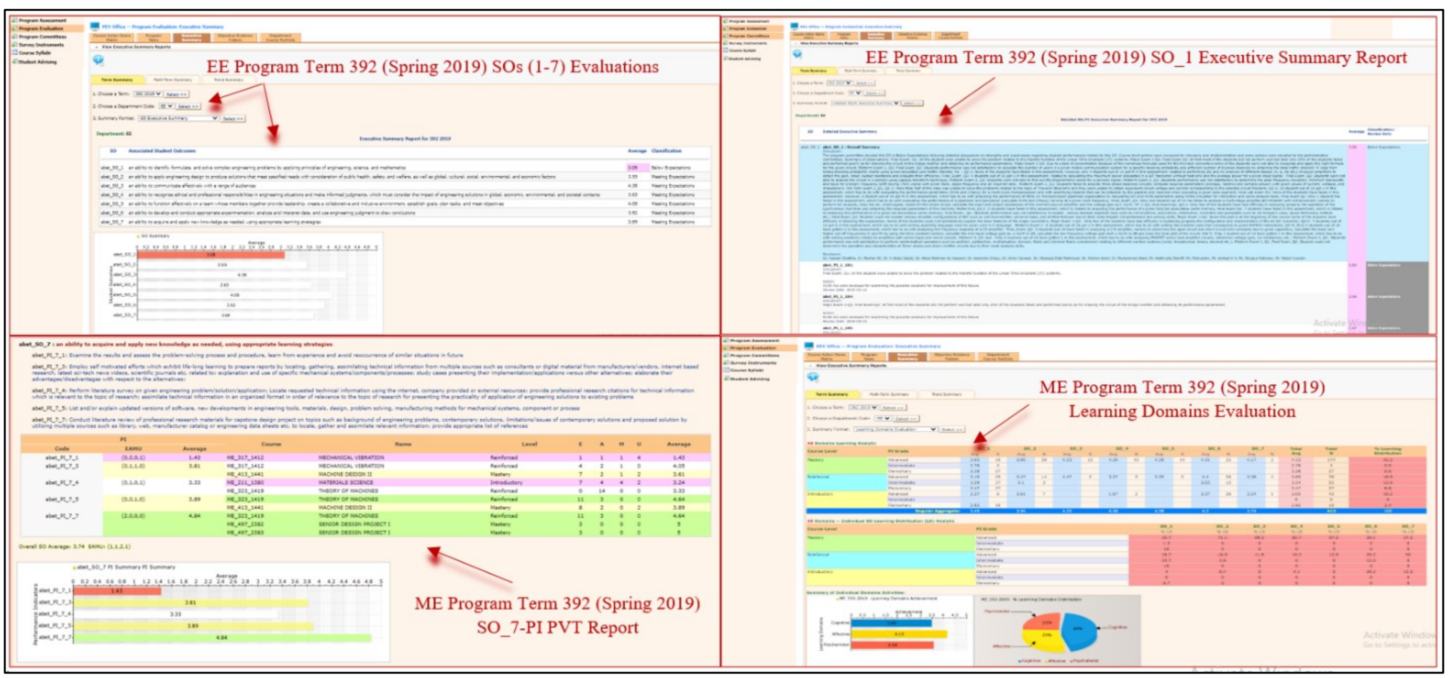


Figure I1. Program evaluation – objective evidence ABET SOs (1-7) folders

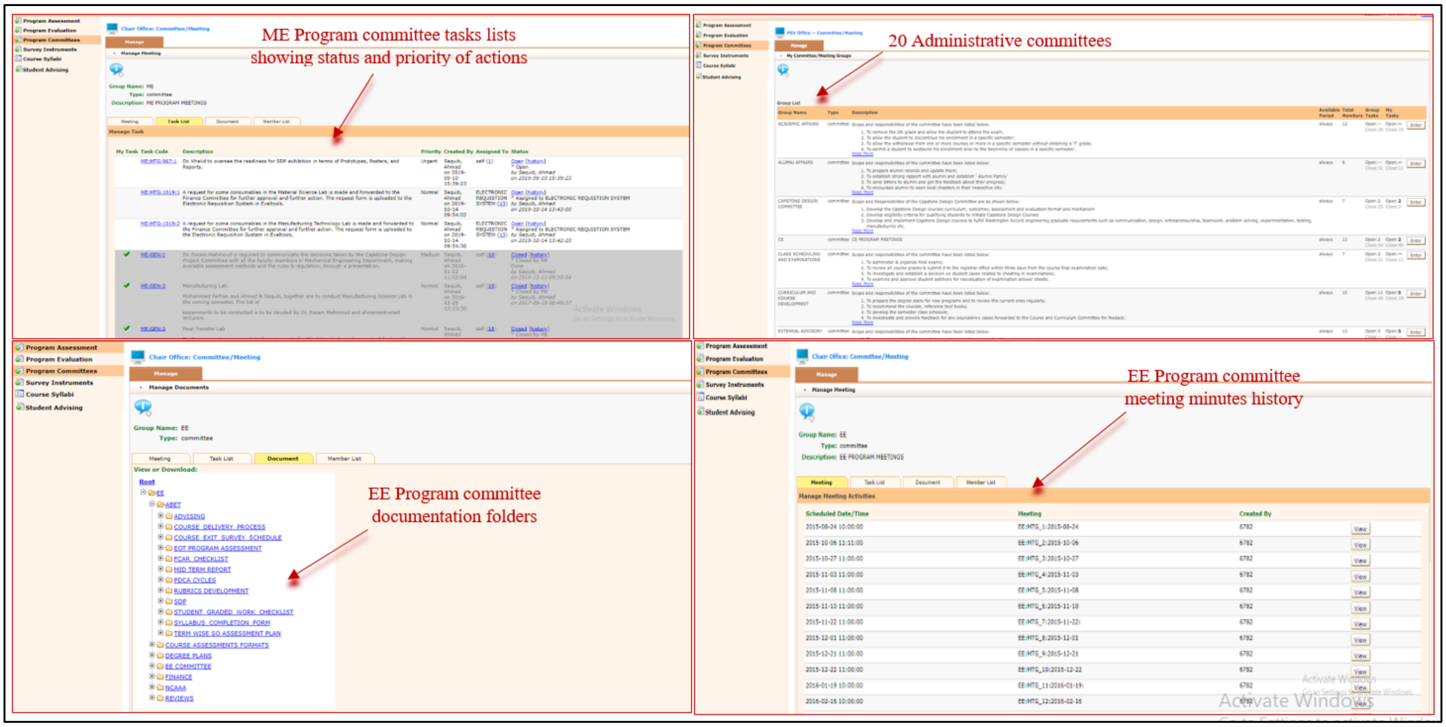


Figure I2. **Program evaluation – executive summary for SOs, PIs and learning domains evaluations**

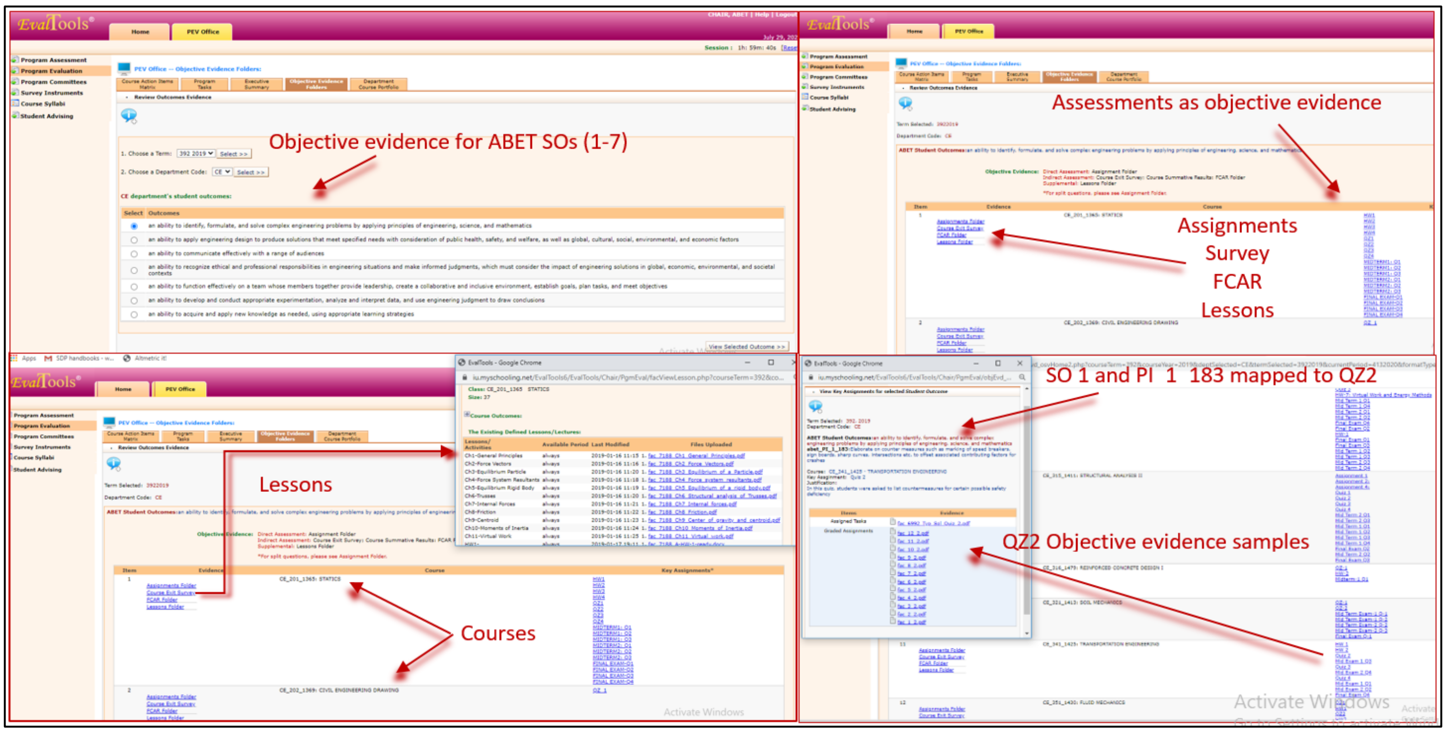


Figure I3. **Program committees – task lists, documentation and meeting minutes history**

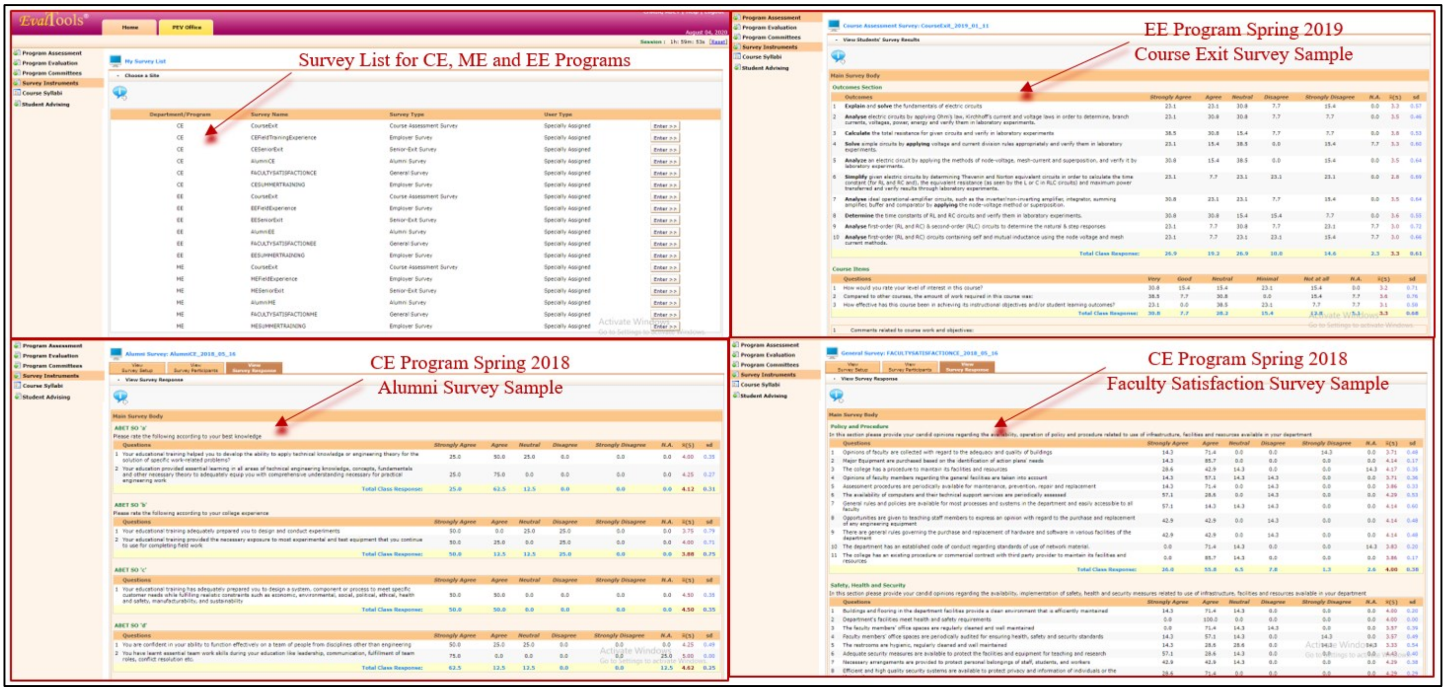


Figure I4. **Survey Instruments – list of surveys and samples of statistical data from survey responses**

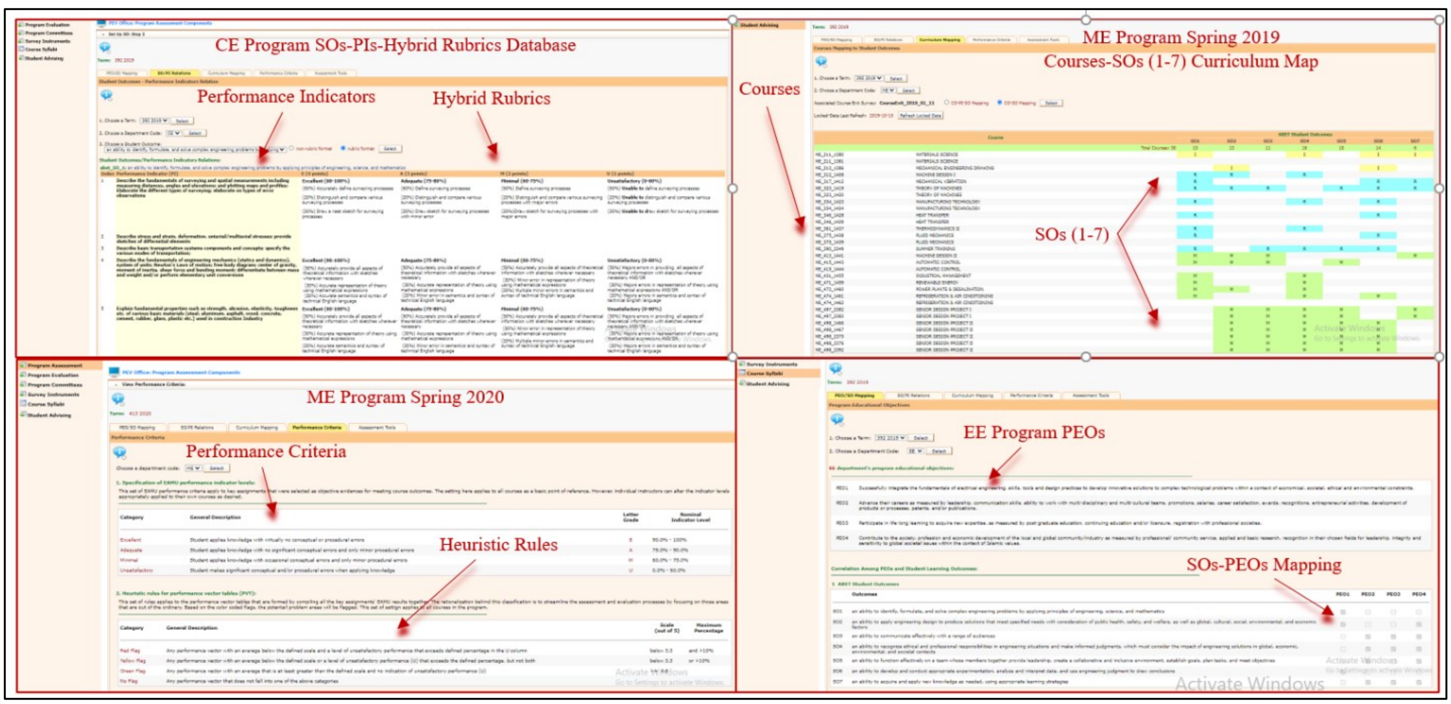


Figure I5. **Program assessment tabs – SOs-PIs relations, curriculum map, performance criteria and SOs-PEOs mapping**

APPENDIX J: *PDCA Quality Cycles Q_1 – Q_6*

1. *PDCA QUALITY CYCLE Q1: COs, PIs, RUBRICS DEVELOPMENT*

Table J1. **ME_323 Theory of machines Course COs, PIs and revised ABET SOs (1-7)**

Class: ME_323 - Theory of Machines	
CO 1 UNDERSTANDING THEORY	**Explain** various terminology associated with theory of machines**.**
[abet_PI_1_8] Cognitive: Understanding	Explain types of constrained motion, degree of freedom related to machines, mechanisms, links, cam, followers etc. and other basic terminology associated with the theory of machines
CO 2 ANALYSIS & DESIGN	**Analyze** the given mechanism to determine the velocity by graphical method.
[abet_PI_2_53] Psychomotor: Adaptation	Analyze the position of the members in the mechanism, their velocity, and acceleration; form a graphical solution representing the known velocities as a vector diagram; graphically solve the unknown parameters like velocity and acceleration, by solving relative vector polygons.
CO 3 ANALYSIS	**Solve** problems related to power transmission in gear trains.
[abet_PI_1_77] Cognitive: Analyzing	Analyze given gear trains to determine the speed of power transmission; calculate the velocity ratio from given data such as number of teeth, diameter of gear, RPM and angular velocity; use velocity ratio to calculate output speed of the driven gear of power transmission.
CO 4 ANALYSIS & EXPERIMENTATION	**Solve** and **Analyze** problems in balancing related to rotating machineries.
[abet_PI_1_78] Cognitive: Analyzing	Solve balancing problems for given rotatory machines; extract in tabular form the angular position of masses with respect to reference plane; calculate the unbalanced critical mass and find its angular position; (different planes) calculate the appropriate distance from reference plane to achieve complete balancing of the shaft;
[abet_PI_6_2] Psychomotor: Complex overt response	Use the balancing machine proficiently by proper selection of slot and angle for given masses to verify the accuracy of calculated magnitude and direction of masses
CO 5 DESIGN & EXPERIMENTATION	**Describe** and **develop** CAMS profile for different types of followers for uniform velocity and Simple harmonic motion
[abet_PI_2_5] Psychomotor: Adaptation	Construct different types of cam profile (simple harmonic, linear, uniform etc.) from given displacement data using various geometric instruments; draw displacement diagram from given information on motion of the follower; derive angular positions from the displacement diagram to draw the cam profile
[abet_PI_6_3] Psychomotor: Adaptation	Construct different types of cam profile from given data using various geometric instruments or AutoCAD for uniform velocity or simple harmonic motion.
CO 6 UNDERSTANDING & ANALYSIS	**Describe** and **Solve** fluctuating speed problems analytically or using turning moment diagrams.
[abet_PI_1_134] Psychomotor: Adaptation	Calculate inertia by constructing turning moment diagrams to solve fluctuating speed problems using given data; draw neatly labeled plots for varying fluctuations (rotation vs. torque); calculate the area under the curve for each section to obtain average torque; determine efficiency of the shaft using average and maximum torque
CO 7 ANALYSIS	**Determine** gyroscopic couple and its effect on rotors.
[abet_PI_1_131] Cognitive: Analyzing	Determine gyroscopic couple of rotating components and its effects
CO 8 DESIGN, REPORT WRITING, PRESENTATION & TEAMWORK	**Design** a model of a mechanism, **write** a technical report and **conduct** an oral presentation.
[abet_PI_5_5] Affective: Internalizing values	Develop the team meeting schedule for fulfillment of various tasks in an engineering project; meet regularly with team members as per meeting schedule; brainstorm, select agenda items, discuss project schedules, implementation, and issues; document meeting minutes; assign action items to team members and follow up for closure
[abet_PI_5_7] Affective: Internalizing values	Report information credibly regarding the performance, interaction and cooperation of team members for the fulfillment of team project
[abet_PI_2_16] Cognitive: Creating	Design a mechanism related to theory of machines such as gears, cams etc.; provide written detail of overall size of the mechanism, list all components and clearly explain their inter-related paths of motion; provide clearly labelled schematics showing constrained motion of the various parts of the mechanism.
[abet_PI_3_8] Affective: Internalizing values	Develop an elaborate project proposal for the design of a mechanism related to theory of machines such as gears, cams etc.: provide a summarized project abstract; reference literature survey detailing the construction (components, dimensions), manufacturability (material, facility, costs) and operation (schematic and text detailing inter-related motions) of the mechanism; provide design specifications (customer requirements and constraints); discuss manufacturability of the design (facilities, materials required and costs); provide a detailed project implementation schedule in the form of a Gantt chart.
[abet_PI_3_6] Affective: Internalizing values	Write complete technical course project reports following appropriate standards, format and style with: title, front matter, list of tables and contents; details of overall organization of the report; proper English(grammar/spelling/sentence structure); neatly labeled sketches/diagrams; abstract/introduction; adequate technical content of problem definition; properly assimilated and relevant literature review; design specifications: customer requirements or constraints; design methodology: concepts development, concepts selection and evaluation; manufacturability: scope, planning, budget, deliverables; detailed design analysis: fulfillment of constraints; conclusion, references, appendices etc.
[abet_PI_3_2] Affective: Internalizing values	Make effective oral presentations in a given time frame to defend course projects with required: professionalism, style, slide quality, delivery, response to questions; adequate technical content of problem definition; properly assimilated and relevant literature review; design specifications: customer requirements or constraints; design methodology: concepts development, concepts selection and evaluation; manufacturability: scope, planning, budget, deliverables; detailed design analysis: fulfillment of constraints; conclusion, references, appendices etc.
[abet_PI_2_17] Psychomotor: Origination	Demonstrate physically the operation of the manufactured mechanism, clearly showing inter-related motions of all components; mechanism should complete one cycle of motion for all components as per specification without detachment

The following Table J2 is a portion of a practice workbook, the sections of which have been used by faculty members for the development of COs, PIs and their hybrid rubrics. This workbook has been presented in workshops conducted at the prestigious International ASEE 2017 conference and ABET symposium 2017. In section A, instructors fill necessary course details like course code, title, learning activities, topics and SOs covered. To explain sections B, C and D of the workbook, we consider the example of a ME_323_2181, Theory of Machines course with the given course topics:

- Dynamics Balancing, Statics and dynamics balancing; balancing of rotating masses
- Dynamics Balancing, Statics and dynamics balancing of single and multi-plane (add or remove mass); unbalanced force and dynamic force on bearing

In section B of the workbook, the instructor provides topics, target learning activity, CO and PI statements. Specifically, the instructor targets solving balancing problems related to the above topics which are then adequately covered by the CO 4: ***Solve** and **Analyze** problems in balancing related to rotating machineries*.

The following specific PIs targeting theoretical and experimental learning activity:

1- [abet_PI_1_78] Cognitive: Analyzing Solve balancing problems for given rotatory machines; extract in tabular form the angular position of masses with respect to reference plane; calculate the unbalanced critical mass and find its angular position; (different planes) calculate the appropriate distance from reference plane to achieve complete balancing of the shaft;

2- [abet_PI_6_2] Psychomotor: Complex overt response Use the balancing machine proficiently by proper selection of slot and angle for given masses to verify the accuracy of calculated magnitude and direction of masses

are developed and appropriately classified to align with the required student learning activities for the CO 4 dealing with solving balancing problems.

In section C of the workbook shown in Table J2, all major steps required in any student learning activity are extracted from PI _1_78 and listed with appropriate language for high expectations in performance. Eventually, these steps will be used to develop descriptors for multiple dimensions in the Excellent scale of the hybrid rubric. As shown in section D of Table J2 related to rubrics development, faculty members make appropriate adjustments to descriptors for the various dimensions of the Adequate, Minimal and Unsatisfactory scales of the rubrics to represent the appropriate level of student performances.

Table J2. **Sections of practice workbook for development of COs, PIs and hybrid rubrics for *ME_323 Theory of machines* course**

A. TABLE OF INPUTS

PROGRAM	Mechanical Engineering	ABET COMMISSION: ☐ ASAC ☐ CAC ☑ EAC ☐ ETAC
COURSE TITLE	ME_323_2181 THEORY OF MACHINES	CREDIT HOURS : 3
MAJOR LEARNING ACTIVITIES	Recall theory and application of theory, Analysis of components of machine	
ABET SOs	☑ SO ‘1’ ☑ SO ‘2’ ☑ SO ‘3’ ☐ SO ‘4’ ☑ SO ‘5’ ☑ SO ‘6’ ☐ SO ‘7’	
CHAPTERS	1. **Mechanisms and Machines.** Introduction. Types of constrained motion, Rigid and resistant bodies, links, kinematic pair, Joints, degree of freedom, Kinematic chain, gruebler’s criterion, Kutzback’s criterion Velocity analysis: absolute and relative motions. Addition and subtraction of vectors Velocity analysis of mechanisms by graphical method 2. **Transmission System:** Introduction; Terms and definition and the basics: gear ratio, velocity and acceleration, efficiency, equivalent bearing friction torque and equivalent mass moment of inertia and torque refer to input or output Mechanical application; Gear system, hoist and vehicle dynamics, Gear train – epicyclic gears; Gear ratio, power and torque requirements 3. **Dynamics Balancing:** Statics and dynamics balancing; balancing of rotating masses Statics and dynamics balancing of single and multi-plane (add or remove mass); unbalanced force and dynamic force on bearing Balancing of reciprocating masses; Balancing of engine (in-line, radial and V engines for primary and secondary force and couple) 4. **Cams:** Types of cams, types of followers, definitions, Motions of the follower, Simple Harmonic Motion (SHM) Constant acceleration and Deceleration, Layout of cam profile. 5. **Fluctuation of Speed and Energy:** Turning moment diagram (constant input-variable output and variable input-constant output) Flywheel (fluctuation of speed and energy, sizes); Constant input-variable output torque and variable input-constant output torque 6. **Gyroscopic Couple:** Gyroscopic couple; Effect of gyroscopic couple on rotor Effect of gyroscopic couple on airplane, naval ship and land vehicle.	

B. COURSE OUTCOME 4 & PERFORMANCE INDICATOR AND HYBRID RUBRICS DEVELOPMENT TABLE

1	**CHAPTER** **(Select relevant chapters for one CO)**	Dynamics Balancing		**LECTURE HOURS: 06**
2	**TOPICS** **(Select relevant topics for one CO)**	Statics and dynamics balancing of single and multi-plane (add or remove mass); unbalanced force and dynamic force on bearing		
3	**COURSE OUTCOME 4**	☑ Operational Verbs ☑ Nominal Content/Topics ☐ Lab ☐ Project ☐ Team Work Solve and Analyze problems in balancing related to rotating machineries.		
4	**PERFORMANCE INDICATOR**	☑ Operational Verb ☑ Nominal Content/Topics ☑ Techniques/Methods ☑ Major Steps [abet_PI_1_78] Cognitive: Analyzing Solve balancing problems for given rotatory machines; extract in tabular form the angular position of masses with respect to reference plane; calculate the unbalanced critical mass and find its angular position; (different planes) calculate the appropriate distance from reference plane to achieve complete balancing of the shaft;		
	ABET SO COVERAGE **(Select one only)** ☑ SO ‘1’ ☐ SO ‘2’ ☐ SO ‘3’ ☐ SO ‘4’ ☐ SO ‘5’ ☐ SO ‘6’ ☐ SO ‘7’	☑ **Cognitive Domain** ☐ Remembering ☐ Understanding ☐ Applying ☑ Analyzing ☐ Evaluating ☐ Creating	☐ **Affective Domain** ☐ Receiving ☐ Responding ☐ Valuing ☐ Organizing Values into Priorities ☐ Internalization	☐ **Psychomotor Domain** ☐ Perception ☐ Set ☐ Guided Response ☐ Mechanism ☐ Complex Overt Response ☐ Adaptation ☐ Origination

C. HIGH EXPECTATIONS: REQUIRED STEPS FOR GIVEN LEARNING ACTIVITY PI_1_78

PI _1_78	**HIGH EXPECTATIONS STUDENT ACTIVITY (SEQUENTIAL WITH ALL GRADABLE MAJOR STEPS INDICATED) :**	**STEP1:** Accurately extract the data in the tabular form to show the shaft parameters, for example, the angular position of masses with respect to reference plane, mass, radial distance etc.
		STEP2: Accurately calculate the unbalanced critical mass and find its angular position and radial distance; AND/OR for dynamics balancing, calculate the appropriate distance from reference plane to achieve complete balancing of the shaft

D. HYBRID RUBRIC DEVELOPMENT PI_1_31

Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
(50%) Accurately extract the data in the tabular form to show the shaft parameters, for example, the angular position of masses with respect to reference plane, mass, radial distance etc.	(50%) Minor error in extracting the data in the tabular form to show the shaft parameters, for example, the angular position of masses with respect to reference plane, mass, radial distance etc.	(50%) Multiple minor errors in extracting the data in the tabular form to show the shaft parameters, for example, the angular position of masses with respect to reference plane, mass, radial distance etc.	(50%) Major errors in extracting the data in the tabular form to show the shaft parameters, for example, the angular position of masses with respect to reference plane, mass, radial distance etc.
(50%) Accurately calculate the unbalanced critical mass and find its angular position and radial distance; **AND/OR** for dynamics balancing, calculate the appropriate distance from reference plane to achieve complete balancing of the shaft	(50%) Minor error in calculating the unbalanced critical mass and find its angular position and radial distance; **AND/OR** for dynamics balancing, minor errors to calculate the appropriate distance from reference plane to achieve complete balancing of the shaft	(50%) Multiple minor errors in calculating the unbalanced critical mass and find its angular position and radial distance; **AND/OR** for dynamics balancing, multiple minor errors to calculate the appropriate distance from reference plane to achieve complete balancing of the shaft	(50%) Major errors in calculating the unbalanced critical mass and find its angular position and radial distance; **AND/OR** for dynamics balancing, Major errors to calculate the appropriate distance from reference plane to achieve complete balancing of the shaft

i. SAMPLES OF COs, PIs AND HYBRID RUBRICS FOR A CAPSTONE DESIGN PROJECT COURSE

In this section, we show samples of development and implementation of COs, PIs, hybrid rubrics and assessments for Capstone design activity related to problem definition and teamwork in a project proposal for a mechanical engineering course ME-497, Senior Design Project-I.

Table J3. Rubric for capstone design course problem definition PI_10_12

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
25%	Develop problem definition for a capstone design project proposal consisting of a summarized abstract mentioning: 1. Accurate English semantics, vocabulary and grammar 2. Engineering problem, limitations/issues 3. Application/alignment with customer needs/requirements	Develop problem definition for a capstone design project proposal consisting of a summarized abstract mentioning: 1. **Minor errors** in English semantics, vocabulary and grammar 2. Engineering problem, limitations/issues 3. Application/alignment with customer needs/requirements **AND/OR**	Develop problem definition for a capstone design project proposal consisting of a summarized abstract mentioning: 1. **Multiple errors** in English semantics, vocabulary and grammar 2. Engineering problem, limitations/issues 3. Application/alignment with customer needs/requirements **AND/OR**	Develop problem definition for a capstone design project proposal consisting of a summarized abstract mentioning: 1. **Multiple errors** in English semantics, vocabulary and grammar 2. **Inaccuracy** in Engineering problem, limitations/issues 3. **Inaccuracy** in Application/alignment with customer needs/requirements **AND/OR**
25%	Background of engineering problems which are: 1. Accurate English semantics, vocabulary and grammar 2. Relevant and current 3. Properly referenced 4. Problems lie within scope of the SDP project	Background of engineering problems which are: 1. Minor errors in English semantics, vocabulary and grammar 2. Relevant and current 3. **Minor errors** in referencing 4. Problems lie within scope of the SDP project **AND/OR**	Background of engineering problems which are: 1. **Multiple** errors in English semantics, vocabulary and grammar 2. **Mostly** Relevant and current 3. **Multiple errors** in referencing 4. Problems lie within scope of the SDP project **AND/OR**	Background of engineering problems which are: 1. **Multiple** errors in English semantics, vocabulary and grammar 2. **Lacking** relevancy and/or currency 3. **Multiple errors** in referencing 4. Problems **partly/not** within scope of the SDP project **AND/OR**
25%	Provide details on contemporary solutions: 1. Accurate English semantics, vocabulary and grammar 2. Methodology: theory/process /system/component 3. Limitations/issues of contemporary solutions 4. Impact on environmental, societal and/or sustainability aspects	Provide details on contemporary solutions: 1. Minor errors in English semantics, vocabulary and grammar 2. Methodology: theory/process /system/component 3. **Minor inaccuracy** in explaining Limitations/issues of contemporary solutions 4. Impact on environmental, societal and/or sustainability aspects **AND/OR**	Provide details on contemporary solutions: 1. **Multiple** errors in English semantics, vocabulary and grammar 2. **Minor inaccuracy** in explaining Methodology: theory/process /system/component 3. **Minor inaccuracy** in explaining Limitations/issues of contemporary solutions 4. **Minor inaccuracy** in explaining Impact on environmental, societal and/or sustainability aspects **AND/OR**	Background of engineering problems which are: 1. **Multiple** errors in English semantics, vocabulary and grammar 2. **Lacking** relevancy and/or currency 3. **Multiple errors** in referencing 4. Problems **partly/not** within scope of the SDP project **AND/OR**

25%	Selected problem should align with customer needs/requirements: 1. Align with design specifications 2. Review/Justification for design specifications 3. Reference to engineering standards and realistic constraints	Selected problem should align with customer needs/requirements: 1. Align with design specifications 2. Review/Justification for design specifications 3. **Few Missing** aspects in reference to engineering standards and realistic constraints	Selected problem should align with customer needs/requirements: 1. Align with design specifications 2. **Minor inaccuracy** in Review /Justification for design specifications **3. Multiple missing** aspects in reference to engineering standards and realistic constraints	Selected problem should align with customer needs/requirements: 1. **Inaccurate/partial** alignment with design specifications 2. **Minor inaccuracy** in Review /Justification for design specifications **3. Multiple missing** aspects in reference to engineering standards and realistic constraints

CO1: ***Submit*** *senior design project team contract and proposal consisting of problem definition, abstract, statements that clearly indicate goals, scope and feasibility of the solution based on literature review incorporating design specifications and fulfillment of realistic constraints*

- [abet_PI_10_12] Affective: Internalizing values Develop problem definition for a capstone design project proposal which is properly referenced, consists of a summarized abstract; background of engineering problems; contemporary solutions; limitations/issues of contemporary solutions; and customer needs/requirements
- [abet_PI_4_12] Affective: Internalizing values Contribute actively to prepare the team contract with collaboration of team members and faculty; define conditions of team contract such as general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution; elaborate individual and team member strengths and weaknesses with faculty and colleagues related to definition of team roles; collect and verify CVs appropriately aligned to required roles; submit signed team contract with finalized assignment of team roles

Table J4. **Assessment methodology for problem definition**

Topics	Activity	%	STU 1	STU 2	STU 3	STU 4
PROBLEM DEFINITION (20)	Summarized abstract;	5				
	Background of engineering problems;	5				
	Contemporary solutions; limitations/issues of contemporary solutions;	5				
	Customer needs/requirements	5				

abet_PI_10_12

abet_PI_4_12

Topics	Activity		%	STU
PROBLEM DEFINITION (12)	Summarized abstract;		3	3
	Background of engineering problems;		3	3
	Contemporary solutions; limitations/issues of contemporary solutions;		3	2
	Customer needs/requirements		3	3
TEAM WORK (13)	Team contract		5	4
	Roles of team members/communication and cooperation/conflict resolution/team meeting schedule		8	7
DESIGN SOLUTION (60)	Goals, objectives and scope		5	5
	Development of design concept 1 (20)	Alternative theory/ processes/ systems/ components/ models	5	4
		Design specification 1: Customer requirements	5	5
		Design specification 2: Constraints	5	4
		Goals to deliverables	5	4
	Development of design concept 2 (20)	Alternative theory/ processes/ systems/ components/ models	5	5
		Design specification 1: Customer requirements	5	4
		Design specification 2: Constraints	5	5
		Goals to deliverables	5	4
	Design concept selection-Pugh Method(20)	Design criteria 1: Procurement and manufacturability:	5	4
		Design criteria 2: Design specifications 1 (Provide values of design parameters according to customer needs)	5	5
		Design criteria 3: Design specifications 2 (Provide estimated values for fulfillment of realistic constraints)	5	5
		Design Concept: Score calculation and selection	5	5
LITERATURE REVIEW (15)	Background of engineering problems, contemporary solutions and their limitations/issues		3	3
	Proposed alternative theory/ processes/ systems/ components/ models		3	3
	Design specifications to meet customer needs and fulfill realistic constraints		3	3
	Utilize multiple sources such as library, web, manufacturer catalogue or engineering data sheets etc. to locate, gather and assimilate relevant information;		3	3
	Provide appropriate list of references		3	3

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Name of ~~Advisor~~/Examiner:

Signature of ~~Advisor~~/Examiner with date: 30/4/18

ME 497 – Senior Design Project Table 4 Page 2 of 2

Figure J1. Capstone design project-I (ME-497) examiner's marking sample

Table J5. Rubric for teamwork assessment of capstone design project, PI_4_12

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
35%	Define all conditions of team contract such as general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution	Define all conditions of team contract such as general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution	Define most conditions of team contract such as general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution **AND/OR**	Many conditions of team contract such as general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution are undefined **AND/OR**
30%	Elaborate individual and team member strengths and weaknesses with faculty and colleagues related to definition of team roles	Elaborate individual and team member strengths and weaknesses with faculty and colleagues related to definition of team roles	Some deficiency in elaborating individual and team member strengths and weaknesses with faculty and colleagues related to definition of team roles **AND/OR**	Multiple deficiencies in elaborating individual and team member strengths and weaknesses with faculty and colleagues related to definition of team roles **AND/OR**
20%	Collect and verify all CVs appropriately aligned to required roles	Collect and verify most of the CVs are appropriately aligned to required roles	Collect and verify most of the CVs are appropriately aligned to required roles	Unable to collect and verify that most of the CVs are appropriately aligned to required roles **AND/OR**
15%	Submit signed team contract with finalized assignment of team roles	Submit signed team contract with finalized assignment of team roles	Submit signed team contract with finalized assignment of team roles	Missing signatures in submitted team contract and/or deficiencies in finalized assignment of team roles

Table J6. Assessment methodology for team work

Topics	Activity	%	STU 1	STU 2	STU 3	STU 4
TEAM WORK (13)	Team Contract	5%				
	Roles of team members/ Communication and cooperation/ conflict resolution/ team meeting schedule	8%				

ii. SAMPLES OF COs, PIs AND HYBRID RUBRICS FOR EXPERIMENTAL LAB WORK

In this section, we will elaborate on sample experimental laboratory activity dealing with angular and linear measurements for civil engineering course *CE 271 Surveying*. Laboratory experimental work is categorized into several activities such as experimental set up, readings/observations, teamwork, safety regulations and interpretation of data with conclusions. A laboratory experiment 06 titled, "*Study of the total station for angular and linear measurements*'' is used for assessing CO 2: *Measure and Compute distances and angles between various natural and artificial ground features*, by targeting specific psychomotor skills for PIs:

1- [abet_PI_2_25] Psychomotor: Adaptation Measure vertical and horizontal angles between various natural and man-made feature using appropriate equipment such as digital Theodolite and Total Stations etc.

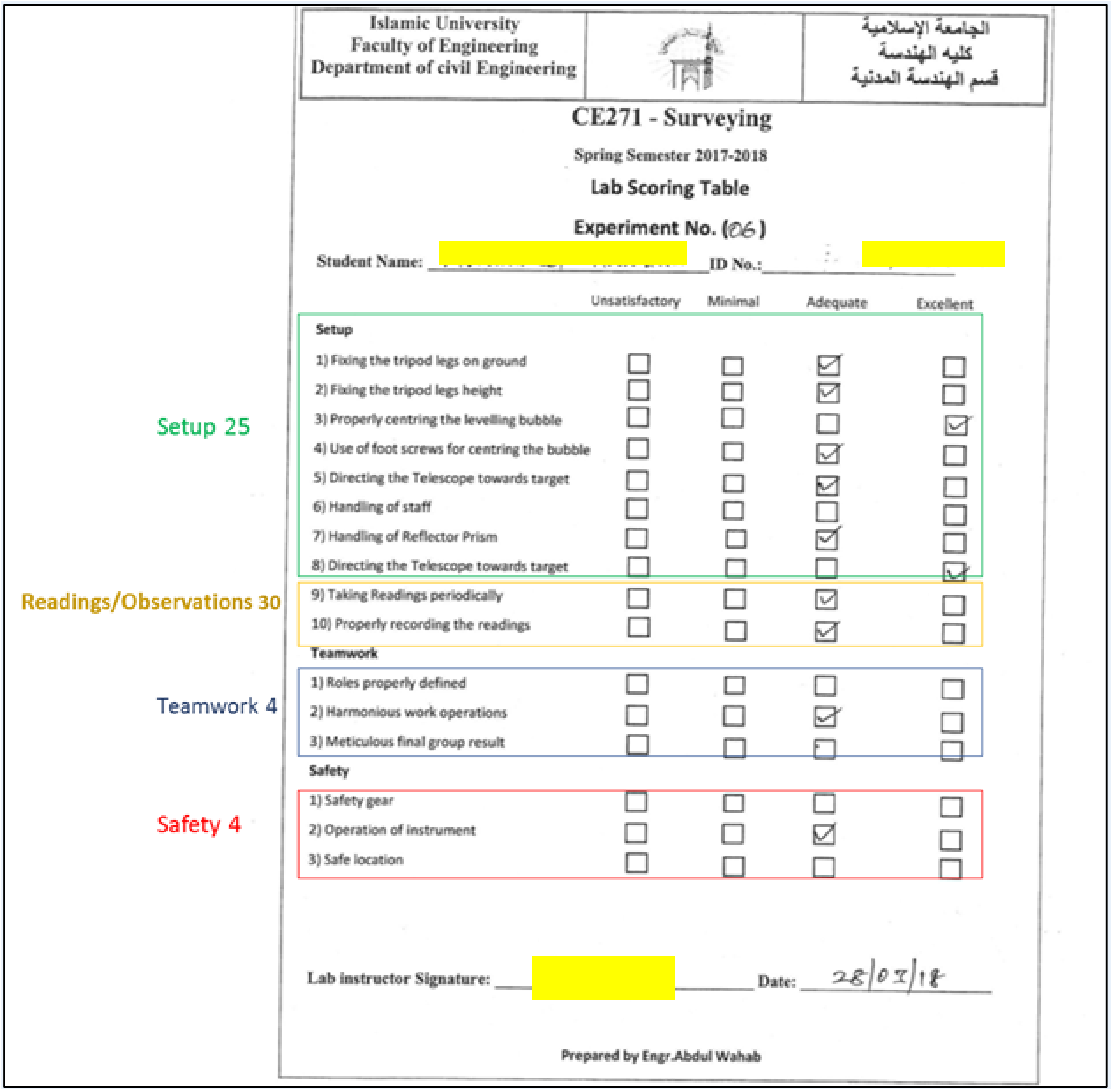
2- [abet_PI_2_26] Psychomotor: Adaptation Measure lengths and distances between various natural and man-made features using appropriate equipment such as Taps, EDM and Total Stations etc.

Specifically, the PI_2_25 is applied to experiment 06 using the rubric shown in Figure J2. A grading sheet shown in Figure J3 listing various categories of experimental activities is prepared using this rubric. The section related to set up and measurements consists of 10 points. The points 1 to 8 are related to experimental setup and 9, 10 are related to making observations and taking readings. The EAMU scales are utilized for assigning grades to various categories of students' experimental performances. Table J7 shows a grading table for various student learning activities related to lab experiment 6.

1	COURSE TITLE:	**CE 271 SURVEYING**
2	COURSE OUTCOME:	CO 2 Measure and Compute distances and angles between various natural and artificial ground features
3	PERFORMANCE INDICATOR:	[abet_PI_2_25] Psychomotor: Adaptation Measure vertical and horizontal angles between various natural and man-made feature using appropriate equipment such as digital Theodolite and Total Stations etc.
4	ABET STUDENT OUTCOME:	[abet_SO_2] an ability to design and conduct experiments, as well as to analyze and interpret data
5	HIGHEST EXPECTATION STUDENT ACTIVITY (SEQUENTIAL WITH ALL GRADABLE MAJOR STEPS INDICATED) :	Measure vertical and horizontal angles between various natural and man-made feature using digital Theodolite and Total Stations etc.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
100%	Measure vertical and horizontal angles between various natural and man-made feature using digital Theodolite and Total Stations etc.	Measure vertical and horizontal angles between various natural and man-made feature using digital Theodolite and Total Stations etc.	Measure vertical and horizontal angles between various natural and man-made feature using digital Theodolite and Total Stations etc.	Measure vertical and horizontal angles between various natural and man-made feature using digital Theodolite and Total Stations etc.
10%	Accurately occupy the required station	Accurately occupy the required station	Accurately occupy the required station	**Major error** in accurately Occupying the required station
40%	Accurately apply the fundamentals of device setting including centering, levelling and focusing.	Accurately apply the fundamentals of device setting including centering, levelling and focusing.	**Minor error** in accurately **applying** the fundamentals of device setting including centering, levelling and focusing.	**Major error** in accurately applying the fundamentals of device setting including centering, levelling and focusing.
40%	Move the device from the starting point to the required point and take the angle measurement between the two points.	**Minor error** in focusing on the starting point or the required point during measuring the angle	**Minor error** in focusing on the starting point or the required point during measuring the angle	**Major error** in accurately applying in focusing on the starting point or the required point during measuring the angle
10%	Record the readings	**Minor error** in recording the readings	**Minor error** in recording the readings	**Major error** in recording the readings

Figure J2. Hybrid rubric sample for laboratory experimental activity from CE 271 surveying course



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CE271 - Surveying

Spring Semester 2017-2018

Lab Scoring Table

Experiment No. (06)

Student Name: ____________ ID No.: ____________

	Unsatisfactory	Minimal	Adequate	Excellent
Setup				
1) Fixing the tripod legs on ground	☐	☐	☑	☐
2) Fixing the tripod legs height	☐	☐	☑	☐
3) Properly centring the levelling bubble	☐	☐	☐	☑
4) Use of foot screws for centring the bubble	☐	☐	☑	☐
5) Directing the Telescope towards target	☐	☐	☑	☐
6) Handling of staff	☐	☐	☐	☐
7) Handling of Reflector Prism	☐	☐	☑	☐
8) Directing the Telescope towards target	☐	☐	☐	☑
9) Taking Readings periodically	☐	☐	☑	☐
10) Properly recording the readings	☐	☐	☑	☐
Teamwork				
1) Roles properly defined	☐	☐	☐	☐
2) Harmonious work operations	☐	☐	☑	☐
3) Meticulous final group result	☐	☐	☐	☐
Safety				
1) Safety gear	☐	☐	☐	☐
2) Operation of instrument	☐	☐	☑	☐
3) Safe location	☐	☐	☐	☐

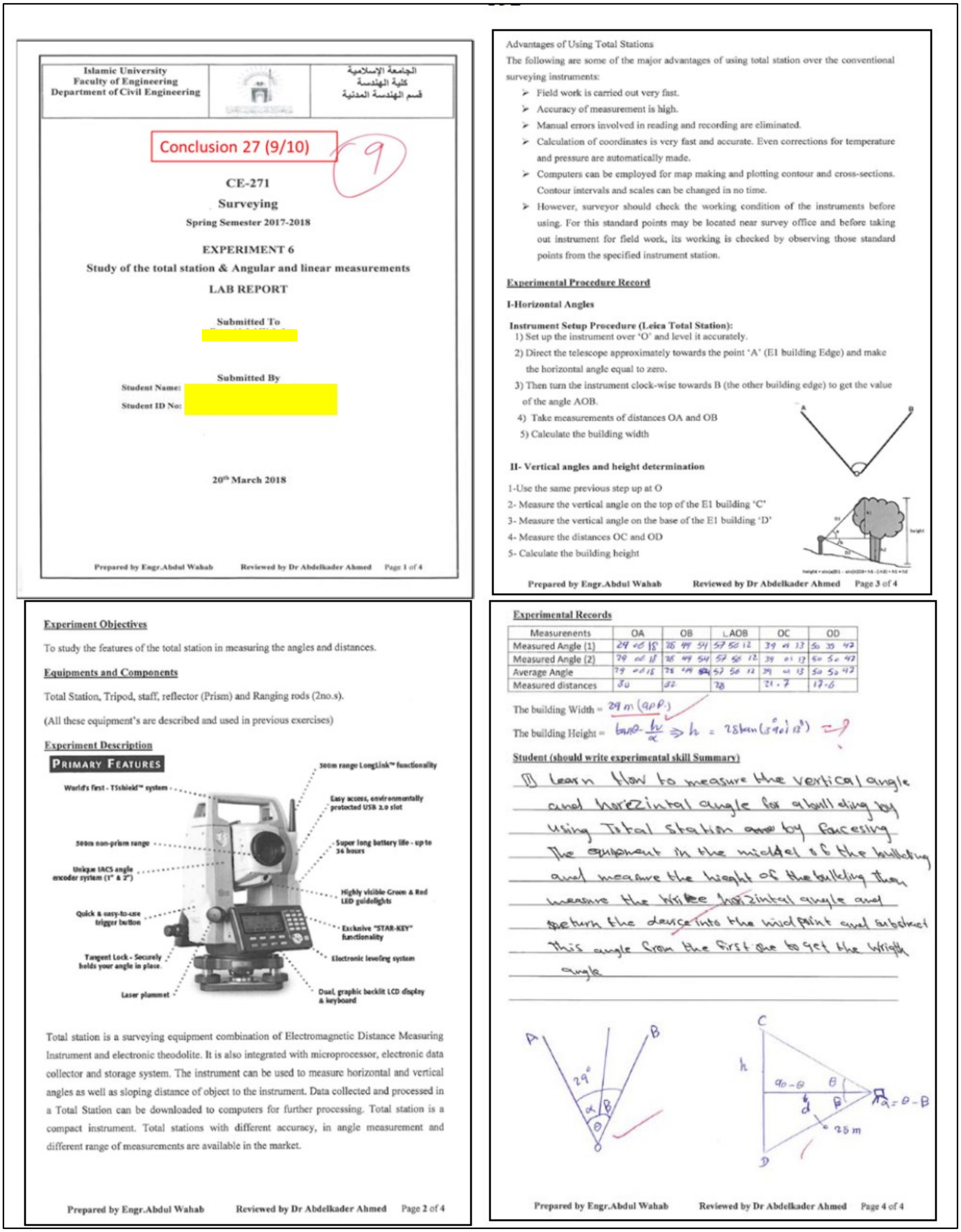
Lab instructor Signature: ____________ Date: 28/03/18

Prepared by Engr.Abdul Wahab

Figure J3. Laboratory experimental activity scoring table from CE 271 surveying course

Table J7. Assessment table showing scores for various experimental activities

Experimental Activity	Total score	Score obtained
Set up	30	25
Readings/Observations	30	27
Teamwork/Safety	10	8
Conclusions	30	27
Total Points	100	88



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قسم الهندسة المدنية

Conclusion 27 (9/10)

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CE-271

Surveying

Spring Semester 2017-2018

EXPERIMENT 6

Study of the total station & Angular and linear measurements

LAB REPORT

Submitted To

Submitted By

Student Name:

Student ID No:

20th March 2018

Prepared by Engr.Abdul Wahab   Reviewed by Dr Abdelkader Ahmed   Page 1 of 4

Experiment Objectives

To study the features of the total station in measuring the angles and distances.

Equipments and Components

Total Station, Tripod, staff, reflector (Prism) and Ranging rods (2no.s).

(All these equipment's are described and used in previous exercises)

Experiment Description

PRIMARY FEATURES

Total station is a surveying equipment combination of Electromagnetic Distance Measuring Instrument and electronic theodolite. It is also integrated with microprocessor, electronic data collector and storage system. The instrument can be used to measure horizontal and vertical angles as well as sloping distance of object to the instrument. Data collected and processed in a Total Station can be downloaded to computers for further processing. Total station is a compact instrument. Total stations with different accuracy, in angle measurement and different range of measurements are available in the market.

Prepared by Engr.Abdul Wahab   Reviewed by Dr Abdelkader Ahmed   Page 2 of 4

Advantages of Using Total Stations

The following are some of the major advantages of using total station over the conventional surveying instruments:

- Field work is carried out very fast.
- Accuracy of measurement is high.
- Manual errors involved in reading and recording are eliminated.
- Calculation of coordinates is very fast and accurate. Even corrections for temperature and pressure are automatically made.
- Computers can be employed for map making and plotting contour and cross-sections. Contour intervals and scales can be changed in no time.
- However, surveyor should check the working condition of the instruments before using. For this standard points may be located near survey office and before taking out instrument for field work, its working is checked by observing those standard points from the specified instrument station.

Experimental Procedure Record

I-Horizontal Angles

Instrument Setup Procedure (Leica Total Station):

1) Set up the instrument over 'O' and level it accurately.
2) Direct the telescope approximately towards the point 'A' (E1 building Edge) and make the horizontal angle equal to zero.
3) Then turn the instrument clock-wise towards B (the other building edge) to get the value of the angle AOB.
4) Take measurements of distances OA and OB
5) Calculate the building width

II- Vertical angles and height determination

1-Use the same previous step up at O
2- Measure the vertical angle on the top of the E1 building 'C'
3- Measure the vertical angle on the base of the E1 building 'D'
4- Measure the distances OC and OD
5- Calculate the building height

Prepared by Engr.Abdul Wahab   Reviewed by Dr Abdelkader Ahmed   Page 3 of 4

Experimental Records

Measurenents	OA	OB	∟AOB	OC	OD
Measured Angle (1)	29 06 18	25 49 54	57 56 12	39 01 13	50 35 47
Measured Angle (2)	29 06 18	25 49 54	57 56 12	39 01 13	50 50 47
Average Angle	29 06 18	25 49 54	57 56 12	39 01 13	50 50 47
Measured distances	30	32	28	21.7	17.6

The building Width = 29 m (app.)

The building Height = $\tan\theta = \frac{h}{x} \Rightarrow h = 28\tan(39°01'13")$ = ?

Student (should write experimental skill Summary)

I learn How to measure the vertical angle and horizintal angle for a building by using Total station and by facesing The equipment in the middel of the building and measure the hieght of the building then measure the ~~write~~ horizintal angle and return the device into the mid point and substract this angle from the first one to get the wright angle

A B 29° α β θ

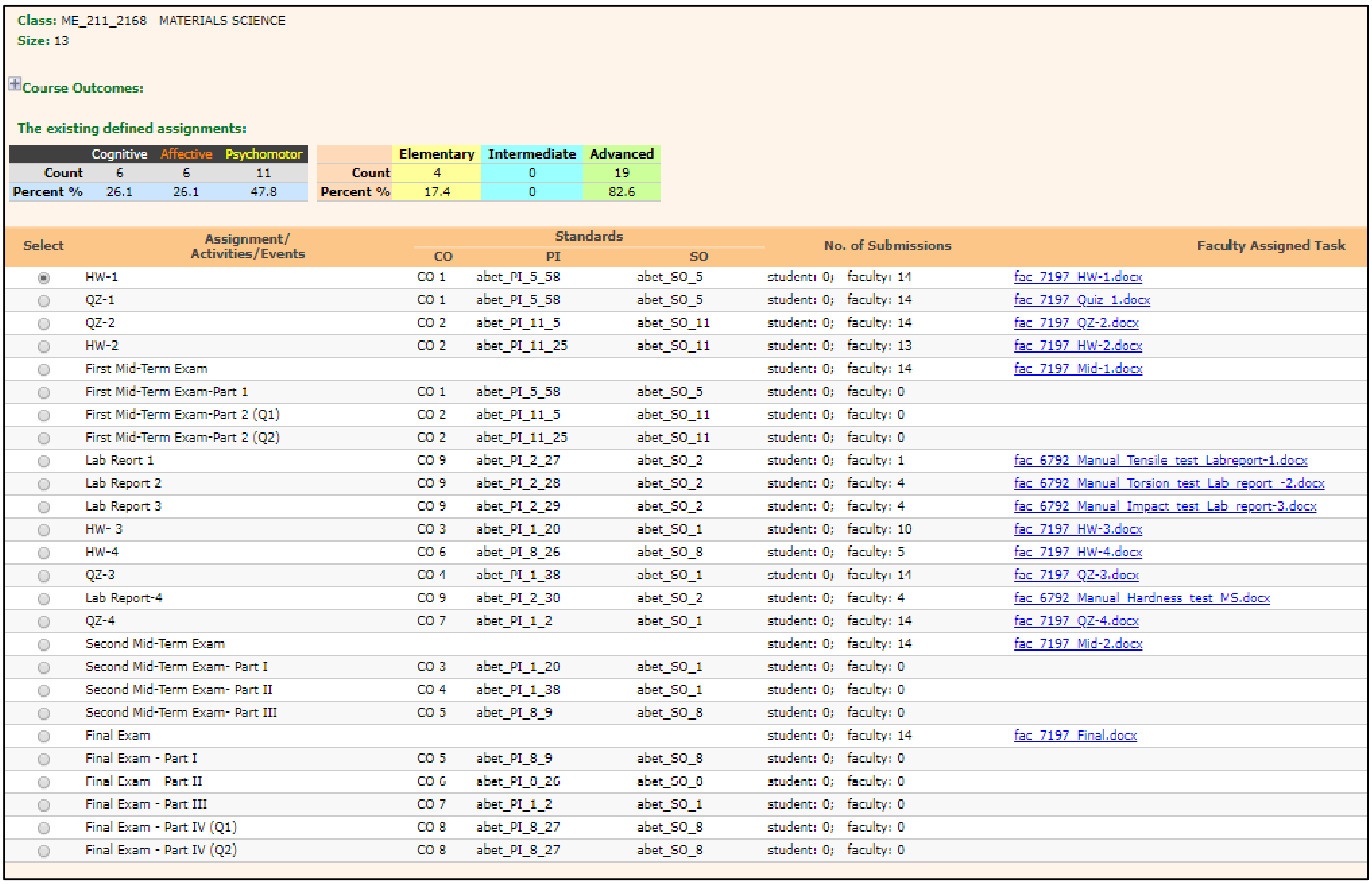
C h 90-θ θ β d α = θ - β 25 m D

Prepared by Engr.Abdul Wahab   Reviewed by Dr Abdelkader Ahmed   Page 4 of 4

Figure J4. Sample graded report experiment no 06 for surveying course

iii. APPLICATION OF SCIENTIFIC CONSTRUCTIVE ALIGNMENT

The Faculty of Engineering programs have implemented scientific constructive alignment following the authentic OBE paradigm and its four power principles of *Clarity of Focus, Expanded Opportunity, High Expectations* and *Design Down*. To achieve scientific constructive alignment of all key assignments a fundamental policy of utilizing unique assessments is rigorously followed. A significant reduction of work is achieved by avoiding the creation of additional assessments specifically for outcomes measurement through the design of curricular grade giving assessments that include scientific constructive alignment for realistic learning outcomes measurement [24,35]. While designing any assessment related to a specific course content the concerned engineering faculty members would consider measurement of the most appropriate performance criteria. For scientific constructive alignment the contribution of various performance criteria to the total score of an assessment would be defined during assessment design [24,35]. The performance criteria of interest to be measured by a specific assessment would be given a nearly 60% or more share in the total score distribution and the effect of grading results of the other performance criteria on the total score would be thus rendered negligible [24,35]. For cases where it is not possible to assign a nearly 60% or more share to a certain performance criterion in an entire assessment, the *Assignment Setup Module* of EvalTools® 6 is used to split a question or sub question of an assessment for achieving 60% high relative coverage of a specific performance criteria. Figure J5 indicates examples of implementation of the splitting of assessments to questions, sub questions using EvalTools® 6 *Assignment Setup Module* to obtain maximum relative coverage and measurement of a specific PI mapping to a certain CO and ABET SO.


Class: ME_211_2168 MATERIALS SCIENCE
Size: 13

Course Outcomes:

The existing defined assignments:

	Cognitive	Affective	Psychomotor
Count	6	6	11
Percent %	26.1	26.1	47.8

	Elementary	Intermediate	Advanced
Count	4	0	19
Percent %	17.4	0	82.6

Select	Assignment/ Activities/Events	Standards CO	Standards PI	Standards SO	No. of Submissions	Faculty Assigned Task
	HW-1	CO 1	abet_PI_5_58	abet_SO_5	student: 0; faculty: 14	fac_7197_HW-1.docx
	QZ-1	CO 1	abet_PI_5_58	abet_SO_5	student: 0; faculty: 14	fac_7197_Quiz_1.docx
	QZ-2	CO 2	abet_PI_11_5	abet_SO_11	student: 0; faculty: 14	fac_7197_QZ-2.docx
	HW-2	CO 2	abet_PI_11_25	abet_SO_11	student: 0; faculty: 13	fac_7197_HW-2.docx
	First Mid-Term Exam				student: 0; faculty: 14	fac_7197_Mid-1.docx
	First Mid-Term Exam-Part 1	CO 1	abet_PI_5_58	abet_SO_5	student: 0; faculty: 0	
	First Mid-Term Exam-Part 2 (Q1)	CO 2	abet_PI_11_5	abet_SO_11	student: 0; faculty: 0	
	First Mid-Term Exam-Part 2 (Q2)	CO 2	abet_PI_11_25	abet_SO_11	student: 0; faculty: 0	
	Lab Reort 1	CO 9	abet_PI_2_27	abet_SO_2	student: 0; faculty: 1	fac_6792_Manual_Tensile_test_Labreport-1.docx
	Lab Report 2	CO 9	abet_PI_2_28	abet_SO_2	student: 0; faculty: 4	fac_6792_Manual_Torsion_test_Lab_report_-2.docx
	Lab Report 3	CO 9	abet_PI_2_29	abet_SO_2	student: 0; faculty: 4	fac_6792_Manual_Impact_test_Lab_report-3.docx
	HW- 3	CO 3	abet_PI_1_20	abet_SO_1	student: 0; faculty: 10	fac_7197_HW-3.docx
	HW-4	CO 6	abet_PI_8_26	abet_SO_8	student: 0; faculty: 5	fac_7197_HW-4.docx
	QZ-3	CO 4	abet_PI_1_38	abet_SO_1	student: 0; faculty: 14	fac_7197_QZ-3.docx
	Lab Report-4	CO 9	abet_PI_2_30	abet_SO_2	student: 0; faculty: 4	fac_6792_Manual_Hardness_test_MS.docx
	QZ-4	CO 7	abet_PI_1_2	abet_SO_1	student: 0; faculty: 14	fac_7197_QZ-4.docx
	Second Mid-Term Exam				student: 0; faculty: 14	fac_7197_Mid-2.docx
	Second Mid-Term Exam- Part I	CO 3	abet_PI_1_20	abet_SO_1	student: 0; faculty: 0	
	Second Mid-Term Exam- Part II	CO 4	abet_PI_1_38	abet_SO_1	student: 0; faculty: 0	
	Second Mid-Term Exam- Part III	CO 5	abet_PI_8_9	abet_SO_8	student: 0; faculty: 0	
	Final Exam				student: 0; faculty: 14	fac_7197_Final.docx
	Final Exam - Part I	CO 5	abet_PI_8_9	abet_SO_8	student: 0; faculty: 0	
	Final Exam - Part II	CO 6	abet_PI_8_26	abet_SO_8	student: 0; faculty: 0	
	Final Exam - Part III	CO 7	abet_PI_1_2	abet_SO_1	student: 0; faculty: 0	
	Final Exam - Part IV (Q1)	CO 8	abet_PI_8_27	abet_SO_8	student: 0; faculty: 0	
	Final Exam - Part IV (Q2)	CO 8	abet_PI_8_27	abet_SO_8	student: 0; faculty: 0	

Figure J5. Assignment setup module of EvalTools ® for course ME_211 materials science

Such assessments or set of questions are said to be unique since they are just used once for the measurement of a certain PI. This methodology of implementing unique assessments with high relative coverage of PIs mapping to COs and ABET SOs would ensure realistic measurement of outcomes assessment data for comprehensive continuous improvement [24,35]. The program faculty generally align all activities/questions of major assignments such as Exams, Project Reports and in some cases even quizzes to outcomes. Figure J6 below shows such an example of a Final Exam coversheet for ME_211 Materials Science course offered in term 391 (Fall 2018). Questions 3 to 7 of the Final Exam are perfectly aligned to COs, their PIs and eventually to the ABET SOs. For Final Exam, Q5 with outcomes mapping index of [CO_5, PI_1_141_54, SO_1] as shown in Figure J6, the CO_5: *Calculate stress transformation on different planes in a member subjected to normal and shear loading;* uses [abet_PI_1_141] Psychomotor: Adaptation *Draw the stress transformation for plane stress condition in mechanical components using Mohr's circle graphically using geometrical instruments or AutoCAD; Extract the orientation and direction of the state of the stress from given element; compute the stress transformation for* *plane stress condition in mechanical components using Mohr's circle graphical method; extract the information related to principal stresses, orientation and direction of other stresses from the solution; determine the normal and shear stresses of given orientation*, to assess Q5.

Islamic University **Faculty of Engineering** **Department of Mechanical Engineering**		**الجامعة الإسلامية** **كليه الهندسة** **قسم الهندسة الميكانيكية**

ME 224 – Mechanics of Materials

Term-391 - Fall 2018

Grade

FINAL EXAM

Name, Family Name: ____

ID #:______________________ **Signature:** ______________

Instructions:

1. *Please do write in detail so that extra marks can be given to you.*
2. *For all questions illustration and additional pictures to support your explanation will earn extra marks.*
3. *Duration of this exam is TWO hour.*

Question. No.	Maximum Marks	Allotted Marks	Remarks
Short Questions			
1	4		
2	4		
Numerical			
3 [CO_3; PI_1_74; SO_1]	16		
4 [CO_4; PI_1_73; SO_1]	16		
5 [CO_5; PI_1_141; SO_1]	20		
6 [CO_6; PI_1_111; SO_1]	20		
7 [CO_6; PI_1_111; SO_1]	20		
	100		

Invigilator Signature	
Coordinator Signature	

Figure J6. ME_211 Materials science course showing scientific constructive alignment

The hybrid rubric for PI_1_141 is shown in Figure J7. Based on the percentage score distribution of [Step 1:10%, Step 2: 15%, Step 3: 50%, Step 4: 25%] allocated for the various steps of the rubric, the 4 steps of the problem in Final Exam Q5 (total score 20) acquire a score distribution of 2,3,10 and 5 respectively.

Figure J8 indicates an instructor's structured marking using hybrid rubric for PI_1_141 on an uploaded digital copy in EvalTools ® of a student's ME_211 Materials Science course final exam sheet for Q5. The student achieves an Excellent performance on the EAMU scale using the rubric for PI_1_141. 2,3,10 and 4 points are marked with red ink by the instructor on the answer sheet for Final Exam Q5 for grading student performance as per the description of 4 major steps for each scale of the rubric

Choose an Assignment/Quiz for Grading: Final Exam: Q5 Select >>

Key Assignment: Yes

Grading Criteria:

PI	E	A	M	U
abet_PI_1_141:Draw the stress transformation for plane stress condition in mechanical components using Mohr's circle graphically using geometrical instruments or AutoCAD; Extract the orientation and direction of the state of the stress from given element; compute the stress transformation for plane stress condition in mechanical components using Mohr's circle graphical method; extract the information related to principal stresses, orientation and direction of other stresses from the solution; determine the normal and shear stresses of given orientation	**Excellent (90-100%)** (10%) Accurately extract the orientation and direction of the state of stress from the given element in the problem. (15%) Accurately mark stresses on the graph paper indicating different orientation with proper signs. (50%) Accurately draw a neatly labeled Mohr's circle on a scaled x-axis and y-axis. (25%) Accurately extract and represent on the plot values and direction for the Principle, average, maximum and minimum normal and shear stresses. Accurately extract and represent the unknown parameters in Mohr's circle (stress values at some different orientation of the element)*. *If required in the question	**Adequate (75-89%)** (10%) Accurately extract the orientation and direction of the state of stress from the given element in the problem. (15%) Accurately mark stresses on the graph paper indicating different orientation with proper signs. (50%) Accurately draw a neatly labeled Mohr's circle on a scaled x-axis and y-axis. (25%) Minor errors to extract and represent on the plot values and direction for the Principle, average, maximum and minimum normal and shear stresses. Minor errors to extract and represent the unknown parameters in Mohr's circle (stress values at some different orientation of the element)*. *If required in the question	**Minimal (60-75%)** (10%) Accurately extract the orientation and direction of the state of stress from the given element in the problem. (15%) Accurately mark stresses on the graph paper indicating different orientation with proper signs. (50%) Minor errors to draw a neatly labeled Mohr's circle on a scaled x-axis and y-axis. (25%) Multiple errors to extract and represent on the plot values and direction for the Principle, average, maximum and minimum normal and shear stresses. Multiple errors to extract and represent the unknown parameters in Mohr's circle (stress values at some different orientation of the element)*. *If required in the question	**Unsatisfactory (0-60%)** (10%) Major errors to extract the orientation and direction of the state of stress from the given element in the problem. AND/OR (15%) Major errors to mark stresses on the graph paper indicating different orientation with proper signs. AND/OR (50%) Major errors to draw a neatly labeled Mohr's circle on a scaled x-axis and y-axis. AND/OR (25%) Major errors to extract and represent on the plot values and direction for the Principle, average, maximum and minimum normal and shear stresses. Major errors to extract and represent the unknown parameters in Mohr's circle (stress values at some different orientation of the element)*. *If required in the question

Figure J7. Hybrid rubric for PI_1_141 shown as grading criteria for Final Exam Q5 in EvalTools® for ME_211 Materials Science course offered term 391 Fall 2018

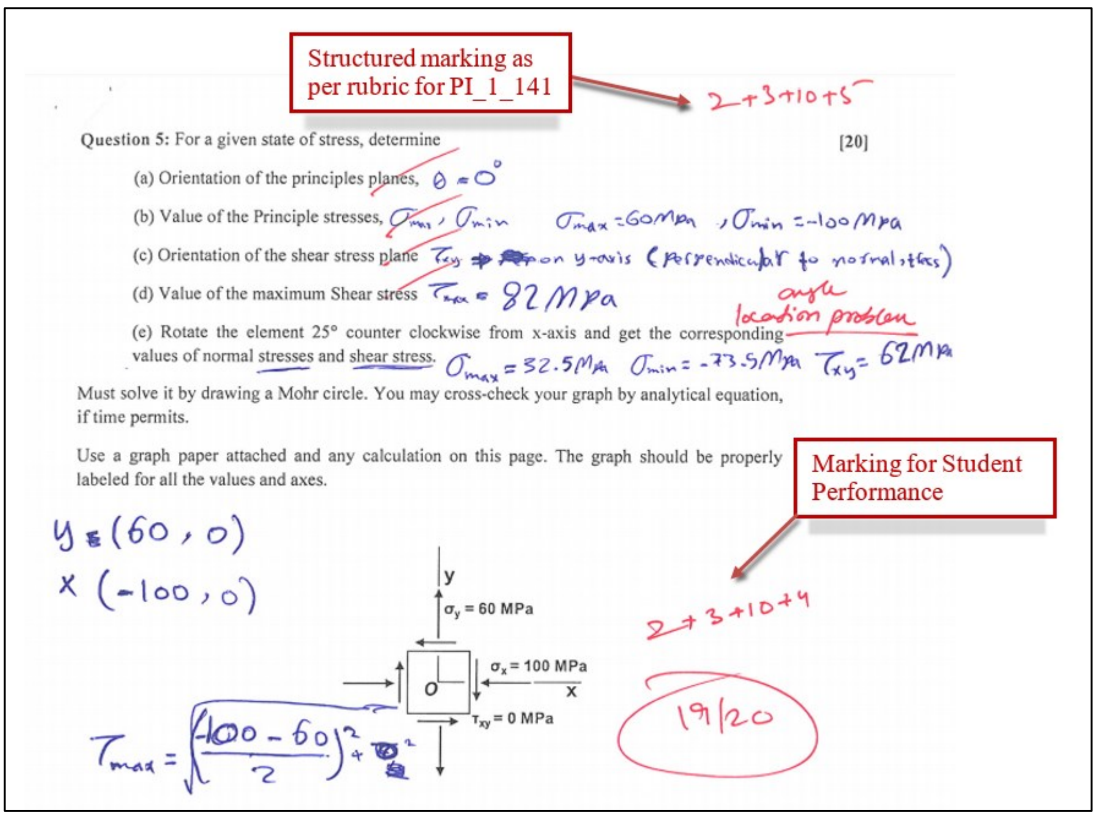


Figure J8. Instructor marking as per hybrid rubric for PI_1_141 shown on student answer sheet for Final Exam Q5 uploaded as digital copy in EvalTools ® for ME_211 Materials Science course.

iv. COURSE LEVEL IMPLEMENTATION OF IDEAL LEARNING DISTRIBUTION

Figure 5 in *Section IV.A.3 Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology*; *Ideal Learning Distribution*, indicates the ideal learning distribution model applied to courses at the Faculty of Engineering programs. Introductory, Reinforced and Mastery courses exhibit progressive learning as per Bloom's taxonomic model. The ME_312 Machine Design course is considered here to indicate efforts of faculty members in designing outcomes, instruction and assessment that implement an ideal learning distribution. This course covers various student learning activities corresponding to Bloom's three domains and their learning levels. As shown in Table J8, the ME_312 Machine Design-**I** course consists of theoretical concepts related to analysis and design (cognitive domain), observing and explaining various engineering standards and codes in design activity (affective domain) as well as experimentation in practical laboratory work (psychomotor domain).

Table J8. ME_312 Machine Design-I course COs, PIs and revised ABET SOs (1-7)

Class: ME_312 - Machine Design - I	
CO 1 UNDERSTANDING THEORY	**Define** the various kinds of stresses in machine components
[abet_PI_4_12] Affective: Organize values into priorities	Explain design considerations, standards and codes; elaborate on standardization in design; discuss quality assurance standards related to International Standards Organization (ISO), Saudi Standards, Metrology and Quality Organization (SASO), American Iron and Steel Institute (AISI), Society of Automotive Engineers (SAE), American Society for Testing and Materials (ASTM), American Society of Mechanical Engineers (ASME) and American Welding Society (AWS D1:1); Dutch International Norm (DIN); Japanese Industrial Standards(JIS) etc.
[abet_PI_1_144] Cognitive: Analyzing	Analyze loads acting on given machine components to calculate the various types of static stresses (normal, shear, bending, torsion) and fatigue stresses (fluctuating, repeated, alternating); plot stress-strain diagrams whenever necessary;
CO 2 ANALYSIS	**Analyze** the stresses in circular components of machines for axial, bending and torsion loading
[abet_PI_1_71] Cognitive: Analyzing	Analyze given tensile, compressive, bending, torsion or shear forces in mechanical systems for given loading conditions; obtain neatly labeled diagrams to represent forces (magnitude and direction) and areas; calculate appropriate perpendicular/parallel area for normal and shear stresses; compute normal and/or shear stresses
CO 3 DESIGN	**Design** machine components by application of accepted failure theories to prevent the conditions leading to static failures.
[abet_PI_2_3] Cognitive: Creating	Design machine components by considering their appropriate size and/or safety factor to prevent static failures by application of accepted failure theories such as maximum distortion, maximum shear stress, maximum normal stress etc.; apply stress concentration factor in the final design.
CO 4 DESIGN	Design machine components by application of accepted failure theories to prevent the conditions leading fatigue failures.
[abet_PI_2_1] Cognitive: Creating	Design machine components by considering their appropriate size and/or safety factor and/or expected remaining life to prevent fatigue failures by application of accepted failure theories (mod-Goodman); apply the endurance limit modifying factors (surface condition, size, load , temperature, reliability, stress concentration factor) to the final design.
CO 5 ANALYSIS	**Analyze** bending moment and shear forces to determine appropriate diameter of shaft.
[abet_PI_2_42] Cognitive: Analyzing	Calculate the appropriate diameter of shaft by analyzing the bending moment and shear forces for combined loading; obtain the loads, reactions and stresses; select the critical section; calculate the minimum diameter of the shaft to withstand given loads
CO 6 ANALYSIS	**Calculate** appropriate size on weld for given loading conditions.
[abet_PI_2_50] Psychomotor: Adaptation	Produce or interpret detailed drawings, symbols and notations for a given welded joints according to international standards and codes; provide complete details for joint types (T, lap, corner, fillet etc.), process (SMAW, TIG, MIG, MAG etc.), location, sequence (on field, all around, strips) dimensions and inspection methods.
[abet_PI_2_32] Affective: Internalizing values	Draw and Design welded joint for given structural loading conditions; identify appropriate technical data from the American Welding Society [(AWS) code D:1.1] to determine the appropriate design conditions to calculate the type and size for weld to withstand given applied loadings without failure
CO 7 ANALYSIS	**Calculate** load and stress on fasteners to determine their appropriate sizes.
[abet_PI_1_79] Cognitive: Analyzing	Calculate load and stress on given fasteners to determine the dimensions of the fastener and/or safety factor for applied loading conditions; determine the appropriate sizes and type of threads for the nut and bolt; and provide neatly labeled sketches wherever necessary
[abet_PI_1_80] Cognitive: Analyzing	Analyze the power screws like c-clamp, swivel vice, screw jack for raising the applied loads; calculate the required torque to raise and lower the applied load; evaluate the efficiency, stresses in threads of the power screw

Table J9 shown below lists all the key assignments of the course ME_312 Machine Design-I to be used as an objective evidence. Each key assignment is classified as a unique assessment when mapped to a single CO, PI and ABET SO.

Since assessments in outcome based education models indicate the level of learning, learning distribution in the course is estimated by utilizing the counts of assessments processed in each learning level of the three learning domains cognitive, affective and psychomotor [25,41, 90]. Table J10indicates 16, 2 and 2 assessments processed in the Cognitive, Affective and Psychomotor domains, respectively. It also indicates 3, 8 and 9 assessments processed in the Elementary, Intermediate and Advanced learning levels according to the *3-Levels Skills Grouping Methodology*. The pie charts (Figure J9) display learning domains distribution information extracted real time from the course assessment and learning activity. Therefore, they provide an excellent source of formative information for improving pedagogy to achieve holistic learning. As per the ideal learning distribution model the ME 312 Machine Design-I course is at a reinforced level of learning and therefore it appropriately exhibits an acceptable distribution of elementary, intermediate, and advanced level skills covering all three domains of Bloom's learning.

Table J9. List of all key assignments for the course ME-312 Machine Design-I

Key Assignments	Outcomes		
	CO	PI	SO
HW-1	CO 1	abet_PI_1_144	abet_SO_1
QZ-1	CO 2	abet_PI_1_71	abet_SO_1
HW-2	CO 3	abet_PI_2_3	abet_SO_2
QZ-2	CO 3	abet_PI_2_3	abet_SO_2
First Mid-Term Exam			
First Mid-Term Exam- Q 1	CO 1	abet_PI_4_12	abet_SO_4
First Mid-Term Exam- Q 2 & Q 3	CO 1	abet_PI_1_144	abet_SO_1
First Mid-Term Exam- Q 4	CO 2	abet_PI_1_71	abet_SO_1
First Mid-Term Exam- Q 5 & Q 6	CO 3	abet_PI_2_3	abet_SO_2
QZ_3	CO 6	abet_PI_2_50	abet_SO_2
HW_3	CO 5	abet_PI_2_42	abet_SO_2
HW-4	CO 7	abet_PI_1_79	abet_SO_1
QZ-4	CO 7	abet_PI_1_80	abet_SO_1
Second Mid-Term Exam			
Second Mid-Term Exam- Part I	CO 4	abet_PI_2_1	abet_SO_2
Second Mid-Term Exam- Part II	CO 5	abet_PI_2_42	abet_SO_2
Final Exam			
Final Exam Part I	CO 5	abet_PI_2_42	abet_SO_2
Final Exam Part II	CO 6	abet_PI_2_32	abet_SO_2
Final Exam Part III	CO 6	abet_PI_2_50	abet_SO_2
Final Exam Part IV	CO 7	abet_PI_1_79	abet_SO_1
Final Exam Part V	CO 7	abet_PI_1_80	abet_SO_1

Table J10. Summary of assignment distributions, ME-312 Machine Design-I course

	Cognitive	Affective	Psychomotor
Count	16	2	2
Percent %	80	10	10

	Elementary	Intermediate	Advanced
Count	3	8	9
Percent %	15	40	45

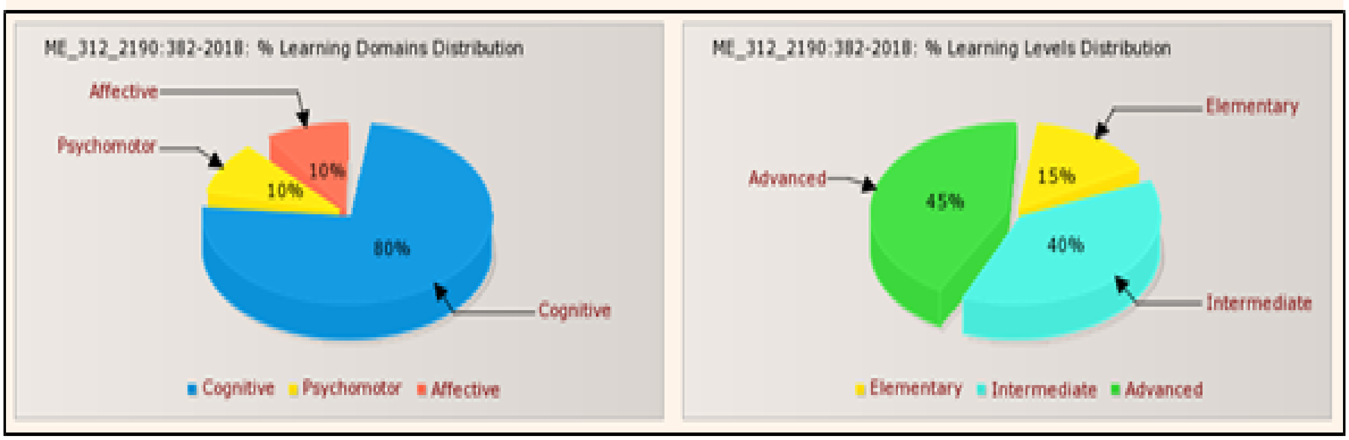


Figure J9. Pie charts showing learning domains distribution in ME 312 Machine Design–I course

v. COURSE SAMPLES OF PIs MODIFICATIONS CE, ME AND EE PROGRAMS

As explained in the earlier section, faculty members perform detailed evaluations of student performance in their courses. On the basis of suggested improvement actions resulting from comprehensive course and program evaluations modifications may be implemented in the course inputs such as learning activities, course topics, assessments etc. Such modifications necessitate appropriate changes to COs, PIs and their hybrid rubrics. The examples in Table J11 indicate such cases of modifications made by faculty members to COs, PIs for their courses.

Table J11. Modifications to PIs made by instructors of CE, EE and ME programs

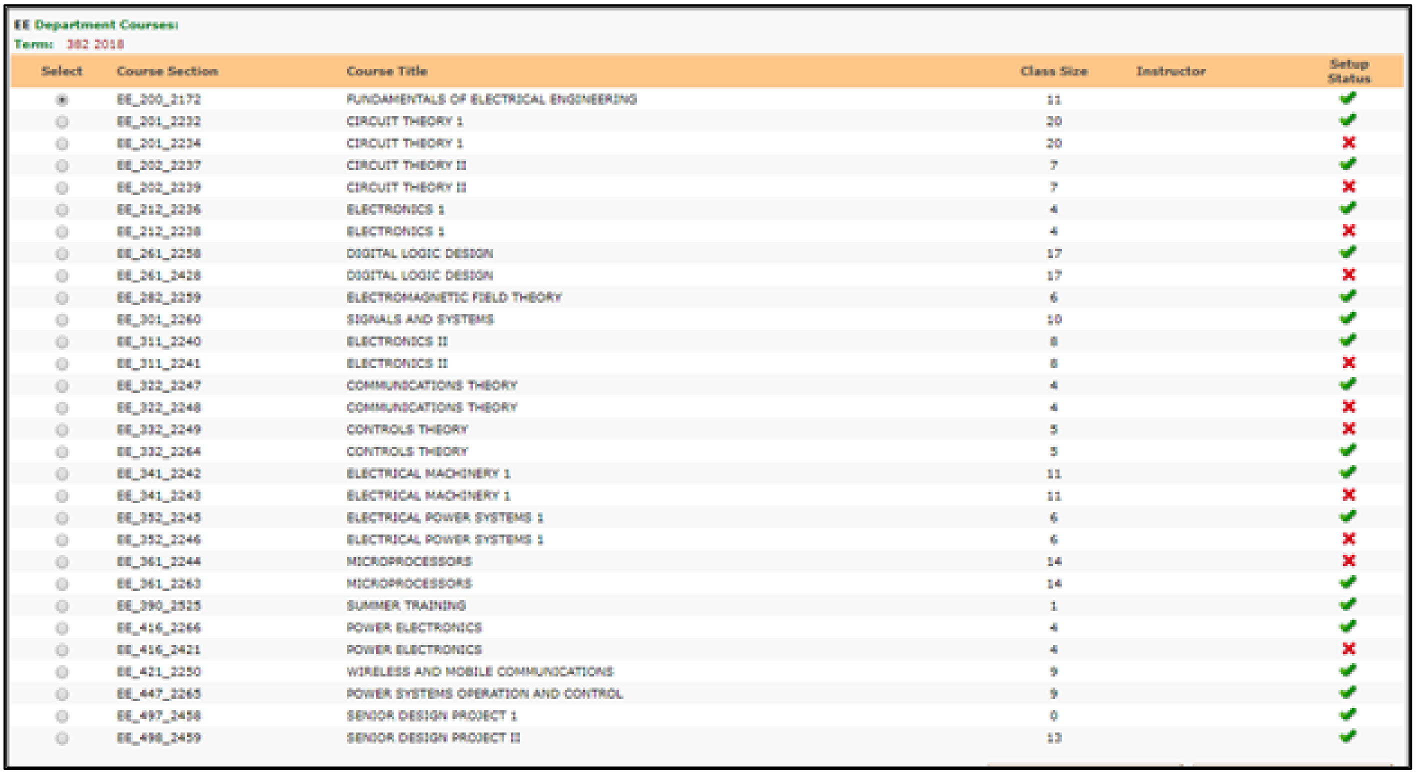
Instructor	Course	Original PI	Modified PI	Justification
Q. U. F.	CE_312 Soil Mechanics	Term 381 (FS 2017); abet_PI_1_47: Explain the soil site exploration methods or collecting/searching information for a desk study, name tools or equipment for site investigation works	Term 382 (SS 2018); abet_PI_1_47: Explain the soil site exploration methods such as percussion, boring, rotary drilling, auger boring etc.; elaborate the collecting/searching information for a desk study; name tools or equipment for site investigation works	PI_1_47 was improved in term 382 to explain site investigation works and its data collection
N. M. T.	CE_201_1017 Statics	Term 381 (FS 2017); abet_PI_1_17: Describe the fundamentals of engineering mechanics (statics and dynamics), system of units; center of gravity, moment of inertia, shear force, bending moment; abet_PI_1_36: Differentiate between mass and weight and/or perform elementary unit conversions	Term 382 (SS 2018); abet_PI_1_17: Describe the fundamentals of engineering mechanics (statics and dynamics), system of units; Newton's Laws of motion; center of gravity, moment of inertia, shear force and bending moment; differentiate between mass and weight and/or perform elementary unit conversions	PI_1_17 was modified in Term 382 to include topic related to Newton's Laws of motion; content of an additional PI_1_36 was combined with PI_1_17.
N. M. T.	CE_201_1017 Statics	Term 381 (FS 2017); abet_PI_5_18: Compute the sectional properties like centroid, moment of inertia, stiffness, flexural rigidity and moment of resistance for beams of different shapes.	Term 382 (SS 2018); abet_PI_5_18: Determine the geometric properties for different cross sections such as circular, rectangular, rods, wide flanges, channels, angles, tees, etc.; compute centroid, first moment, second moment of inertia, polar moment of inertia, radius of gyration, sectional modulus and plastic modulus	Abet_PI_5_18 was generalized in term 382 to determine geometric properties for various cross sections.
O. H.	CE_321 Structural Analysis I	Term 381 (FS 2017); abet_PI_11_38: Analyze determinate structures using the slope deflection methods	Term 382 (SS 2018); abet_PI_11_38: Analyze determinate structures using the slope deflection methods; calculate the support reactions, shear force and bending moment force; draw neatly labeled shear forces and bending moment diagrams.	PI_11_38 was modified in term 382 and different steps of slope deflection method were added.
K. S. Z.	ME_222_1087 Dynamics	Term 381 (FS 2017); [abet_PI_1_28]: Calculate for given problems the coefficients of restitution, forces and momentum; classify the impact (elastic or plastic) and determine the related energy losses	Term 382 (SS 2018); [abet_PI_1_28]: Explain concepts of Linear Impulse and linear momentum; the coefficients of restitution, forces and momentum; define elastic or plastic impact and related energy losses	PI_1_28 was improved in term 382 to explain details of the linear impulse and linear momentum.
BM. A. S.	ME_471_2202 Renewable Energy	Term 381 (FS 2017); [abet_PI_8_11]: Explain wind power technology including wind farms, their construction, installation and power generation systems	Term 382 (SS 2018) [abet_PI_8_11]: Explain wind power technology including wind farms, their construction, installation and power generation systems with respect to impact on environment, society, safety and health, economy etc.	PI_8_11 was improved in term 382 to include wider aspects of the wind power technology.
B. M.	ME_346_2192 Heat Transfer	Term 381 (FS 2017); [abet_PI_2_22]: Study heat conduction and find thermal conductivity of a material.	Term 382 (SS 2018); [abet_PI_2_22]: Setup the heat conduction apparatus to determine thermal conductivity of various materials; adjust the setting of the electric heater; observe temperature readings at multiple positions through the length of the material to determine the temperature gradient and thermal conductivity	PI_2_22 was improved in term 382 to include details of the experimental setup.
M. E.	ME_431_2196 Industrial Management	Term 381 (FS 2017); [abet_PI_5_82]: Cognitive: Evaluating Calculate the elements of major models of	Term 382 (SS 2018); [abet_PI_5_82]: Cognitive: Evaluating Identify variables for data corresponding to given inventory control systems;	PI_5_82 was improved in term 382 to update specific details.

		inventory control systems such as Economic Order Quantity (EOQ) and reorder point, for a given data.	convert the variable data to appropriate units for the Economic Order Quantity (EOQ) equation; determine the EOQ and hence the reorder point;	
AW. M.	EE_212_2236 Electronics 1	Term 381 (FS 2017); abet_PI_1_74: Illustrate and explain the operation and characteristics of Zener diode, photo diode and light-emitting diode circuits	Term 382 (SS 2018); abet_PI_1_74: Illustrate and explain the operation and characteristics of Zener diode; describe breakdown region, Peak Inverse Voltage (PIV); elaborate its use and applications; provide neat diagrams wherever necessary.	PI_1_74 was improved in term 382 to illustrate and explain the characteristics of Zener diode, its breakdown voltage and related parameters.
A. C.	EE_311_2240 Electronics II	Term 381 (FS 2017); abet_PI_5_37: Analyze the frequency response of transistor circuits with capacitors.	Term 382 (SS 2018); abet_PI_5_37: Determine the frequency response of BJT/MOSFET/JFET transistor circuits with capacitors (bypass, coupling); Analyze given BJT/MOSFET/JFET transistor circuits; write the transfer function; calculate the cut off frequency for coupling and bypass capacitors; and draw neatly labeled bode plots indicating cut off frequency, roll off etc.	PI_5_37 was modified in term 382 to include frequency response of BJT/MOSFET/JFET transistor circuits with capacitors. Furthermore, BJT/MOSFET/JFET transistor circuits, its transfer function, cut off frequency calculation and drawing of bode plots are also included.
K. B. M	EE_322_2247 Communications Theory	Term 381 (FS 2017); abet_PI_5_56: Analyze AM switching, multiplier, non-linear, modulators and demodulators.	Term 382 (SS 2018); abet_PI_5_56: Analyze AM switching, multiplier, non-linear, modulators and demodulators; draw neatly labeled block diagrams of AM modulators clearly indicating all components, input and output signals; obtain required parameters such as local oscillator frequency, image frequency, modulated or demodulated output signal amplitude etc.	PI_5_56 was improved and detailed information related to AM modulators, input and output signals and parameters like local oscillator frequency, image frequency, modulated or demodulated output signal amplitude etc. were added.
M. J.	EE_332_2264 Controls Theory	Term 381 (FS 2017); abet_PI_11_17: Use analytical and numerical techniques and computerized simulation tools, such as Matlab software (or equivalent), to investigate the performance of linear or non-linear control systems and examine their operating behavior	Term 382 (SS 2018); abet_PI_11_17: Use analytical and numerical techniques and computerized simulation tools, such as Matlab software or equivalent, to investigate the performance of linear or non-linear control systems and examine their operating behavior; develop Simulink model by selecting appropriate components from the MATLAB toolbox; develop layout of the system as per specifications; select simulation time, solver and other parameters to run simulation; analyze output using scope or plot required graphs.	PI_11_17 was modified in term 382 and details related to linear or non-linear control systems and their Simulink model and simulation time were added.

2. *PDCA QUALITY CYCLE Q2: SYLLABI CHECKLIST, FCAR CHECKLIST, END OF TERM (EOT) CHECKLIST*

i. SYLLABI CHECKLIST TERM 382 (2ND WEEK OF EVERY TERM)

The purpose of the syllabi checklist is to ensure the course syllabi are submitted to students in the first week of the term and contain accurate and updated information regarding course descriptions, pre-requisites/co-requisites, reference texts, COs, lecture outline, teaching learning strategies, class and grading policy, assessment information, etc. Figure J10 below shows how EvalTools® 6 syllabi checklist module streamlines efforts for verifying completion of major items in the programs' course syllabi.


EE Department Courses:
Term: 382 2018

Select	Course Section	Course Title	Class Size	Instructor	Setup Status
◉	EE_200_2172	FUNDAMENTALS OF ELECTRICAL ENGINEERING	11		✔
○	EE_201_2232	CIRCUIT THEORY 1	20		✔
○	EE_201_2234	CIRCUIT THEORY 1	20		✘
○	EE_202_2237	CIRCUIT THEORY II	7		✔
○	EE_202_2239	CIRCUIT THEORY II	7		✘
○	EE_212_2236	ELECTRONICS 1	4		✔
○	EE_212_2238	ELECTRONICS 1	4		✘
○	EE_261_2258	DIGITAL LOGIC DESIGN	17		✔
○	EE_261_2428	DIGITAL LOGIC DESIGN	17		✘
○	EE_282_2259	ELECTROMAGNETIC FIELD THEORY	6		✔
○	EE_301_2260	SIGNALS AND SYSTEMS	10		✔
○	EE_311_2240	ELECTRONICS II	8		✔
○	EE_311_2241	ELECTRONICS II	8		✘
○	EE_322_2247	COMMUNICATIONS THEORY	4		✔
○	EE_322_2248	COMMUNICATIONS THEORY	4		✘
○	EE_332_2249	CONTROLS THEORY	5		✘
○	EE_332_2264	CONTROLS THEORY	5		✔
○	EE_341_2242	ELECTRICAL MACHINERY 1	11		✔
○	EE_341_2243	ELECTRICAL MACHINERY 1	11		✘
○	EE_352_2245	ELECTRICAL POWER SYSTEMS 1	6		✔
○	EE_352_2246	ELECTRICAL POWER SYSTEMS 1	6		✘
○	EE_361_2244	MICROPROCESSORS	14		✘
○	EE_361_2263	MICROPROCESSORS	14		✔
○	EE_390_2525	SUMMER TRAINING	1		✔
○	EE_416_2266	POWER ELECTRONICS	4		✔
○	EE_416_2421	POWER ELECTRONICS	4		✘
○	EE_421_2250	WIRELESS AND MOBILE COMMUNICATIONS	9		✔
○	EE_447_2265	POWER SYSTEMS OPERATION AND CONTROL	9		✔
○	EE_497_2458	SENIOR DESIGN PROJECT 1	0		✔
○	EE_498_2459	SENIOR DESIGN PROJECT II	13		✔

Figure J10. **EvalTools® 6 syllabi checklist module showing the status of EE program course syllabi completion**

ii. MIDTERM FCAR CHECKLIST AUDIT

The audit for fulfillment of a midterm FCAR checklist, as shown in Figure J11, is conducted after the first mid-term exam in the 9-10th week of every term and ensures completion of 8 items for all courses offered in a given term:

a) Score Entry/document uploading for Home Works (HW1, HW2);
b) Score Entry/document uploading for Quizzes (QZ 1, QZ 2) and Midterm_1 exam;
c) Program's standardized assignment nomenclature should be followed for 2 HWs, 2 QZs and MT_1;
d) PIs mappings with unique assessment completed for 2 HWs, 2 QZs and MT_1;
e) Weighting factors programming should be completed for 2 HWs, 2 QZs and MT_1;
f) Grade book completed for 2 HWs;
g) Reflections/Action Items for categorical failures (all old action items should be ported into the FCAR in EvalTools ® and followed up for closure);
h) Any modification required/done in teaching strategy, course contents and/or course outcomes based on categorical failures should be documented; and

ABET coordinators provide orientations every term to ensure all faculty members understand the course completion requirements of the 8-point FCAR checklist audit. Regular reminders are made in program council meetings, through official email and any requests for training sessions with the QA office are also scheduled when needed.

FACULTY OF ENGINEERING

MIDTERM (AFTER TEN WEEKS) PROGRAM ACCREDITATION WORK ASSESSMENT REPORT

PROGRAM COORDINATO Chattha

TERM: 382

ABET COORDINATOR: Dr Mahmood

SO_ NO.	Activity / action related to ABET SOs	EE 200 Fund. of Electrical Eng.	EE 201 Circuit Theory 1	EE 202 Circuit Theory II	EE 212 Electronics I	EE 261 Digital Logic Design	EE 282 Electromagnetic Field Theory	EE 301 Signals & Systems	EE 311 Electronics II	EE 322 Communication Theory	EE 332 Controls Theory	EE 341 Electrical Machinary 1	EE 352 Electrical Power system 1	EE 361 Microprocessors	EE 41 Elec
1	HomeWorks Uploaded (HW1, HW2)	HW2 Not Uploaded	Yes	Yes	Yes	Yes	Yes	Yes	HW1& HW2 marks will be entered shortly	Yes	Yes	Yes	Yes	Yes	
2	Quizs (QZ1, QZ2) and Midterm_1 Uploaded	QZ2 Not Uploaded	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
3	Program's standardized assignment nomenclature followed for 2 HWs, 2 QZs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
4	Are PIs mappings with unique assessment done for 2 HWs, 2 QZs and MT_1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
5	Are Weighting factors completed for 2 HWs, 2 QZs and MT_1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
6	Is the grade book completed for 2 HWs, 2 QZs and MT_1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
7	Any modification required / done in teaching strategy, course contents and / or course outcomes based on categorical failures	No	No	No	No	No	No	No	No	No	No	No	No	No	

Figure J11. **Portion of midterm FCAR checklist for EE program term 382 (Spring 2018)**

iii. FCAR CHECKLIST SAMPLE

Figure J12 shows an authenticated scanned copy of the FCAR checklist, filled by a faculty member for the EE 261 Digital Logic Design course, term 391 (Fall 2018). The ABET coordinator verifies the information in the checklist by performing an online audit of course work using EvalTools® 6. The FCAR checklist, once verified for completion, is then authenticated by the ABET and Program Coordinators. The FCAR checklists of all courses in the program are then collected together to extract critical information to complete the program EOT forms. In Figure J13, is presented the excel version for better reading of all the 22 items in the questionnaire presented as requirements to each faculty member for course completion by end of each term.

FACULTY OF ENGINEERING: FCAR CHECKLIST

FACULTY: TERM: 391

COURSE TITLE: Digital Logic Design COURSE CODE: EE 261

NO	FCAR ITEMS	STATUS	COMMENTS
1	Major syllabus items completion date	Sep-18	
2	Are the lecture topics with dates completed?	Y	
3	Is the University Grading Policy Entered?	Y	
4	Is the course description written per ABET standards?	Y	
5	Are COs covering major topics according to sequence of lecture delivery (6 to 14)	Y	
6	Do COs consist of measurable action verbs (Bloom's), subject content, generic (not targeting theory/practicals) with proper coverage of elem, inter and adv levels?	Y	
7	Are the Old action items ported, closed and course modified accordingly?	Y	
8	Are assessment methods complete?	Y	
9	Are teaching & learning strategies related to selected assessments defined?	Y	
10	PIs for theretical assignments,lab, project, reports, presentation (cognitive, affective & psychomotor); Same Elem, Inter or Adv level as COs (enter status)	Y	
11	Is this course covering certain assigned affective domain SOs this term? If so are the PIs and assessment tools defined for this SO?	Y	
12	Program's standardized assignment nomenclature followed	Y	
13	Are the COs synchronized and course exit surveys completed?	Y	
14	Are the Faculty self evaluations completed?	Y	
15	Are PIs mappings with unique assessment done sequentially as the assignments submitted or in the last week? (enter status)	Y	
16	Are Weighting factors completed sequentially or all at once?	Y	
17	Are the course reflections entered?	Y	
18	Are the course AIs entered and matching reflections	Y	
NO	**CQI**	**STATUS**	**COMMENTS**
1	AIs followed for closure?(enter status)	Y	
2	FCAR reviewed in formative mode?	Y	
3	Any modifications in course teaching and learning strategy during course delivery? (enter status)	N	
4	Any modifications in COs during course delivery? (enter status)	N	

Notes and signature by Faculty: Course has been instructed followed by the required ABET standard

19/12/2018

Notes and Signature by ABET Coordinator:

Course checked

Signed Program Coordinator:

Figure J12. **Authenticated copy of FCAR checklist for EE_261 digital logic design course**

FACULTY OF ENGINEERING: FCAR CHECKLIST

FACULTY: | TERM: 391

COURSE TITLE: | COURSE CODE: EE 261

NO	FCAR ITEMS	STATUS	COMMENTS
1	Major syllabus items completion date	Sep-18	
2	Are the lecture topics with dates completed?	Y	
3	Is the University Grading Policy Entered?	Y	
4	Is the course description written per ABET standards?	Y	
5	Are COs covering major topics according to sequence of lecture delivery (6to 14)	Y	
6	Do COs consist of measurable action verbs (Bloom's), subject content, generic (not targeting theory/practicals) with proper coverage of elem, inter and adv levels?	Y	
7	Are the Old action items ported, closed and course modified accordingly?	Y	
8	Are assessment methods complete?	Y	
9	Are teaching & learning strategies related to selected assessments defined?	Y	
10	PIs for theretical assignments,lab, project, reports, presentation (cognitive, affective & psychomotor); Same Elem, Inter or Adv level as COs (enter status)	Y	
11	Is this course covering certain assigned affective domain SOs this term? If so are the PIs and assessment tools defined for this SO?	y	
12	Program's standardized assignment nomenclature followed	Y/N	
13	Are the COs synchronized and course exit surveys completed?	Y/N	
14	Are the Faculty self evaluations completed?	Y/N	
15	Are PIs mappings with unique assessment done sequentially as the assignments submitted or in the last week? (enter status)	Y/N	
16	Are Weighting factors completed sequentially or all at once?	Y/N	
17	Are the course reflections entered?	Y/N	
18	Are the course AIs entered and matching reflections	Y/N	
NO	**CQI**	**STATUS**	**COMMENTS**
1	AIs followed for closure?(enter status)	Y/N	
2	FCAR reviewed in formative mode?	Y/N	
3	Any modifications in course teaching and learning strategy during course delivery? (enter status)	Y/N	
4	Any modifications in COs during course delivery? (enter status)	Y/N	

Notes and signature by Faculty:

Notes and Signature by ABET Coordinator:

Signed Program Coordinator:

Figure J13. Excel version of FCAR checklist for EE_261 digital logic design course

iv. END OF TERM FORM (EOT) FOR TERM 381 (FS 2017)

The program EOT form is an excellent tool for quality monitoring purposes (See Table J12). It summarizes all the major items necessary for completing course work in any given term. It provides critical information from all courses offered by the program in a given term and facilitates quick failure analysis and remediation. Once all the course work is fully completed the EOT form is approved by the QA office and finally authenticated by the supervisor of QD. A copy of the authenticated EOT form is reported in EvalTools® 6. The final approval and authentication of the EOT clears the way for the program to proceed to program term evaluation.

Table J12. **Portion of EOT form for EE program**

FACULTY OF ENGINEERING PROGRAM ACCREDITATION WORK ASSESSMENT INSTRUMENT

Program End of Term Faculty Accreditation Work Assessment Form[1]

Course Information	FCAR*	Graded Work**	Comments
Title: FUNDAMENTALS OF ELECTRICAL ENGINEERING Code: EE 200 Section: 2172 Faculty: Dr. M A Lecturer: Engr. M M	☑ Syllabus complete ☑ Lessons uploaded ☑ Course exit surveys completed ☑ COs, PIs format followed ☑ Weighting Factors complete ☑ Comprehensive PIs Mapping ☑ Reflections & AIs complete ☑ Continuous Improvement ☑ Self-Evaluations complete ☐ Affective domain SOs assessment ☑ Grade Book complete	☑ All Assignments Uploaded ☑ Proper Naming Format ☑ Proper Orientation ☑ One-One Correspondence ☑ Scores Entered ☑ On Time submission ☑ On Time uploading	No Affective domain SOs are assigned for this course since it's the fundamental course.
Title: CIRCUIT THEORY 1 Code: EE 201 Section: 2232 Faculty: Dr. M U Lecturer : Engr. N S	☑ Syllabus complete ☑ Lessons uploaded ☑ Course exit surveys completed ☑ COs, PIs format followed ☑ Weighting Factors complete ☑ Comprehensive PIs Mapping ☑ Reflections & AIs complete ☑ Continuous Improvement ☑ Self-Evaluations complete ☑ Affective domain SOs assessment ☑ Grade Book complete	☑ All Assignments Uploaded ☑ Proper Naming Format ☑ Proper Orientation ☑ One-One Correspondence ☑ Scores Entered ☑ On Time submission ☑ On Time uploading	Self-Evaluations Missing
Title: CIRCUIT THEORY II Code: EE 202 Section: 2237 Faculty: Dr. M U Lecturer : Engr. N S	☑ Syllabus complete ☑ Lessons uploaded ☑ Course exit surveys completed ☑ COs, PIs format followed ☑ Weighting Factors complete ☑ Comprehensive PIs Mapping ☑ Reflections & AIs complete ☑ Continuous Improvement ☑ Self-Evaluations complete ☑ Affective domain SOs assessment ☑ Grade Book complete	☑ All Assignments Uploaded ☑ Proper Naming Format ☑ Proper Orientation ☑ One-One Correspondence ☑ Scores Entered ☑ On Time submission ☑ On Time uploading	Nil
Title: ELECTRONICS 1 Code: EE 212 Section: 2236	☑ Syllabus complete ☑ Lessons uploaded ☑ Course exit surveys completed	☑ All Assignments Uploaded ☑ Proper Naming Format ☑ Proper Orientation	Nil

Faculty: **Dr. A W M** Lecturer : Engr. S R T	☑ COs, PIs format followed ☑ Weighting Factors complete ☑ Comprehensive PIs Mapping ☑ Reflections & AIs complete ☑ Continuous Improvement ☑ Self-Evaluations complete ☑ Affective domain SOs assessment ☑ Grade Book complete	☑ One-One Correspondence ☑ Scores Entered ☑ On Time submission ☑ On Time uploading	

V. COURSE LEVEL EVALUATION AND CQI

Faculty members electronically port old action items status details from previous offerings of a certain course into the current FCAR. Modifications and proposals to a course are made with consideration of the status of the old action items. Program faculty report failing COs, their associated PIs, ABET SOs, comments on student indirect assessments and other general issues of concern in the respective course reflections section of the FCAR. Based upon these course reflections, new action items are proposed by the faculty. The course reflections and action items maintain headings related to format CO_N1; PI_N2_N3; SO_N2; where N1: CO index; N2: ABET SO index (1 being 'a' and 11 being 'k'; or 1-7 for revised ABET SOs); and N3: PI index. Additionally, course reflections have to also mention the failing assessments in abbreviated form.

Figure J14 shows for a EE course EE_416, Power Electronics, the CO_5: "*Examine the performance of the given thyristor rectifier circuits both theoretically and in practical settings*"; measured using PI_5_66: "*Analyze the operation of single and three-phase thyristor rectifiers with varying loads by obtaining their characteristics such as voltage, current, power etc.; draw any necessary neatly labeled equivalent circuit diagrams with voltage and current waveforms*". The PI_5_66 corresponding to SO_5 or SO 'e': "*an ability to identify, formulate, and solve engineering problems*" is assessed using multiple assessments such as quiz 2 (QZ 2), final exam question 3 (Final Exam: Q3), midterm exam 1 question 3 (Midterm Exam 1: Q3). The performances in these assessment have failed and therefore, the failing CO, PI and ABET SO are headlined for reflections and action items.

Reflection on Course Delivery:

CO_1; PI_1_86; SO_1:

- Midterm Exam 1: Q1: Some of the students have had the written explanation of technical information not satisfactory, they could not differentiate the gating characteristics of various power electronic devices.

CO_5;PI_5_66;SO_5:

- QZ 2,Final Exam: Q3,Midterm Exam 1: Q3: Due to the many formulas used for the numerous topologies of the thyristor controlled converters most of the students were not able to recognize and apply the right formula for the given circuit.

CO_9;PI_1_90;SO_1:

- Midterm Exam 2: Q3: Most of the students could not explain the reason for the use of transformer based switch mode power converters.

CO_10; PI_5_69; SO_5

- Final Exam: Q6: Almost all students could not explain the advantages of the Squared Wave and the Pulse Width Modulation techniques used to improve the operation of DC-AC converters.

CO_11; PI_1_91; SO_1

- Midterm Exam 2: Q4: Due to the limited time allowed for this term, most of the students were not able to fully understand the basic operation of the inverter and to cover topics for PWM since no assessments were undertaken.

SURVEY FEEDBACK

- No Comments.

CO_6:

- CO_6: The effect of freewheeling diodes in rectifier circuits operation was not assessed during this term because it is a sub-topic of CO_5 (Examine the performance of the given thyristor rectifier circuits both theoretically and in practical settings) and contains very small percentage. It will be merged with CO_5 in the next offering of this course to maintain its coverage.

New Action Items:

Action Items	Owner	Closing Date
CO_1; PI_1_86; SO_1: Reduce the number of devices to be studied and simplify the explanation of their gating characteristics.		391, 2018
CO_5; PI_5_66; SO_5: Provide the students with a table showing all topologies of the thyristor controlled converters with their respective formulas used to be able to apply the right formula for the given circuit.		
CO_9; PI_1_90; SO_1: A simplified lecture detailing the explanation of the most common types of switched mode power supplies using DC choppers will be added in the next semester		
CO_10; PI_5_69; SO_5: An additional lecture will be provided to oversee the advantages of the different modulation techniques used to improve the operation of DC-AC converters.		
CO_11; PI_1_91; SO_1: An additional lecture on the overview of different examples of PWM methods shall be offered		
CO_6: This CO was not checked in this semester but it will be covered in the next iteration of this course.		

Figure J14. Course EE_416, Power Electronics, showing easy identification of root cause failures and CQI activity using specific PIs

The reason for failure is documented in the reflections section. In this case, the reason was observed as, 30% of students were not able to recognize and apply the right formula for the given circuit due to the many formulas used for the numerous topologies of the thyristor controlled converters. Therefore, the action item suggested by the instructor for this failure was to provide the students with a table showing all the topologies of thyristor controlled converters with their respective formulas so that students could apply the accurate formulas for given circuits.

vi. DEFERRED COURSE ACTIONS AND CQI USING PORTED ACTIONS FEATURE OF FCAR IN EVALTOOLS ®

The AIs reported for a given course offered in a recent past term are ported electronically into the FCAR of the same course being offered in the current term by the concerned faculty member. The purpose of porting old AIs is to follow up on recommended improvements from recent offerings of the same course. Any suggestions for required modifications to course topics, learning activities, assessments, COs, PIs, rubrics etc. are then examined by the instructor for on time implementation to achieve significant improvements in course delivery. The format for reporting the status of ported old AIs for the engineering programs was modified in term 382 (Spring 2018) to include information related to the specific course inputs where curricular/instructional modifications were made. The modified format provided reporting evidence for closure of the past ported actions significantly improved quality assurance efforts. Figure J15 shows EE_301 Signal and systems course' ported old AIs were effectively implemented in multiple assignments such as HW1, Mid Term and Final exams questions and the status of AIs was therefore closed. A description of the improvement and justification was documented in program meetings and reproduced below for better understanding:

Description: The format for ported old action items status was modified in term 382 to include specification of lecture, assessment for coverage of additional examples and assignments related to a failing CO and PI.

Justification: Student performance failures corresponding to various course topics required remediation efforts for improvement. Most faculty suggested coverage of additional examples, assignments, tutorials, lectures, and in some cases, a change of teaching strategy for improvement of failures in specific course topics. Therefore, for quality monitoring and control purposes it was decided by the QA committee to implement from term 382 a modified format specifying the lecture, assignment, tutorials, or change of pedagogy along with the closed status of any given ported action item.

Old Action Items:

Term/Course	Action Items	Owner	Closing Date	Status
CourseExit_2016_10_01 EE_201_2882	CO_2; PI_1_1; SO_1: Additional feedback on homework and examinations is given promptly in order to make sure that the students do not repeat the same errors later on. All assignments including examinations, homework, quizzes should be dynamic and changed for each new semester due to the fact that EvalTools exposes solutions and questions to students. Another reason is the intended questions bank proposed by some committee		372, 2017	Closed
	CO_9; PI_1_5; SO_1: Additional office hours were reserved for answering questions.			Closed
	CO_2; PI_1_27; SO_1: Dedicate more time for explaining solutions to problems on the white board.			Closed
	CO_5; PI_1_27; SO_1: Dedicate more time for explaining solutions to problems on the white board.			Closed
	CO_9; PI_1_27; SO_1: Discourage students from attending the class late.			Closed
	CO_6; PI_5_5; SO_5: Encourage students to be present more often in order to grasp the theory in class and depend less on personal efforts.			Closed
	CO_9; PI_5_7; SO_5: Solve more problems on the white board regarding the theory of RL circuits with initial conditions. Give additional solution to the problem with simulation results for justification.			Closed
	CO_5; PI_5_19; SO_5: Nothing to be done since all students have good performance in this PI, scores: 90, 74 and 74 out of 100.			Closed
	CO_6; PI_5_19; SO_5: Encourage the students to spend more time in the laboratory in order to accomplish experiments without haste.			Closed
	CO_7; PI_5_39; SO_5: Solve more problems on the op-amp circuits on the white board.			Closed
	CO_7; PI_5_44; SO_5: Add more problems as homework on the op-amp circuits on the white board.			Closed
	CO_1; PI_8_1; SO_8: Nothing to be done since the performance of students was good, grades: 8, 8 and 6.1 out of 10.			Closed
	CO_1; PI_8_8; SO_8: More feedback and explanation on the solution of the problem of boosting batteries.			Closed

Old Action Items:

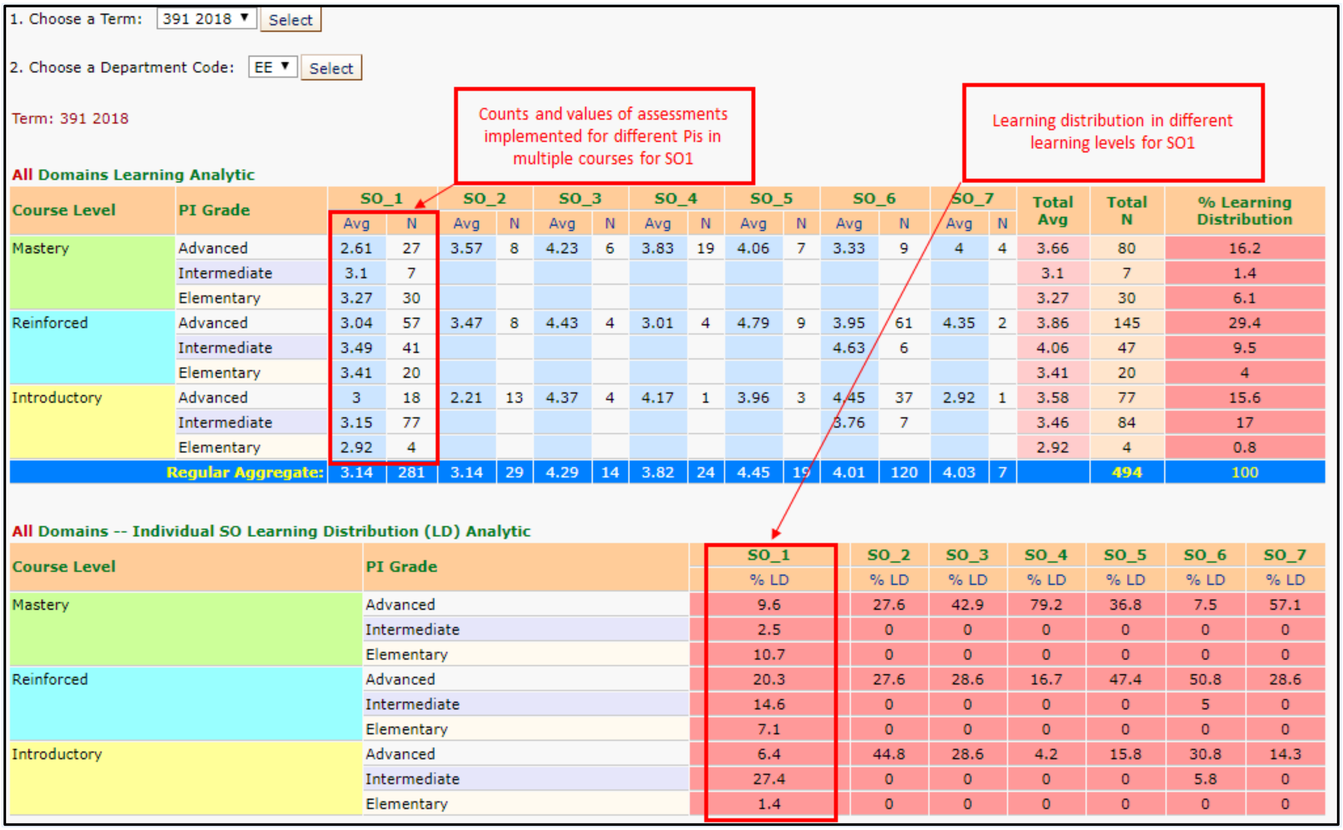
Term/Course	Action Items	Owner	Closing Date	Status
CourseExit_2017_09_14 EE_301_1061	CO_1, PI_1_59, SO_1: More problems need to be solved in the class to enable the student to solve problems related to various time domain operation on signals		382, 2018	Closed (Covered in HW-1, Midterm Exam-1_Q1, Final Exam_Q1(a))
	CO_8, PI_11_54, SO_11: More problems need to be solved in the class to enable the student to identify the difference between the Fourier Transforms and Inverse Fourier Transforms for continuous-time and discrete-time signals.			Closed (Covered in Midterm Exam-2_Q3, Final Exam_Q4)
	CO_10, PI_11_61, SO_11: More problems needs to solved in the class and make the students to practice more to tackle the problems related to finding the Z-transform, poles and zeros, and the region of convergence for the given discrete time signal			Closed (Covered in QZ-4, Final Exam_Q5)

Figure J15. Modification of reporting status for ported old AIs

3. PDCA QUALITY CYCLE Q3: PROGRAM TERM REVIEW – LEARNING DOMAINS, PIs AND SOs EVALUATION

i. LEARNING DOMAINS EVALUATION

Since assessments are equivalent to learning in the OBE model, the Faculty of Engineering programs have decided to consider the type of assessments, their frequency of implementation, and the learning levels of measured specific PIs in Bloom's 3 domains for courses and overall program evaluations [24,35,41]. At the course level, the types of assessments are classified using the course formats chart to calculate their weighting factors, which are then applied using the setup course portfolio module of EvalTools® 6 [24,35,41]. The results can be seen in the FCAR and are used for course evaluations. The program level ABET SO evaluations employ a weighting scheme HFWFS, which considers the frequency of assessments implemented in courses for a given term to measure PIs related to specific learning levels of Bloom's domains [24,41]. Figure J17 shows the EE program term 391 (Fall 2018) composite learning domains evaluation data for their 7 ABET SOs. For each SO, the counts of total assessments and their aggregate average values are tabulated for each learning level.



1. Choose a Term: 391 2018 Select

2. Choose a Department Code: EE Select

Term: 391 2018

Counts and values of assessments implemented for different PIs in multiple courses for SO1

Learning distribution in different learning levels for SO1

All Domains Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced	2.61	27	3.57	8	4.23	6	3.83	19	4.06	7	3.33	9	4	4	3.66	80	16.2
	Intermediate	3.1	7													3.1	7	1.4
	Elementary	3.27	30													3.27	30	6.1
Reinforced	Advanced	3.04	57	3.47	8	4.43	4	3.01	4	4.79	9	3.95	61	4.35	2	3.86	145	29.4
	Intermediate	3.49	41									4.63	6			4.06	47	9.5
	Elementary	3.41	20													3.41	20	4
Introductory	Advanced	3	18	2.21	13	4.37	4	4.17	1	3.96	3	4.45	37	2.92	1	3.58	77	15.6
	Intermediate	3.15	77									3.76	7			3.46	84	17
	Elementary	2.92	4													2.92	4	0.8
	Regular Aggregate:	3.14	281	3.14	29	4.29	14	3.82	24	4.45	19	4.01	120	4.03	7		494	100

All Domains -- Individual SO Learning Distribution (LD) Analytic

Course Level	PI Grade	SO_1	SO_2	SO_3	SO_4	SO_5	SO_6	SO_7
		% LD	% LD	% LD	% LD	% LD	% LD	% LD
Mastery	Advanced	9.6	27.6	42.9	79.2	36.8	7.5	57.1
	Intermediate	2.5	0	0	0	0	0	0
	Elementary	10.7	0	0	0	0	0	0
Reinforced	Advanced	20.3	27.6	28.6	16.7	47.4	50.8	28.6
	Intermediate	14.6	0	0	0	0	5	0
	Elementary	7.1	0	0	0	0	0	0
Introductory	Advanced	6.4	44.8	28.6	4.2	15.8	30.8	14.3
	Intermediate	27.4	0	0	0	0	5.8	0
	Elementary	1.4	0	0	0	0	0	0

Figure J16. **A given term learning domains evaluation for EE program showing all 3 domains' composite data with assessments counts and their aggregate average values for various learning levels and ABET SO '1' highlighted.**

Figure J17 also shows the overall percentage learning distribution for each learning level of the 7 ABET SOs. The details of how these entries are computed are explained in detail in our previous work. Figure J18 shows analytical results for the individual cognitive, affective and psychomotor— Bloom's domains of learning. The counts of assessments in various learning levels and their calculated values for all 7 ABET SOs are displayed for each learning domain. The ABET SO '1' is highlighted for understanding.

Cognitive Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced	2.48	15	3.8	4			4	3							3.43	22	7.3
	Intermediate	3.1	7													3.1	7	2.3
	Elementary	3.27	30													3.27	30	9.9
Reinforced	Advanced	3	55	2.99	5							4.17	3			3.39	63	20.8
	Intermediate	3.49	41									4.45	4			3.97	45	14.9
	Elementary	3.41	20													3.41	20	6.6
Introductory	Advanced	3	18	2.21	13							4.09	4			3.1	35	11.6
	Intermediate	3.15	77													3.15	77	25.4
	Elementary	2.92	4													2.92	4	1.3
																3.36	303	100.1

Affective Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced			2.88	4	4.23	6	3.81	16	4.06	7			4	4	3.8	37	56.9
	Intermediate															0	0	0
	Elementary															0	0	0
Reinforced	Advanced					4.43	4	3.01	4	4.79	9			4.35	2	4.15	19	29.2
	Intermediate															0	0	0
	Elementary															0	0	0
Introductory	Advanced					4.37	4	4.17	1	3.96	3			2.92	1	3.86	9	13.8
	Intermediate															0	0	0
	Elementary															0	0	0
																3.91	65	99.9

Psychomotor Domain Learning Analytic

Course Level	PI Grade	SO_1		SO_2		SO_3		SO_4		SO_5		SO_6		SO_7		Total Avg	Total N	% Learning Distribution
		Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N	Avg	N			
Mastery	Advanced	2.83	12									3.33	9			3.08	21	16.7
	Intermediate															0	0	0
	Elementary															0	0	0
Reinforced	Advanced	4.05	2	4.12	3							3.93	58			4.03	63	50
	Intermediate											5	2			5	2	1.6
	Elementary															0	0	0
Introductory	Advanced											4.53	33			4.53	33	26.2
	Intermediate											3.76	7			3.76	7	5.6
	Elementary															0	0	0
																4	126	100.1

Figure J17. Learning domains distribution for EE Program ABET SOs (1-7) showing composite data for affective, physcomotor and cognitive learning domains with assessments counts and their aggregate average values for various learning levels

Figure J18 shows average values calculated on a 5.0 scale for the cognitive, affective and psychomotor domains, providing a good overall indication of how the program has performed in each learning domain. The pie chart indicates the EE program Term 391 (Fall 2018) outcomes assessment activity percentage distribution in the 3 Bloom's learning domains.

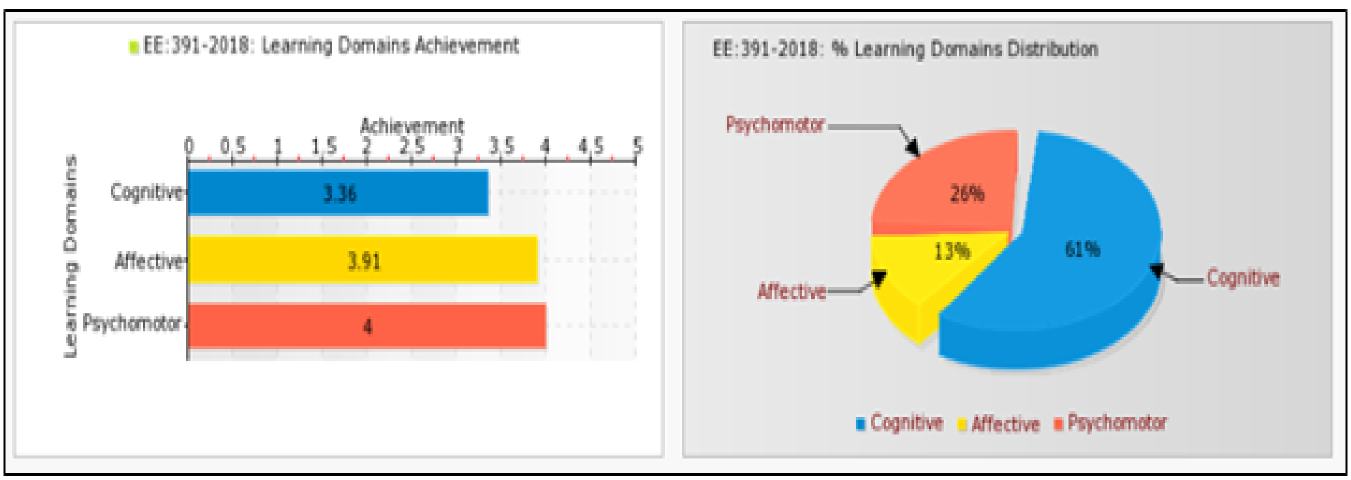


Figure J18. Learning domains evaluation histogram and pie chart for learning domains achievement and distribution for EE program term 391

ii. DESCRIPTION OF PROCESS FOR DEVELOPMENT OF PROGRAM CURRICULUM MAPPING

Termwise ABET SOs Assessment Plan

As mentioned in *Section VI.A* on PDCA Quality Cycle Q1: *COs, PIs, rubrics development*; that courses measure the ABET SOs based on the designated course topics and target student learning activity. However, the Program Committee can assign asssessment of certain affective domain ABET SOs related to contemporary issues, impact of engineering solutions, teamwork etc. to specific courses that contain appropriate content or project activity. Therefore, the termwise ABET SO assessment plan mostly presents coverage of ABET SOs which are a product of routine coverage of each course assessment activity plus any additional SOs that may be allocated to it by the Program Committee. The *Learning Domains Evaluation* conducted in the program term review examines the learning distribution coverage related to ABET SOs assessments in the current term. As an example, the term 371 (Fall 201) learning domain distribution exhibits information on assessments corresponding to various learning levels for each ABET SO processed in multiple courses of a given term. This information is examined in detail in the *Learning Domains Evaluation* phase of the program term review. Refer Table J13 below for detail on discussions and actions related to *Learning Domain Evaluations* term 371. Justifications are made for the achieved learning domains coverage or corrective actions generated for improvement of deficiencies in the subsequent ABET SO assessment plan for the following term 372 . The actions relating to the development of the ABET SO assessment plan for following Term 372 are highlighted in yellow in Table J13below. Specifically, SO ‘f’ (SO_6, professional and ethical responsibility) and SO ‘j’ (SO_10, contemporary issues) needed additional assessments in following term 372 due to the low coverage observed consistently in previous terms. Table 28 shows the EE program’s ABET SOs (a-k) assessment plan for Term 372 (Spring 2017).

Table J13. **Learning domains evaluation discussion and actions Term 371 (Fall 2016)**

Summary of Individual Domains Activities:

Discussion	Action	Review Date
COMPOSITE LEARNING DOMAINS EVALUATION: Affective domain coverage has improved to 17% versus last term of 10 %. SOs 2,3,4,5,6,7,8,9 and 10 Psychomotor has percentage distribution of 23% in term 371 due to several lab courses and practical activities. SO1, SO2, SO3, SO5 and SO11 have been covered in the psychomotor domain Cognitive has coverage of 61% with ABET SO1, SO2, SO3, SO5, SO11 have been covered for the cognitive domain. **INDIVIDUAL SO LEARNING DOMAINS EVALUATION:** **SO_1:** Introductory courses did not measure advanced level skills **SO_2:** Introductory, Reinforced and Mastery level courses do not have any elementary skills **SO_3:** Design skills were mainly focused on advanced level skills of all course levels. Mastery and Reinforced level courses did not measure the intermediate and elementary skills. Introductory courses did not measure the elementary skills.	**COMPOSITE LEARNING DOMAINS EVALUATION:** Additional courses assessments, PIs, rubrics should be developed to cover the soft skills SOs to increase percentage assessment/learning of psychomotor and affective domain skills **INDIVIDUAL SO LEARNING DOMAINS EVALUATION:** **SO_1:** There will be no advanced level skills in this SO since just remembering, understanding, application will be covered. No significant AI. **SO_2:** Introductory, Reinforced and Mastery course levels do not have intermediate and elementary skills due to psychomotor domain measuring advanced and intermediate skills. But additional experimental skills assessments, rubrics need to be developed. **SO_3:** Design skills were mainly focused on advanced level skills. Analysis, Evaluation and knowledge of design can measure the intermediate and elementary skills in 200, 300 and 400 level courses **SO_4:** Since the affective domain team work skill focusses on characterization so we do not have measurements on the elementary and intermediate skills levels. but knowledge of teamwork activity can be assessed in 200 and 300 level courses	2017-06-12

SO_4: Mastery, Reinforced and Introductory courses did not measure the intermediate and elementary skills. **SO_5:** Introductory, Reinforced and Mastery level course have no elementary skills assessments since much of the activity is related to application, analysis of basic principles and evaluations in problem solving. **SO_6:** Major concern: Mastery courses do not measure any skills levels Reinforced and introductory courses did not measure the intermediate and elementary skills. **SO_7:** Mastery, Reinforced and introductory courses did not measure the intermediate and elementary skills. **SO_8:** Mastery, Reinforced and introductory courses did not measure the intermediate and elementary skills. **SO_9:** Mastery, Reinforced and introductory courses did not measure the intermediate and elementary skills. **SO_10:** Mastery and Introductory courses did not measure the intermediate and elementary skills. Major concern: No measurements were made in the Reinforced level courses **SO_11:** Introductory, Reinforced level courses have no elementary skills assessments Reviewers: Dr. IK, Dr. LK, Dr. M, Dr. HAW, Dr. AD, Dr. HC, Dr. AC, Dr. KBM, Dr. MJ, Dr. MU, Dr. AM, Dr. AWM, Mr. NS, Mr. M, Mr. AKV, Mr. SR, Mr. WH	**SO_5:** Introductory, Reinforced and Mastery level courses have no elementary skills assessments since much of the activity is related to application, analysis of basic principles and evaluations in problem solving. Will continue development of assessments, PIs, rubrics for remaining courses yet to be offered. **SO_6:** Courses that involve industry standards, labs, safety regulations to operate machines or equipment can assess basic comprehension and explanation of professional and safety ethics and cover the elementary skill level. Future 200, 300 and 400 level courses will be utilized for assessing additional professional and ethical skills of students **SO_7:** Oral and written communication skills target the advanced skill levels of internalization in the affective domain therefore the elementary and intermediate levels were not measured. Projects and presentations shall be target for measurement of communication skills in the future 200, 300 and 400 level courses. Certain lab reports can also be utilized for the measurement of these skills. **SO_8:** 300 and 400 level courses can target comprehension and analysis levels of this SO. The forum module shall be utilized in the future for measurement of this skill **SO_9:** Senior design project report formats, PIs, rubrics, proposals, presentations formats have been specially designed to facilitate the measurement and assessment process for skills in this SO. Summer training, Senior design project, Forum module and assessments that involve students in research activities shall be targeted in the future terms and especially the 400 level courses. Lifelong learning sample assessments to be shared among all faculty **SO_10:** Forum Module, Summer training and reinforced and mastery level courses can target measurement of this SO. will engage the students in activities which will measure their comprehension of contemporary issues in the field of electrical engineering. Specific 300 level courses that measure SO 9 have to be included in the termwise program SO assessment plan **SO_11:**	

	Since it is not trivial to classify the psychomotor/cognitive skills for this SO into multiple proficiency levels. Explanation of techniques, skills, tools or software is intermedial and not the objective, so this activity needs further research for assessment of this skill level for the 200, 300 level courses.	

The ABET SOs 'f' (SO_6) and 'j' (SO_10) were included in the ABET SOs assessment plan in Term 372 (Spring 2017). The mastery level courses EE_497 SDP I and EE_498 SDP II additionally covered assessments related to SOs 'f' (SO_6). The reinforced level courses EE_322 Communication Theory and EE_341 Electrical Machinery 1 additionally covered assessments related to SOs 'j' (SO_10). These additions are indicated by entries in green color in the ABET SOs (a-k) assessment plan as shown by Table J14. The justifcations and corrective actions for the SO_6 and SO_10 are reproduced below for a better understanding.

Justifications:

a) *SO_6:* Major concern: Mastery courses do not measure any skills levels.

Corrective action: Additional ABET SOs '6' was included in the ABET SOs assessment plan in Term 372 (Spring 2016). The mastery level courses EE_497 SDP I and EE_498 SDP II additionally covered assessments related to SOs 'f' (SO_6).

b) *SO_10**:*** Major concern: No measurements were made in the Reinforced level courses.

Corrective action: Additional ABET SOs '10' was included in the ABET SOs assessment plan in Term 372 (Spring 2016). The reinforced level courses EE_322 Communication Theory and EE_341 Electrical Machinery 1 additionally covered assessments related to SOs 'j' (SO_10).

As shown in Learning Domain Distribution Figure J17 for term 391, SO_4 lists only one assessment for the introductory course level. The actions relating to the development of the ABET SOs (1-7) assessment plan for following Term 392 are highlighted in yellow in Table J13. Specifically, SO_4 (professional and ethical responsibility) needed additional assessments in the following term 392 due to the low coverage observed in previous terms. The ABET SOs '4' was included in the ABET SOs assessment plan in Term 392 (Spring 2019) for multiple introductory level courses such as EE_201 Circuit Theory 1, EE_212 Electronics I and EE_282 Electromagnetic Field Theory. These additions are indicated by entries in green color in the ABET SOs (1-7) assessment plan as shown by Table J14. A brief write-up on the justification for the additional assignments by the EE Program Committee has been included below:

Justification:

a) SO_4:Concern: Only one assessment in the introductory level

Corrective action: Additional ABET SOs '4' assessments were added to multiple introductory level courses such as EE_201 Circuit Theory 1, EE_212 Electronics I and EE_282 Electromagnetic Field Theory of the ABET SOs assessment plan in Term 392 (Spring 2019) for enhancing the coverage of skills related to professional and ethical responsibility.

Table J14. ABET SOs assessment plan for EE program Term 372

FACULTY OF ENGINEERING							EE PROGRAM TERM 372 OUTCOME ASSESSMENT PLAN											
PROGRAM COORD							ABET COORDINATOR: DR.											
ABET SOs.	EE 200 Fund. of Electrical Eng.	EE 201 Circuit Theory I	EE 202 Circuit Theory II	EE 212 Electronics I	EE 261 Digital Logic Design	EE 282 Electromagnetic Field Theory	EE 301 Signals & Systems	EE 311 Electronics II	EE 322 Communication Theory	EE 332 Controls Theory	EE 341 Electrical Machinery I	EE 352 Electrical Power system I	EE 361 Microprocessors	EE 416 Power Electronics	EE 447 Power Systems Operation & Control	EE 421 Wireless & Mobile Communication	EE 497 Senior Design Project I	EE 498 Senior Design Project II
SO_1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SO_2		X	X	X	X			X	X	X	X	X	X	X				
SO_3				Project	Project			Project	X	X			Project	Project	X		X	X
SO_4				Project	Project			Project	X	X	Project		Project	Project	X		SDP	SDP
SO_5	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X
SO_6		X	X	X	Lab Performance			X		X	HW		X				X	X
SO_7				Report/ Presentation	Report/ Presentation			Report/ Presentation		X	Report/ Presentation		Report/ Presentation	Report/ Presentation	X		Report/ Presentation	Report/ Presentation
SO_8		HW, Exam											HW, Exam		X			
SO_9			HW				HW, Exam									X		
SO_10						HW			X		HW			Project			X	X
SO_11	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		

Table J15. Learning domains evaluation discussion and actions Term 391 (Fall 2018)

Summary of Individual Domains Activities:

Discussion	Action	Review Date
COMPOSITE LEARNING DOMAINS EVALUATION: Affective domain coverage has reduced to 13% versus last term of 23%. SOs 2,3,4,5 and 7 were covered in term 391 Psychomotor has percentage distribution of 26% in term 381 an improvement versus 25% in term 382 due to capstone, several lab courses and practical activities. SOs 1,2 and 6 have been covered in the psychomotor domain Cognitive has coverage of 61% with ABET SOs 1,2,4 and 6 have been covered for the cognitive domain. **INDIVIDUAL SO LEARNING DOMAINS EVALUATION:** **SO_1:** All learning levels have been adequately covered **SO_2:** Design skills were mainly measured in the advanced level skills in Mastery, Reinforced and Introductory courses. **SO_3:** Mastery, Reinforced and Introductory courses did not measure the intermediate and elementary skills. **SO_4:** Mastery, Reinforced and Introductory courses did not measure any elementary any intermediate skills. Concern: Only one assessment in the introductory level **SO_5:** Mastery, Reinforced and introductory courses did not measure any elementary any intermediate skills. **SO_6:** Introductory, Reinforced and Mastery level courses do not have any elementary skills due to psychomotor domain measuring mostly advanced skills Mastery courses did not measure the intermediate skills. **SO_7:** Mastery, Reinforced and Introductory courses did not measure the intermediate and elementary skills. **Reviewers:** Dr. HC, Dr. MA, Dr. HAW, Dr. ARAK, Dr. AD, Dr. AC, Dr. KBM, Dr. MJ, Dr. MU, Mr. NS, Mr. MM, Mr. AKV, Mr. SR, Mr. WH	**SO_1:** No action **SO_2:** Projects in 200,300 courses will continue to be targeted in the term 391 and onwards for a thorough analysis of this SO. Elementary, intermediate skills related to design can also be measured **SO_3:** Oral and written communication skills target the advanced skill levels of internalization in the affective domain therefore the elementary and intermediate levels were not measured. Projects and presentations shall be target for measurement of communication skills in the future 200, 300 and 400 level courses. **SO_4:** Courses that involve industry standards, labs, safety regulations to operate machinery or equipment can assess basic comprehension and explanation of professional and safety ethics and cover the elementary skill level. Future 300 and 400 level courses will be utilized for assessing additional professional and ethical skills of students. There should be a special focus on 400 level courses. **SO_5:** Since the affective domain team work skill focuses on characterization we do not have measurements on the elementary and intermediate skills levels. Reinforced and Introductory courses should continue to measure some aspect of teamwork through projects. Knowledge of teamwork can also be assessed **SO_6:** Introductory and Reinforced level courses do not have elementary skills due to psychomotor domain measuring intermediate and advanced skills related to complex overt response, origination, and adaptation. Additional experimental skills assessments, rubrics need to be developed. **SO_7:** Life long learning displays an essential aspect of internalization and therefore covers advanced affective domain skills Senior design project report formats, PIs, rubrics, proposals, presentations formats have been specially designed to facilitate the measurement and assessment process for skills in this SO. Summer training,Senior design project, Forum module and assessments that involve students in research activities shall be targeted in the future terms for 200,300 and especially the 400 level courses.	2019-02-04

Table J16. **ABET SOs assessment plan for EE Program Term 392**

FACULTY OF ENGINEERING						PROGRAM TERMWISE OUTCOME ASSESSMENT PLAN											
PROGRAM COORDINATOR: PROGRAM: EE TERM: 392						ABET COORDINATOR:											
ABET SOs.	EE 201	EE 202	EE 212	EE 261	EE 282	EE 301	EE 311	EE 322	EE 332	EE 341	EE 352	EE 361	EE 416	EE 421	EE 456	EE 497	EE 498
	Circuit Theory I	Circuit Theory II	Electronics I	Digital Logic Design	Electromagnetic Field Theory	Signals & Systems	Electronics II	Communication Theory	Controls Theory	Electrical Machinery I	Electrical Power system I	Microprocessors	Power Electronics	Wireless & Mobile Communications	Renewable Energy Systems	Senior Design Project I	Senior Design Project II
SO_1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
SO_2				X			X		X		X	X	X		X	X	X
SO_3			X	X			X		X		X		X			X	X
SO_4	X		X		X			X	X	X	X			X	X		X
SO_5				X							X	X	X			X	X
SO_6	X	X	X	X			X	X	X	X	X	X	X				X
SO_7		X-HW				X		X					X	X		X	X

Curriculum Maps for EE, ME and CE Programs

Curriculum maps for the EE, ME and CE programs' 38x curriculum (started Fall 2018) extracted from implemented SOs assessment plans are automatically generated by EvalTools ®. Figures J19, J20 and J21 show mapping of courses to ABET SOs.

Course vs. Student Outcomes Curriculum Matrix 38X*

Department: EE

	1	2	3	4	5	6	7		
	ABET Student Outcomes								
Course ID	SO_1	SO_2	SO_3	SO_4	SO_5	SO_6	SO_7	Semester	Year
ENGR_103	I					I		1	1
ENGR_104	I	I	I	I	I	I		2	
EE_201	I			I		I		3	2
EE_263	I	I	I		I	I			
ENGR_205	I								
EE_202	I			I		I	I	4	
EE_212	I	I	I			I			
EE_282	I			I					
EE_301	R						R	5	3
EE_311	R	R	R		R	R			
EE_341	R		R	R	R	R			
EE_361	R	R	R		R	R	R		
ENGR_203	I					I			
ENGR_202	I							6	
EE_322	R			R		R	R		
EE_332	R	R	R	R	R	R			
EE_352	R	R	R	R	R	R	R		
EE_456	M	M		M				7	4
EE_471	M	M		M					
EE_497	M	M	M		M		M		
ENGR_301	R		R	R	R				
EE_416	M	M	M	M	M	M	M	8	
EE_421	M			M			M		
EE_498	M	M	M	M	M	M	M		
ENGR_302			R	R					
ENGR_402	R	R		R	R	R	R		
EE_390	R	R	R	R	R	R		After 6	

Figure J19. Curriculum map (38x) for EE program showing courses to ABET SOs (1-7)

	ABET Student Outcomes								
Course ID	SO_1	SO_2	SO_3	SO_4	SO_5	SO_6	SO_7	Semester	Year
ENGR_103	I					I		1	1
ENGR_104	I	I		I	I	I		2	
ME_211	I			I		I		3	2
ME_213	I					I			
CE_201	I								
ME_222	I							4	
ME_224	I	I				I			
ME_262	I								
ENGR_203	I					I			
EE_200	I								
ME_323	R	R	R			R		5	3
ME_361	R								
ME_375	R					R			
ENGR_202	I								
ME_312	R	R		R				6	
ME_317	R	R							
ME_334	R			R		R			
ME_346	R	R				R			
ENGR_302			R	R					
ME_413	M	M						7	4
ENGR_301	R		R	R	R	R			
ME_471	M			M					
ME_474	M	M		M		M			
ME_497		M	M	M	M		M		
ME_472	M	M		M				8	
ME_498		M	M	M	M	M			
ME_431	M			M					
ME_415	M		M	M		M			
ENGR_402	M	M		M	M	M	M		
ME_390	R	R	R	R	R	R		After 6	

Figure J20. Curriculum map (38x) for ME program showing courses to ABET SOs (1-7)

Course vs. Student Outcomes Curriculum Matrix 38X ABET SOs (1-7)*

	ABET Student Outcomes								
Course ID	SO_1	SO_2	SO_3	SO_4	SO_5	SO_6	SO_7	Semester	Year
ENGR_103	I					I		1	1
ENGR_104	I	I	I	I	I	I		2	
CE_201	I							3	2
CE_202	I					I			
ENGR_203	I					I			
CE_219	I	I				I		4	
ENGR 205	I								
CE_271	I					I			
ENGR_202	I								
CE_281	I					I			
CE_312	R		R					5	3
ENGR_301	R		R	R	R				
CE_321	R			R		R	R		
CE_351	R								
CE_316								6	
CE_341	R	R				R			
CE_352	R					R			
ENGR_302			R	R					
CE_415	M	M	M					7	4
CE_442	M	M				M			
CE_417	M	M		M					
CE_442	M	M				M			
CE_423	M	M							
CE_497	M		M		M	M	M	8	
CE_431	M	M		M		M			
CE_432	M			M					
CE_482	M			M			M		
CE_498	M	M	M	M	M		M		
ENGR_402	M	M		M	M	M	M		
CE_390	R		R	R	R	R		After 6	

Figure J21. Curriculum map (38x) for CE program showing courses to ABET SOs (1-7)

iii. PIs EVALUATION

Figure J22 shows that the PI evaluation phase begins with a snap shot consolidated view of all ABET SOs, measured in the specified term with a scientific color coding scheme to indicate failures for investigation. The aggregate value for each measured ABET SO is calculated by averaging its corresponding aggregate PIs data. The aggregate value for each PI measured for this specific ABET SO is calculated by weighted averaging according to class size the PIs data measured by multiple raters across different courses. Performance indicator evaluation is focused on failing SOs and their contributing PIs for analysis and discussions relating to improvement. Courses contributing to failing PIs and SOs are examined by selection. The investigations involve the study of course reflections and generated action items in the respective FCARs and the reviewers enter their comments for the selected failing courses and PIs. Action items in respective FCARs are edited, updated or deleted as per the program chair decision in agreement with review members. Certain action items may be elevated to the program level from course level depending upon the scope of the problem or degree of importance. Figure J23 shows the PI review comments for ABET SO '4' for the CE program in term 391.

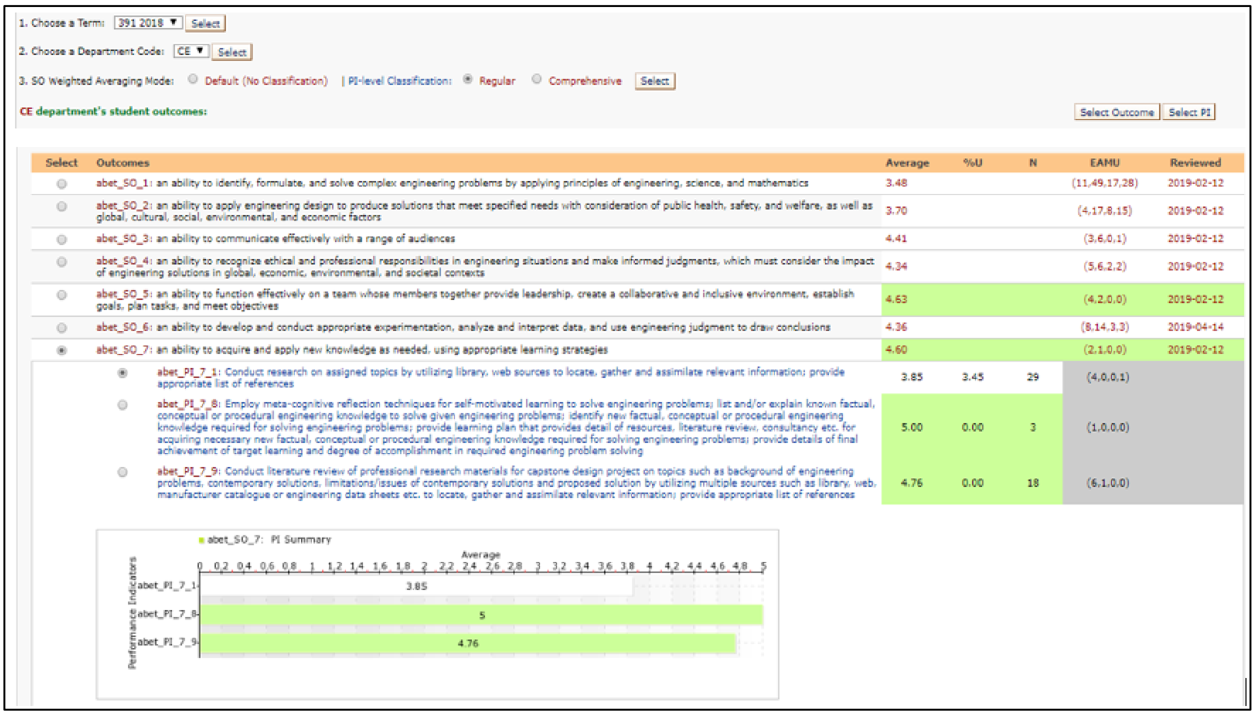


Figure J22. PIs evaluation module showing composite PIs data collected from multiple courses for assessing CE program ABET SOs (1-7)

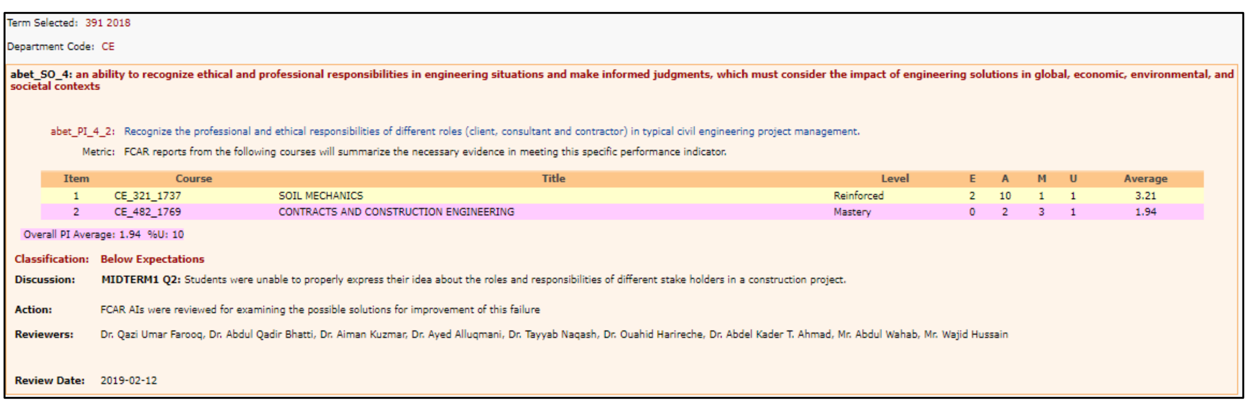
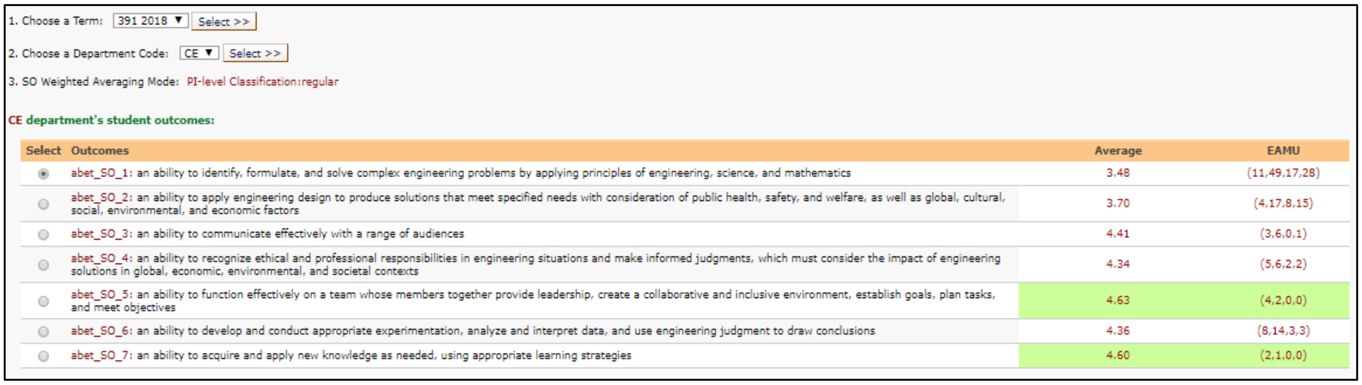


Figure J23. PIs evaluation module in term 391 showing corresponding courses, detailed failure analysis and review for PI_4_2

1) SOs EVALUATION

The ABET SO evaluation phase integrates review information from the PI evaluation module for each listed SO. Overall comments on a specific ABET SO are integrated with the comments of review and analysis of its failing PIs taken from the Performance Indicator Evaluation module of EvalTools® 6. Figure J23 shows the SOs evaluation module on EvalTools® for CE program term 391 (Fall 2018) dsiplaying ABET SOs (1-7) aggregate average values with EAMU vectors for course contributions.


1. Choose a Term: 391 2018 ▼ Select >>

2. Choose a Department Code: CE ▼ Select >>

3. SO Weighted Averaging Mode: PI-level Classification:regular

CE department's student outcomes:

Select	Outcomes	Average	EAMU
◉	abet_SO_1: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	3.48	(11,49,17,28)
○	abet_SO_2: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	3.70	(4,17,8,15)
○	abet_SO_3: an ability to communicate effectively with a range of audiences	4.41	(3,6,0,1)
○	abet_SO_4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	4.34	(5,6,2,2)
○	abet_SO_5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	4.63	(4,2,0,0)
○	abet_SO_6: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	4.36	(8,14,3,3)
○	abet_SO_7: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	4.60	(2,1,0,0)

Figure J24. SOs evaluation module showing term 391 (Fall 2018) results for CE Program

Figure J25 shows the detailed PI analysis for a selected ABET SO_3 listing the contributing courses and their group EAMU calculations. The overall SO_3 average value is 4.41 displaying a white flag with a *Meeting Expectations* result as per the performance criteria and heuristics rules shown in Table 6. The detailed analysis for SO_3 shows just one PI_3_3 failing in a CE_315 Structural Analysis-II course with an average value of 2.92. Reviewers for the CE program SOs evaluation audit the FCAR actions for verification of course results and accuracy of corrective actions. Figure J26 shows a snapshot of a portion of the detailed SO/PI executive summary of a sample CE program term review. In this figure, the PIs failures related to SO_3 on Communication Skills are reviewed. A summary of all major failures related to ABET SO 3 is reported here. We see discussions mentioning PI_3_3 failure attributed to deficient student performances related to oral presentations for a course project.

EvalTools ® SOs evaluation module generates the following electronic term review reports in printable word or pdf format:

a) SO executive summary

b) Detailed SO/PI executive summary

c) SO/PI Performance Vector Table PVT summary and

(d) Course reflections/action items

Samples of these reports have been presented in the *Section IV.D.4 SOs, PIs Evaluations.*

abet_SO_3 : an ability to communicate effectively with a range of audiences

abet_PI_3_2: Make effective oral presentations in a given time frame to defend course projects with required: professionalism, style, slide quality, delivery, response to questions; adequate technical content of problem definition; properly assimilated and relevant literature review; design specifications: customer requirements or constraints; design methodology: concepts development, concepts selection and evaluation; manufacturability: scope, planning, budget, deliverables; detailed design analysis: fulfillment of constraints; conclusion, references, appendices etc.

abet_PI_3_3: Prepare technical reports for course projects implementing relevant software for civil engineering problems that follow appropriate standards, format and style with: title, front matter, list of tables and contents; details of overall organization of the report; provide inputs such as: pre-processing multidimensional models, details of loading, boundary conditions and material properties; output results such as: member forces, reaction forces, deflections, deformed shapes etc.; and detailed design

abet_PI_3_8: Write technical reports to analyze and design given bridge structures using well-known Finite Element Analysis structural software like SAP2000 containing: cover page, table of contents, introduction, the given constrains, sections summarizing each of the above, with calculations, results, drawings, plots, comparison tables, conclusions and references

abet_PI_3_9: Deliver oral presentations to analyze and design given bridge structures using well-known Finite Element Analysis structural software like SAP2000/CSIBridge by communicating clearly the introduction, given constraints, results with calculations, drawings, plots, comparison tables, conclusions and references

abet_PI_3_11: Make a professional poster presentation of Capstone design Project; display Abstract, Methodology, Summarized simulation/mathematical Results, conclusions, references; Provide necessary technical diagrams

abet_PI_3_12: Make a professional poster presentation of Capstone design Project; interact with audience, visitors, reviewers; respond/answer questions proactively in an appropriate technical and professional manner.

abet_PI_3_14: Prepare complete technical senior design project final reports following appropriate standards, format and style with: title, front matter, list of tables and contents; details of overall organization of the report; proper English(grammar/spelling/sentence structure); neatly labeled sketches/diagrams; abstract/introduction; adequate technical content of problem definition; properly assimilated and relevant literature review; design specifications: customer requirements or constraints; design methodology: concepts development, concepts selection and evaluation; manufacturability: scope, planning, budget, deliverables; detailed design analysis: fulfillment of constraints; conclusion, references, appendices etc.

abet_PI_3_15: Make effective oral presentations in a given time frame to defend senior design projects with required: professionalism, style, slide quality, delivery, response to questions; adequate technical content of problem definition; properly assimilated and relevant literature review; design specifications: customer requirements or constraints; design methodology: concepts development, concepts selection and evaluation; manufacturability: scope, planning, budget, deliverables; detailed design analysis: fulfillment of constraints; conclusion, references, appendices etc.

abet_PI_3_16: Prepare interim senior design project report following a specific/standard format, incorporating modifications in literature review, any suggestions for improvement based on advisor feedback to present (a) problem definition: summarized abstract, background of engineering problems, contemporary solutions, limitations/issues of contemporary solutions, customer needs/requirements; (b) develop design solutions: goals of project, scope of project; (c) develop two design concepts (design specifications: customer requirements, constraints); and (d) select design concepts based on Pugh method;

abet_PI_3_23: Write technical reports to analyze and design given structure using well-known Finite Element Analysis structural software like SAP2000 containing: cover page, table of contents, introduction, the given constrains, sections summarizing each of the above, with calculations, results, drawings, plots, comparison tables, conclusions and references

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_3_2	(0,0,1,0)	2.92	CE_315_1752	STRUCTURAL ANALYSIS II	Reinforced	1	1	2	0	2.92
abet_PI_3_3	(0,1,0,0)	3.75	CE_315_1752	STRUCTURAL ANALYSIS II	Reinforced	1	3	0	0	3.75
abet_PI_3_8	(0,1,0,0)	3.48	CE_415_1773	BRIDEG ENGINEERING	Mastery	1	10	0	0	3.48
abet_PI_3_9	(0,1,0,0)	3.48	CE_415_1773	BRIDEG ENGINEERING	Mastery	1	10	0	0	3.48
abet_PI_3_11	(1,0,0,0)	5	CE_498_2348	SENIOR DESIGN PROJECT II	Mastery	4	0	0	0	5
abet_PI_3_12	(2,0,0,0)	5	CE_498_2348	SENIOR DESIGN PROJECT II	Mastery	4	0	0	0	5
			CE_498_2349	SENIOR DESIGN PROJECT II	Mastery	2	0	0	0	5
abet_PI_3_14	(1,2,0,0)	4.11	CE_418_1767	REINFORCED CONCRETE DESIGN II	Mastery	3	1	1	0	4
			CE_498_2348	SENIOR DESIGN PROJECT II	Mastery	4	0	0	0	5
			CE_498_2349	SENIOR DESIGN PROJECT II	Mastery	0	2	0	0	3.33
abet_PI_3_15	(1,1,0,0)	4.17	CE_498_2348	SENIOR DESIGN PROJECT II	Mastery	4	0	0	0	5
			CE_498_2349	SENIOR DESIGN PROJECT II	Mastery	0	2	0	0	3.33
abet_PI_3_16	(8,2,0,0)	4.67	CE_498_2348	SENIOR DESIGN PROJECT II	Mastery	4	0	0	0	5
			CE_498_2349	SENIOR DESIGN PROJECT II	Mastery	0	2	0	0	3.33
			CE_497_2357	SENIOR DESIGN PROJECT I	Mastery	3	0	0	0	5
			CE_497_2358	SENIOR DESIGN PROJECT I	Mastery	2	0	0	0	5
			CE_497_2359	SENIOR DESIGN PROJECT I	Mastery	2	0	0	0	5
			CE_497_2360	SENIOR DESIGN PROJECT I	Mastery	3	0	0	0	5
			CE_497_2361	SENIOR DESIGN PROJECT I	Mastery	0	2	0	0	3.33
			CE_497_2362	SENIOR DESIGN PROJECT I	Mastery	3	0	0	0	5
			CE_497_2363	SENIOR DESIGN PROJECT I	Mastery	3	0	0	0	5
			CE_497_2364	SENIOR DESIGN PROJECT I	Mastery	3	0	0	0	5
abet_PI_3_23	(0,1,0,0)	3.33	CE_418_1767	REINFORCED CONCRETE DESIGN II	Mastery	2	1	2	0	3.33

Overall SO Average: 4.41 EAMU: (3,6,0,1)

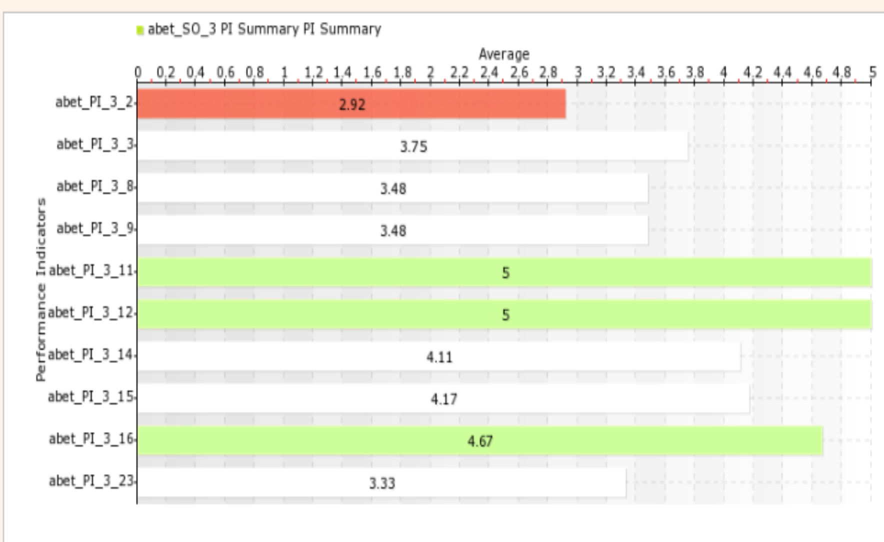
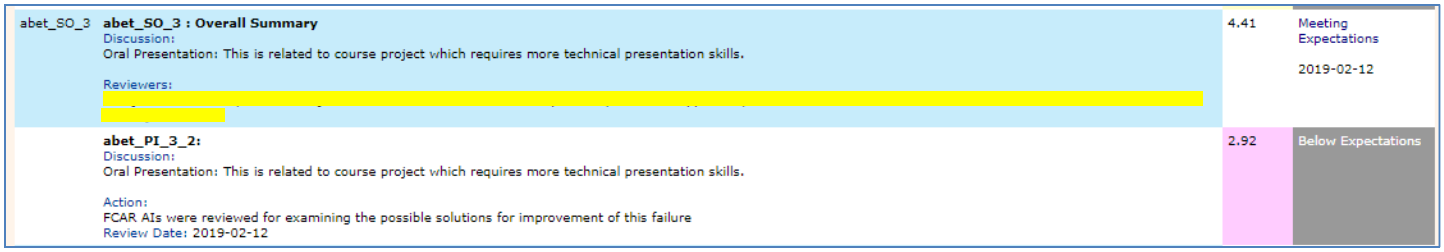


Figure J25. SOs Evaluation module for CE program Term 391 (Fall 2018) zooming into SO_3 results


abet_SO_3 **abet_SO_3 : Overall Summary** 4.41 Meeting Expectations 2019-02-12
Discussion:
Oral Presentation: This is related to course project which requires more technical presentation skills.
Reviewers:

abet_PI_3_2: 2.92 Below Expectations
Discussion:
Oral Presentation: This is related to course project which requires more technical presentation skills.
Action:
FCAR AIs were reviewed for examining the possible solutions for improvement of this failure
Review Date: 2019-02-12

Figure J26. ABET SOs (1-7) Evaluation module for term 391 (Fall 2018) showing PIs assessed for ABET SO 3 (Communication Skills)

A list of attending reviewers and date of review is recorded for future reference. The student outcomes information from multiple term reviews for a program can be consolidated and utilized for review of the Program Educational Objectives. Certain action items in the FCARs which were elevated to the program level during the term review process are appropriately escalated to the responsible departments/committees for closure. The remaining action items in the FCARs are followed up by the concerned faculty for implementation.

4. *PDCA QUALITY CYCLE Q4: PIs 3 YEAR MULTI-TERM REVIEW*

Table J17. Sample results for 3 year PIs database review for ME, EE and CE programs

Redunandant PIs	Action
Mechanical Engineering Program	
[abet_PI_1_30]] Cognitive: Applying Apply first law of thermodynamics to flow devices [abet_PI_5_87] **Cognitive: Evaluating** Calculate heat, work and mass flow in open systems (Shower head, nozzles, ducts & pipes, exchangers, compressors, turbines, mixing chambers and expansion of valves) by applying first law of thermodynamics	[abet_PI_1_30] No Classification 3 Year PIs Review Cycle Feb 25 2018 – Deleted – Redundant
Justification: The PI_1_30 was very broad in language and the topic was adequately covered by PI_5_87 and therefore was deleted as redundant.	
Civil Engineering Program	
[abet_PI_1_3] Cognitive: Remembering Describe the basics of engineering geology [abet_PI_1_89] Cognitive: Understanding Explain nature and origin of soils; different types of rocks and their inter-conversion; provide sketches wherever necessary; [abet_PI_1_118] Cognitive: Understanding Elaborate on the importance of weathering and erosion phenomena on the rock cycle;	[abet_PI_1_3] No Classification 3 Year PIs Review Cycle Feb 26 2018 – Deleted - Redundant
Justification: The PI_1_3 related to the topic of engineering geology was adequately covered by the PI_1_89 and PI_1_118 and therefore deleted as redundant.	
Electrical Engineering Program	
[abet_PI_1_7] Cognitive: Understanding Explain the meaning, symbols and notations associated with various electronics engineering terms and quantities, such as use of per-unit system notation, electronics circuit diagrams, and complex vectors [abet_PI_1_13] Cognitive: Applying Explain and/or use symbols and notations associated with various electrical engineering terms and quantities such as use of per-unit system notation, single -line diagrams, electronics circuit diagrams, and complex vectors;	[abet_PI_1_7] No Classification 3 Year PIs Review Cycle Mar 8 2018 Session II – Deleted - Redundant
Justification: The PI_1_7 was exact copy of PI_1_13 and duplicated in error and therefore deleted as redundant.	
Moved PIs	**Action**
Mechanical Engineering Program	
[abet_PI_5_3] Cognitive: Analyzing Analyze mechanism position, velocity, and acceleration graphically by solving relative vector equations and using velocity and acceleration polygons [abet_PI_11_69] Psychomotor: Adaptation Analyze the position of the members in the mechanism, their velocity, and acceleration; form a graphical solution representing the known velocities as a vector diagram; graphically solve the unknown parameters like velocity and acceleration, by solving relative vector polygons.	[abet_PI_5_3] No Classification 3 Year PIs Review Cycle Mar 4 2018 – Deleted - Redundant - Moved to SO11
Justification: PI_5_3 was related to drawing vector polygons for analyzing position of members in a mechanism. This is a specific engineering tool and practice therefore the content of this PI was moved to SO 'k' (SO _11).	
Civil Engineering Program	
[abet_PI_3_11] Affective: Organize values into priorities Develop a complete time plan and project schedule for a project Moved to SO 'k' (SO 11) from SO 'c' (SO 3)	[abet_PI_11_103] Psychomotor: Adaptation Develop a complete time plan and project schedule for a civil engineering design project; clearly indicating in detail resource allocation of man power, machinery and materials; project schedule should implement prioritization of design, manufacturing activities
Justification: Comprehensive time line and project schedule is a necessary engineering practice and therefore PI_3_11 was deleted and its content was introduced into PI_11_103	
Electrical Engineering Program	
[abet_PI_3_17] Cognitive: Understanding Describe the basic design features of transformer devices, such as construction, types, equivalent circuit and operation of single-phase, three-phase and auto transformers [abet_PI_1_68] Cognitive: Understanding Explain the concepts of inductance and mutual inductance with reference to the operation of transformers (step up and step down) and draw corresponding phasor diagrams; elaborate on construction and types of single-phase and three-	[abet_PI_3_17] No Classification 3 Year PIs Review Cycle Mar 8 2018 Session II – Deleted - Moved SO1

phase transformers such as unit, substations, distribution, potential and current transformers; and obtain their equivalent circuits	
Justification: The content of PI_3_17 was related to theory of transformer devices and not strictly design therefore the content of this PI was adequately covered by PI_1_68 and moved to SO 'a' (SO _1).	
Inaccurate PIs	**Action**
Mechanical Engineering Program	
[abet_PI_3_8] Cognitive: Creating Design transportation systems including roads, runway and pavements	[abet_PI_3_8] No Classification 3 Year PIs Review Cycle Mar 1 2018 – Deleted - Inaccurate
Justification: The PI_3_8 was related to civil engineering course on transportation systems and inaccurate to list in the ME PIs database and was therefore deleted.	
Civil Engineering Program	
[abet_PI_9_10] Affective: Valuing Describe the relevance of literature.	[abet_PI_9_10] No Classification 3 Year PIs Review Cycle Mar 19 2018 Session V – Deleted - inaccurate
Justification: The PI_9_10 was deleted due to vague description which does not align with the purpose of ABET SO 'j' on lifelong learning	
Electrical Engineering Program	
[abet_PI_4_1] Affective: Internalizing values Research and gather information	[abet_PI_4_1] No Classification 3 Year PIs Review Cycle Mar 13 2018 Session III – Deleted - inaccurate
Justification: The PI_4_1 was deleted due to vague description which does not describe details of assessment of teamwork and therefore was deleted as inaccurate	
Too Basic PIs	**Action**
Mechanical Engineering Program	
[abet_PI_1_5] Cognitive: Applying Use matrices for solving systems of linear equations	[abet_PI_1_5] No Classification 3 Year PIs Review Cycle Feb 25 2018 – Deleted – Too Basic
Justification: The content mention in PI_1_5 was related to using matrices for solving systems of linear equations. These mathematical skills are adequately covered in several PIs corresponding to SO 'c' (SO_3), SO 'e' (SO_5) and SO 'k' (SO_11) and therefore deleted as too basic in content.	
Futuristic PIs	**Action**
Civil Engineering Program	
[abet_PI_5_55] Cognitive: Analyzing Analyze and determine the structural adequacy of hydraulic structures like dams against water pressure. [abet_PI_5_12] Cognitive: Applying Apply energy conservation concept of moving fluids to hydraulic structures	[abet_PI_5_55] No Classification PIs 3 Year review cycle March 19 2018 Session V – Futuristic [abet_PI_5_12] No Classification PIs 3 Year review cycle March 7 2018 Session III - Futuristic
Justification: PI_5_12 and PI_5_55 were originally introduced into the PIs database from QIYAS National Standardized outcomes guide (November 2014 Draft). These PIs related to an advanced elective course on Hydraulic Structures and are not currently considered in the degree plan and therefore they were deleted as being futuristic.	
Electrical Engineering Program	
[abet_PI_11_3] Psychomotor: Adaptation Employ electronics engineering application software, such as functional simulation tools, to help in the design process of low and high level design and implementation of digital electronic circuits	[abet_PI_11_3] No Classification PIs Review MAR 20 2018 Session 5 - Futuristic
Justification: PI_11_3 was originally introduced into the PIs database from Qiyas National Standardized outcomes guide (November 2014 Draft). This PI is related to the use of simulation software for design and implementation of digital electronic circuits and is currently not feasible for the implementation with existence laboratory facilities and therefore was deleted as being futuristic.	

5. PDCA QUALITY CYCLE Q5: SOs MULTI-TERM REVIEW

i. DIRECT ASSESSMENT OF ABET SOs (a-k) – MULTI-TERM ANALYSIS (382, 381, 372, 371, 362, 361, 352 AND 351)

In this section, we present summarized data for the attainment of SOs and also samples of EE, ME and CE program level multi-term ABET SOs (a-k) executive summary reports. A summary of 8 terms of ABET SOs (a-k) and CQI data from term 351 (Fall 2014) up to term 382 (Spring 2018) is presented in this section. The multi-term detailed executive summary report presented does not include any data related to the revised ABET SOs (1-7) since the ABET EAC Commission approved changes to the 2019-20 accreditation cycle for implementation by mid-2018. As per the Q_5 PDCA Quality Cycle's assessment plan, the multi-term SOs evaluation is conducted every three years necessitating collection of at least 6 terms of outcomes and CQI data related to revised ABET SOs (1-7). Therefore, a detailed multi-term review related to the revised ABET SOs (1-7) shall be conducted in Spring 2022.

Attainment of ABET SOs (a-k) – Multi-Term Executive Summary Report (Terms 382, 381, 372, 371, 362, 361, 352 and 351)

Tables J18, Table J19 and Table J20 below show a summary of EE, ME and CE program committee decisions *Exceeding, Meeting* or *Below Expectations* for overall review of ABET SOs (a-k) score results spanning 8 terms from term 351 (Fall 2014) up to term 382 (Spring 2018). The Red, Yellow, Green and White flags and criteria for *Exceeding, Meeting* and *Below Expectations* have already been explained in section Table 6.

Table J18. EE program multi-term executive summary report Fall 2014 to Spring 2018 (Terms 382, 381, 372, 371, 362, 361, 352 and 351)

Department: EE **Multi-Term Executive Summary Report**

SO	382 2018		381 2017		372 2017		371 2016		362 2016		361 2015		352 2015		351 2014	
	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification
SO_1	2.71	Below Expectations	2.80	Below Expectations	2.81	Below Expectations	2.35	Below Expectations	1.98	Below Expectations	2.50	Below Expectations	1.80	Below Expectations	2.69	Below Expectations
SO_2	4.40	Meeting Expectations	4.10	Meeting Expectations	3.83	Meeting Expectations	3.47	Meeting Expectations	3.42	Meeting Expectations	2.97	Below Expectations	3.67	Meeting Expectations	4.32	Meeting Expectations
SO_3	3.47	Meeting Expectations	3.78	Meeting Expectations	4.04	Meeting Expectations	3.33	Meeting Expectations	2.64	Below Expectations	1.67	Below Expectations	2.96	Meeting Expectations	1.76	Below Expectations
SO_4	4.69	Meeting Expectations	4.59	Meeting Expectations	4.40	Meeting Expectations	4.35	Meeting Expectations	2.43	Below Expectations	0.00	Below Expectations		N/A	4.49	Meeting Expectations
SO_5	2.97	Below Expectations	2.89	Below Expectations	2.96	Below Expectations	2.08	Below Expectations	2.05	Below Expectations	2.48	Below Expectations	2.61	Below Expectations	3.14	Below Expectations
SO_6	4.29	Meeting Expectations	3.16	Below Expectations	3.66	Meeting Expectations	2.98	Below Expectations	2.88	Below Expectations	1.96	Below Expectations		N/A		N/A
SO_7	4.12	Meeting Expectations	3.56	Meeting Expectations	3.94	Meeting Expectations	4.32	Meeting Expectations	3.52	Meeting Expectations	3.06	Below Expectations		N/A	0.49	Below Expectations
SO_8	3.46	Meeting Expectations	3.73	Meeting Expectations	4.02	Meeting Expectations	4.43	Meeting Expectations	2.76	Below Expectations	0.71	Below Expectations		N/A		N/A
SO_9	4.23	Meeting Expectations	3.85	Meeting Expectations	3.64	Meeting Expectations	4.27	Meeting Expectations	4.58	Meeting Expectations		N/A		N/A		N/A
SO_10	2.88	Below Expectations	3.39	Meeting Expectations	1.43	Below Expectations	2.54	Below Expectations	4.72	Meeting Expectations	2.14	Below Expectations		N/A		N/A
SO_11	3.58	Meeting Expectations	3.22	Below Expectations	3.27	Below Expectations	2.61	Below Expectations	2.13	Below Expectations	1.81	Below Expectations	1.63	Below Expectations	2.82	Below Expectations

Table J19. ME program multi-term executive summary report Fall 2014 to Spring 2018 (Terms 382, 381, 372, 371, 362, 361, 352 and 351)

Department: ME **Multi-Term Executive Summary Report**

SO	382 2018		381 2017		372 2017		371 2016		362 2016		361 2015		352 2015		351 2014	
	A*	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification
SO_1	3.35	Meeting Expectations	3.28	Below Expectations	3.41	Meeting Expectations	3.71	Meeting Expectations	2.60	Below Expectations	2.63	Below Expectations	1.79	Below Expectations	3.53	Meeting Expectations
SO_2	4.49	Meeting Expectations	3.65	Meeting Expectations	3.62	Meeting Expectations	3.57	Meeting Expectations	3.97	Meeting Expectations	3.56	Meeting Expectations	3.78	Meeting Expectations	4.52	Meeting Expectations
SO_3	4.06	Meeting Expectations	3.86	Meeting Expectations	4.24	Meeting Expectations	3.08	Below Expectations	3.34	Meeting Expectations		N/A		N/A		N/A
SO_4	4.61	Meeting Expectations	4.11	Meeting Expectations	4.93	Meeting Expectations	4.15	Meeting Expectations		N/A		N/A		N/A		N/A
SO_5	3.58	Meeting Expectations	3.30	Meeting Expectations	3.13	Below Expectations	3.21	Below Expectations	3.17	Below Expectations	2.22	Below Expectations	2.29	Below Expectations	2.89	Below Expectations
SO_6	3.53	Meeting Expectations	3.41	Meeting Expectations	4.40	Meeting Expectations	2.88	Meeting Expectations		N/A	3.33	Meeting Expectations		N/A		N/A
SO_7	4.42	Meeting Expectations	3.81	Meeting Expectations	4.67	Meeting Expectations	3.60	Meeting Expectations	3.88	Meeting Expectations		N/A	2.25	Below Expectations	3.41	Below Expectations
SO_8	3.79	Meeting Expectations	3.36	Meeting Expectations	4.02	Meeting Expectations	3.66	Meeting Expectations		N/A		N/A		N/A		N/A
SO_9	4.17	Meeting Expectations	3.33	Meeting Expectations	4.51	Meeting Expectations	3.87	Meeting Expectations		N/A		N/A		N/A		N/A
SO_10	3.60	Meeting Expectations	1.68	Below Expectations		N/A		N/A		N/A		N/A		N/A		N/A
SO_11	3.14	Below Expectations	3.18	Below Expectations	3.14	Below Expectations	3.52	Meeting Expectations	3.13	Below Expectations	3.59	Meeting Expectations	2.81	Below Expectations	3.08	Below Expectations

Table J20. CE program multi-term executive summary report Fall 2014 to Spring 2018 (Terms 382, 381, 372, 371, 362, 361, 352 and 351)

Department: CE

Multi-Term Executive Summary Report

SO	382 2018		381 2017		372 2017		371 2016		362 2016		361 2015		352 2015		351 2014	
	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification
SO_1	3.89	Meeting Expectations	3.82	Meeting Expectations	3.67	Meeting Expectations	3.95	Meeting Expectations	2.57	Below Expectations	3.49	Meeting Expectations	2.23	Below Expectations	3.10	Below Expectations
SO_2	4.73	Meeting Expectations	4.32	Meeting Expectations	4.28	Meeting Expectations	3.80	Meeting Expectations	3.15	Below Expectations	3.12	Below Expectations	3.64	Meeting Expectations	3.14	Below Expectations
SO_3	3.08	Below Expectations	3.99	Meeting Expectations	3.66	Meeting Expectations	3.62	Meeting Expectations	2.41	Below Expectations	3.68	Meeting Expectations		N/A		N/A
SO_4	4.47	Meeting Expectations	4.50	Meeting Expectations	4.74	Meeting Expectations	4.76	Meeting Expectations		N/A		N/A		N/A		N/A
SO_5	3.34	Meeting Expectations	3.05	Below Expectations	3.26	Below Expectations	2.80	Below Expectations	3.20	Below Expectations	2.90	Below Expectations	2.35	Below Expectations	3.35	Meeting Expectations
SO_6	3.42	Meeting Expectations	2.92	Below Expectations	3.50	Meeting Expectations	3.89	Meeting Expectations		N/A		N/A		N/A		N/A
SO_7	4.34	Meeting Expectations	3.49	Meeting Expectations	3.39	Meeting Expectations	3.99	Meeting Expectations	2.64	Below Expectations	3.66	Meeting Expectations		N/A		N/A
SO_8	4.22	Meeting Expectations	3.76	Meeting Expectations	4.00	Meeting Expectations	2.14	Below Expectations	2.41	Below Expectations	1.25	Below Expectations		N/A		N/A
SO_9	4.30	Meeting Expectations	4.63	Meeting Expectations	3.13	Meeting Expectations	4.49	Meeting Expectations		N/A		N/A		N/A		N/A
SO_10	3.47	Meeting Expectations	2.82	Below Expectations	4.07	Meeting Expectations	3.33	Meeting Expectations		N/A		N/A		N/A		N/A
SO_11	3.64	Meeting Expectations	3.43	Meeting Expectations	3.45	Meeting Expectations	3.58	Meeting Expectations	3.31	Below Expectations	3.20	Below Expectations	2.13	Below Expectations	3.09	Below Expectations

ii. ME PROGRAM SAMPLE - MULTI-TERM EXECUTIVE SUMMARY REPORT FOR ABET SOs (a-k)

Since the multi-term executive summary reports are detailed and lengthy, running into tens of pages for each program, we present a small portion of the ME program's multi-term report as a sample in Table J21 for just SO 'g' (SO_7) on "*an ability to communicate effectively*". The executive summary report shows a list of PIs, courses assessed, terms covered followed by summarized notes and actions by attending program faculty members for deficiencies reviewed during program term reviews spanning Fall 2014 to Spring 2018 time period. The overall summary includes a program level decision of whether the ABET SO is *Exceeding, Meeting* or *Below Expectations*. The actions of the multi-term SOs executive summary report as mentioned in an earlier *Section IV.D.7 CIMS Program and administrative committee action items, reporting and documentation,* mainly involve either review and approval of faculty actions in the FCAR or their elevation to the program level for assignment to administrative committees for closure.

Table J21. ME program multi-term executive summary report for ABET SOs (A-K)

abet_SO_7 : an ability to communicate effectively

abet_PI_7_2: Present technical information with proper Format and Organization

abet_PI_7_3: Communicate Graphical Information

abet_PI_7_4: Write complete technical reports with title, front matter, list of tables and contents, details of overall organization of the report, English(grammar/spelling/sentence structure), abstract/introduction, description of training program, case studies/measurements/supervision and design, theory and field applications, research activities, conclusions & recommendations etc. with proper formatting and style

abet_PI_7_5: Make effective oral presentations in a given time frame to defend course projects with required professionalism, style, slide quality, delivery, response to questions and adequate technical content of problem definition, literature review, design specifications, design estimation and target determination, deliverables, methodology, design decision identification, design concepts, concepts evaluation, concepts selection, detailed design presentation, necessary planning, budget, conclusion, references, appendices etc.

abet_PI_7_12: Communicate on time and effectively with the concerned stake holders using oral and written means in the form of presentations, technical reports, diagrammatic representations using electronic or other media

abet_PI_7_13: Write complete technical reports with title, front matter, list of tables and contents, details of problem definition, literature review, design specifications, design estimation and target determination, deliverables, methodology, design decision identification, design concepts, concepts evaluation, concepts selection, detailed design presentation, necessary planning, budget, conclusion, references, appendices etc. with proper formatting and style.

abet_PI_7_14: Make effective clear oral presentations in given time frame providing details of title, front matter, list of tables and contents, details of overall organization of the report, English(grammar/spelling/sentence structure), abstract/introduction, description of training program, case studies/measurments/supervision and design, theory and field applications, research activities, conclusions & recommendations etc. with proper formatting and style

abet_PI_7_15: Develop an elaborate project proposal for the design of a mechanism related to theory of machines such as gears, cams etc.: provide a summarized project abstract; reference literature survey detailing the construction (components, dimensions), manufacturability (material, facility, costs) and operation (schematic and text detailing inter-related motions) of the mechanism; provide design specifications (customer requirements and constraints); discuss manufacturability of the design (facilities, materials required and costs); provide a detailed project implementation schedule in the form of a Gantt chart.

abet_PI_7_16: Prepare interim Senior Design Report incorporating modifications in literature review, any other suggestion for improvements based on advisor feedback; Write a detail technical report following a specific/standard format to present: Abstract; Problem Definition; Problem Statement; Problem Formulation (Goals of Project, Scope of Project); Literature Review; Design Concepts Development (List all existing design methods, Propose new design methods); Design Evaluation & Selection (Concept Evaluation & Selection, Design Specifications, Constraints, Customer requirements (modifiable with customer agreement)

abet_PI_7_17: Make a professional poster presentation of Capstone design Project; display Abstract, Methodology, Summarized simulation/mathematical Results, conclusions, references; Provide necessary technical diagrams

abet_PI_7_18: Make a professional poster presentation of Capstone design Project; interact with audience, visitors, reviewers; respond/answer questions proactively in an appropriate technical and professional manner.

Student Outcomes	382 2018		381 2017		372 2017		371 2016		362 2016		361 2015		352 2015		351 2014	
	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification	Avg	Classification

abet_SO_7	4.42	Meeting Expectations	3.81	Meeting Expectations	4.67	Meeting Expectations	3.60	Meeting Expectations	3.88	Meeting Expectations		N/A	2.25	Below Expectations	3.41	Below Expectations

PI	Assessment Resources	Evaluation							
		382 2018	381 2017	372 2017	371 2016	362 2016	361 2015	352 2015	351 2014
abet_PI_7_2	ME_317_1531 ME_312_1536					EAMU:(0,2,0,0) Avg:3.64			
abet_PI_7_3	ME_262_962 ME_211_1593							EAMU:(0,0,0,1) Avg:2.25 Below Expectations	EAMU:(0,0,1,0) Avg:3.41 Below Expectations
abet_PI_7_4	ME_498_928			EAMU:(1,0,0,0) Avg:4.91					
abet_PI_7_5	ME_323_2181 ME_413_2200 ME_323_1091 ME_497_1104 ME_323_791 ME_498_928 ME_497_3008	EAMU:(2,0,0,0) Avg:5	EAMU:(1,0,1,0) Avg:3.36	EAMU:(0,2,0,0) Avg:4.09	EAMU:(0,1,0,0) Avg:4.26				
abet_PI_7_12	ME_431_3022				EAMU:(0,1,0,0) Avg:3.61				
abet_PI_7_13	ME_323_2181 ME_413_2200 ME_498_2461 ME_323_1091 ME_497_1104 ME_323_791 ME_498_928 ME_323_2994 ME_497_3008 ME_317_1531 ME_334_1532 ME_312_1536	EAMU:(1,2,0,0) Avg:4.71	EAMU:(0,2,0,0) Avg:4.17	EAMU:(0,1,1,0) Avg:4.25	EAMU:(0,1,1,0) Avg:2.92 Below Expectations	EAMU:(1,2,0,0) Avg:4.05			
abet_PI_7_14	ME_498_2461 ME_323_2994	EAMU:(0,1,0,0) Avg:4.5			EAMU:(1,0,0,0) Avg:5				
abet_PI_7_15	ME_323_2181 ME_323_1091 ME_323_791	EAMU:(1,0,0,0) Avg:5	EAMU:(0,1,0,0) Avg:4.17	EAMU:(0,1,0,0) Avg:3.79					
abet_PI_7_16	ME_497_2460 ME_498_2461 ME_498_928	EAMU:(0,2,0,0) Avg:3.75		EAMU:(1,0,0,0) Avg:5					
abet_PI_7_17	ME_498_2461 ME_498_928	EAMU:(0,1,0,0) Avg:4.33		EAMU:(1,0,0,0) Avg:5					
abet_PI_7_18	ME_498_2461 ME_498_928	EAMU:(0,1,0,0) Avg:4.5		EAMU:(1,0,0,0) Avg:5					

Discussion/Action Items: 382 2018

Discussion	Action Items
This SO is meeting expectations	FCARs were reviewed

Discussion/Action Items: 381 2017

Discussion	Action Items
This SO is meeting expectations	No action

Discussion/Action Items: 372 2017

Discussion	Action Items
This SO is meeting expectations: The evaluation and assessment process for communication skills was discussed	Review of evaluation forms for project communication skills

Discussion/Action Items: 371 2016

	Discussion	Action Items
Some students performed marginally to writing complete technical reports with title, front matter, list of tables and contents, details of problem definition, literature review, design specifications		FCAR AIs were reviewed for examining the possible solutions for improvement of this failure
abet_PI_7_13	Some students performed marginally to writing complete technical reports with title, front matter, list of tables and contents, details of problem definition, literature review, design specifications	FCAR AIs were reviewed for examining the possible solutions for improvement of this failure

Discussion/Action Items: 362 2016

Discussion	Action Items
The overall results in this SO met expectations. Students fared well in their presentation and report writing skills	Additional PIs with details on several aspects of written and oral presentations have been prepared and ready for implementation in various courses of current and future terms. The capstone design projects shall comprehensively measure this SO in the future.

Discussion/Action Items: 361 2015

Discussion	Action Items

Discussion/Action Items: 352 2015

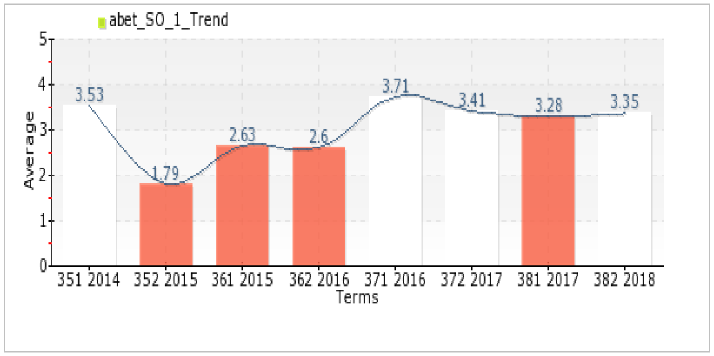
	Discussion	Action Items
Additional strategies of teaching and learning like interactive assessments, viva with pre-announced question bank was discussed		AIs were elevated to the ME Committee for review and action
abet_PI_7_3	Additional methods of teaching and learning like interactive assessments were discussed	AIs were elevated to the ME Committee for review and action

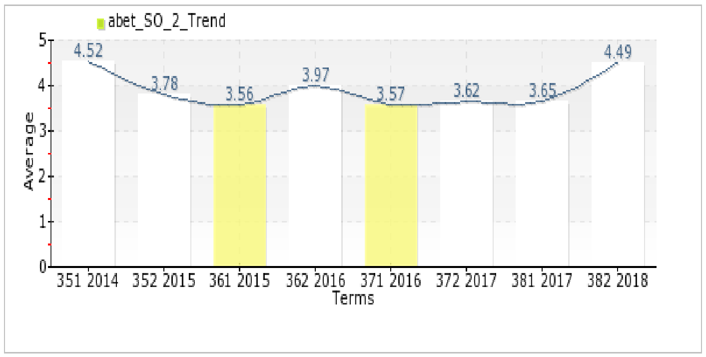
Discussion/Action Items: 351 2014

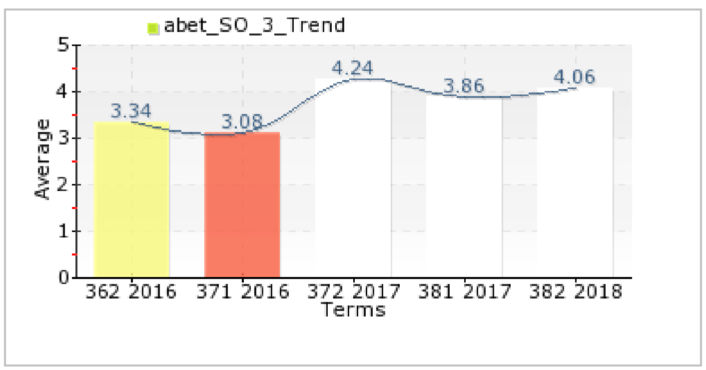
	Discussion	Action Items
Some students displayed poor graphical representation skills and the faculty suggested more problems covering this PI in class.		
abet_PI_7_3	Some students displayed poor skills related to graphical representation of technical information	AIs in the respective FCARs were reviewed

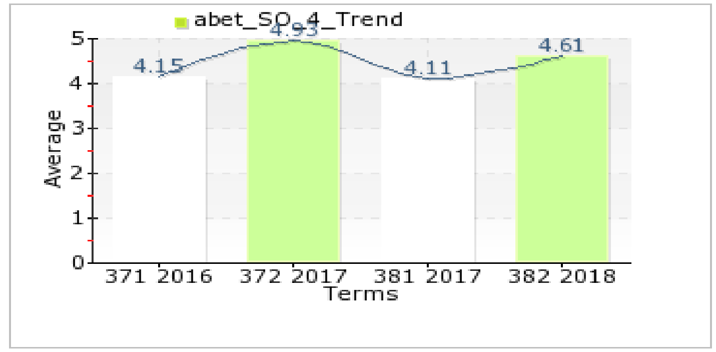
iii. MULTI-TERM SOS REVIEW - TREND ANALYSIS

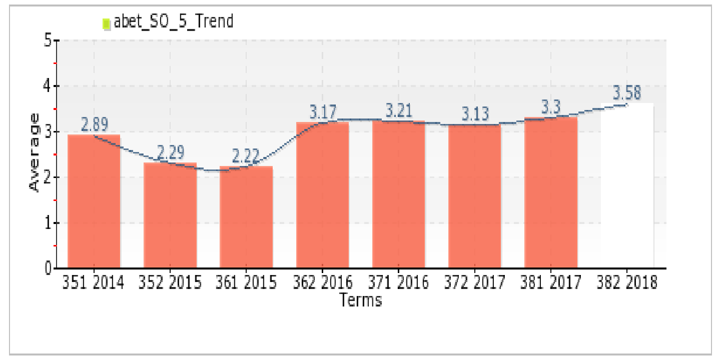
Multi-term Trend Analysis for ME, EE and CE programs 11 SOs (a-k) terms 351 to 382 (Fall 2014 to Spring 2018) is shown in Figures J27, J28 and J29.

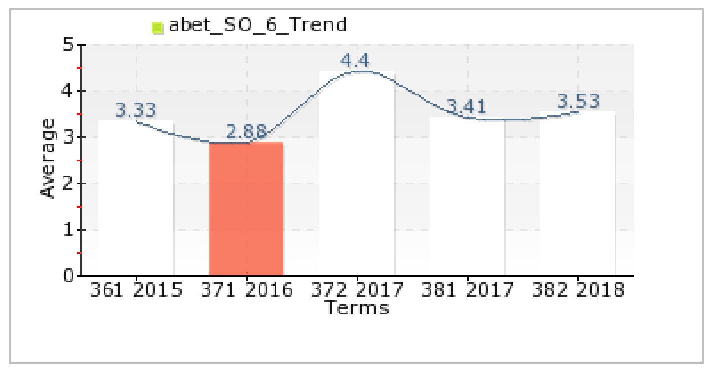


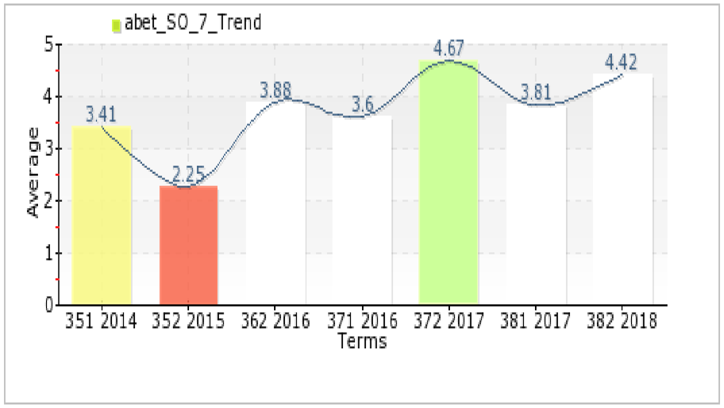


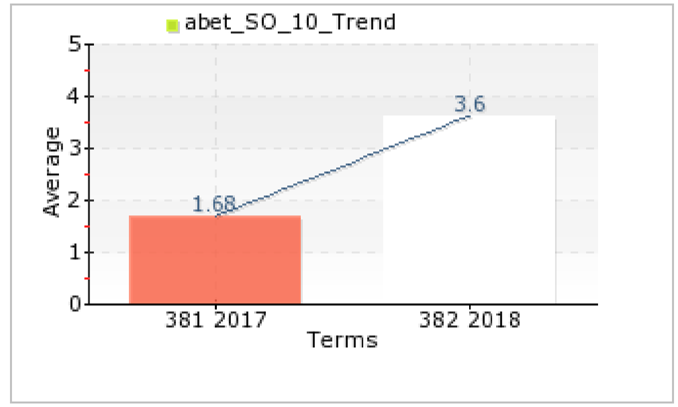


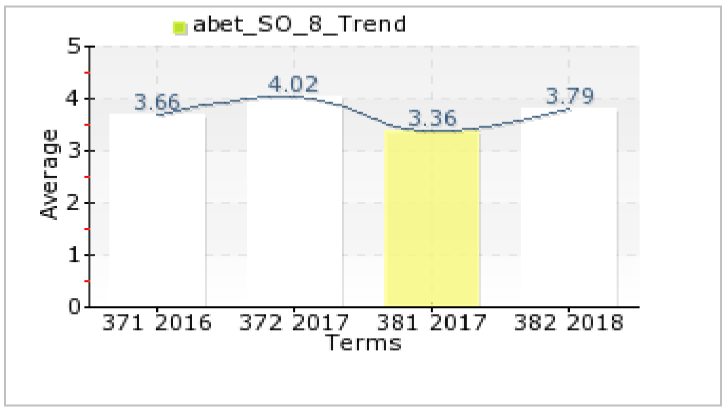


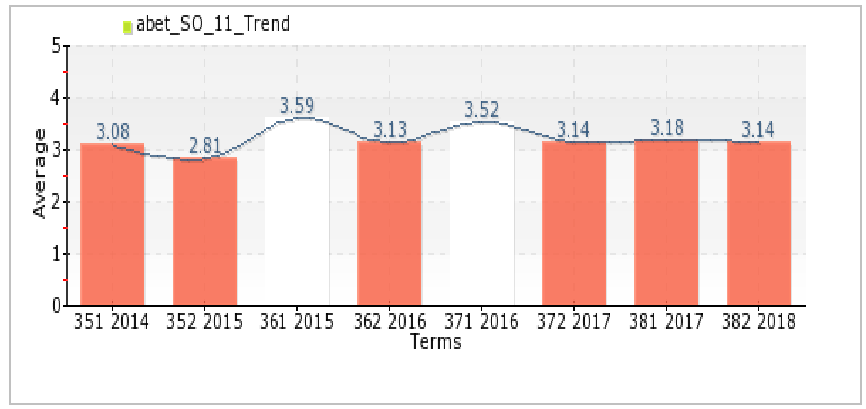












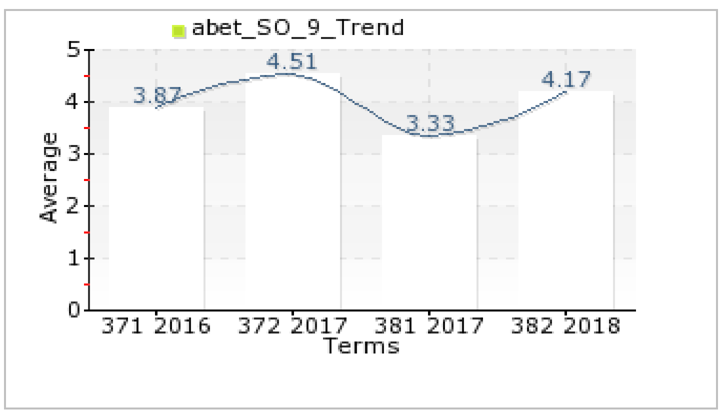
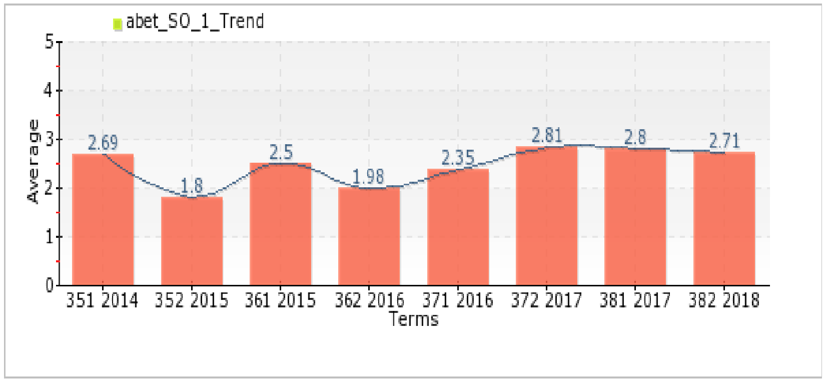
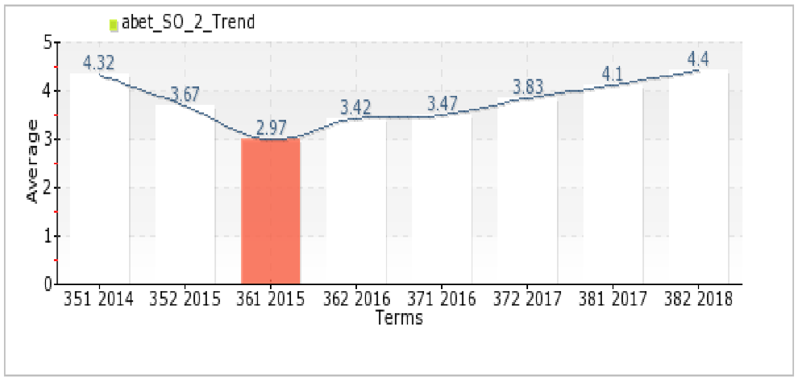
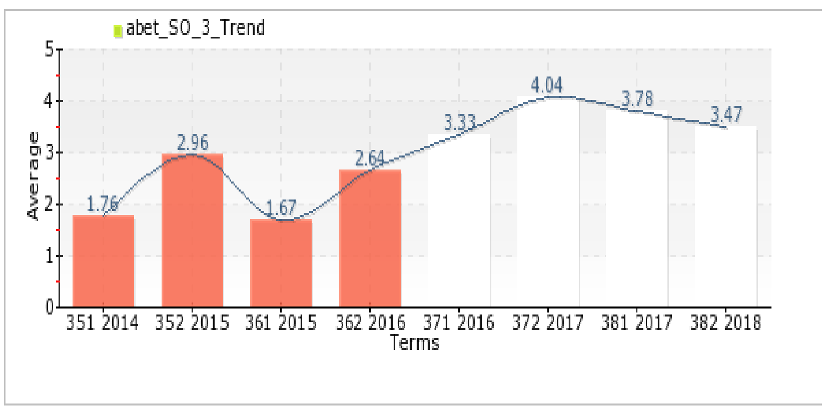


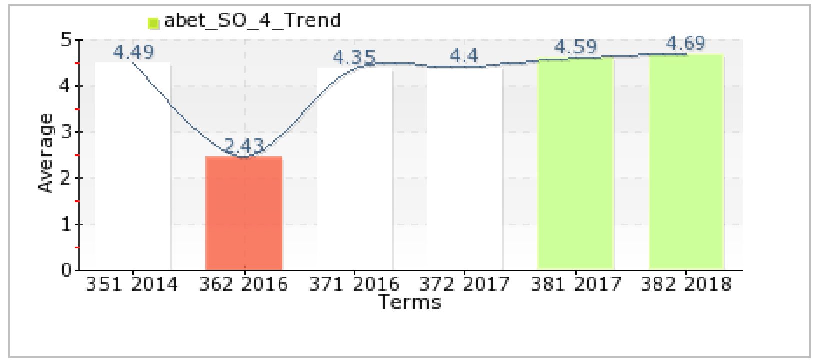
Figure J27. Consolidated Plot for ME program ABET SOs (a-k) multi-term trend analysis.

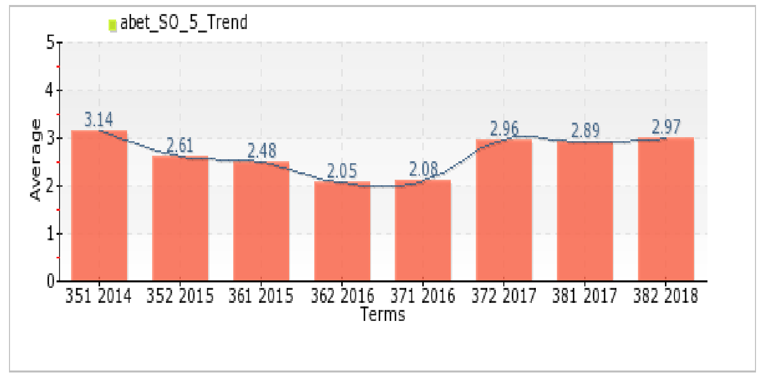
Multi-term Trend Analysis for EE program is shown in Figure J28 for 11 SOs (a-k) terms 351 to 382 (Fall 2014 to Spring 2018).

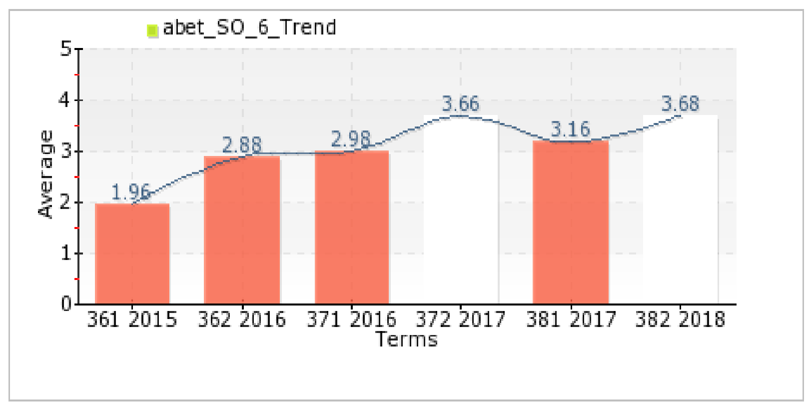


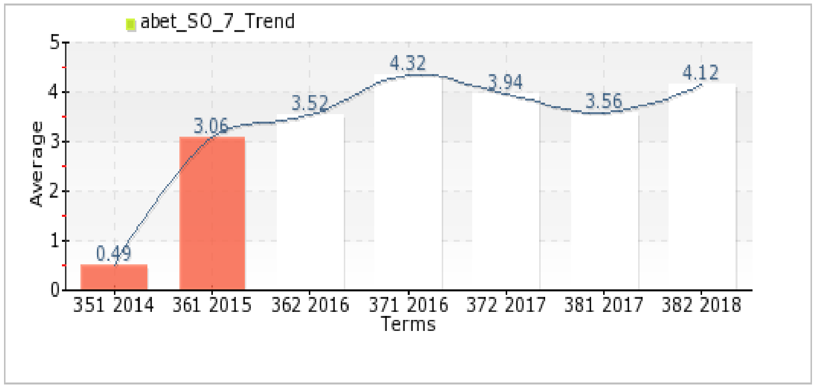


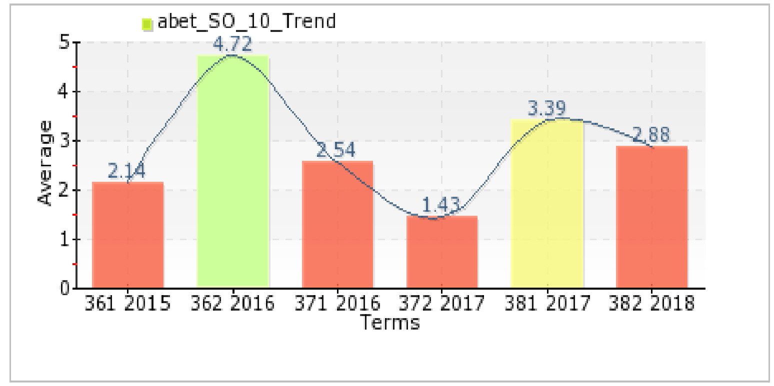


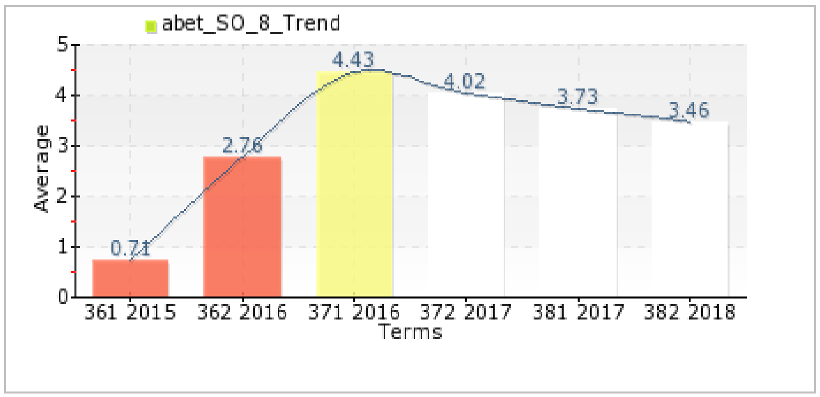


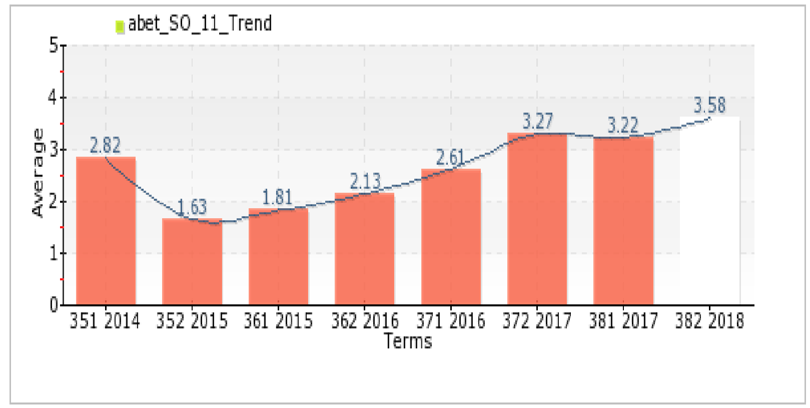












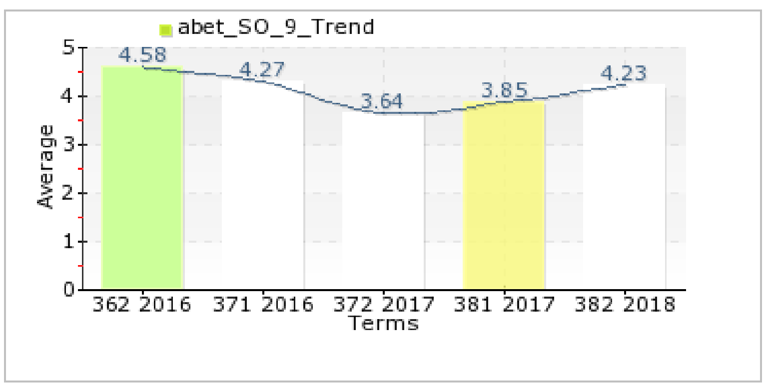
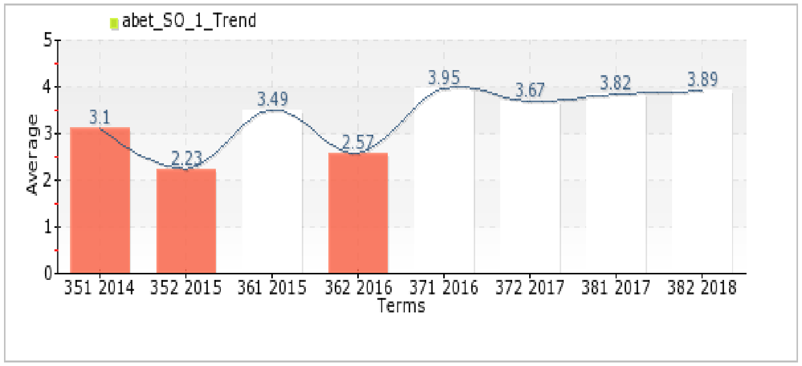
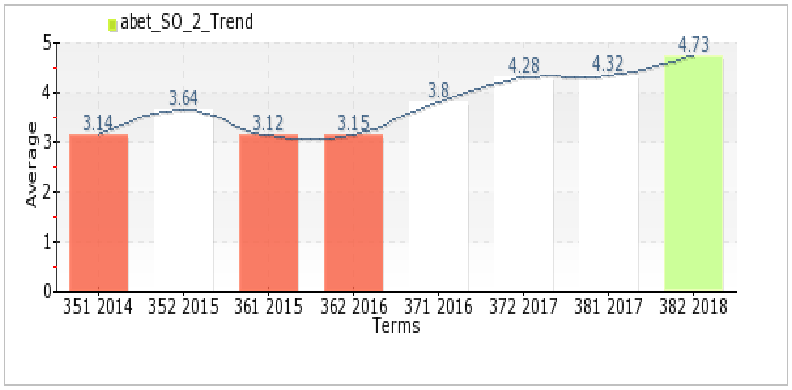
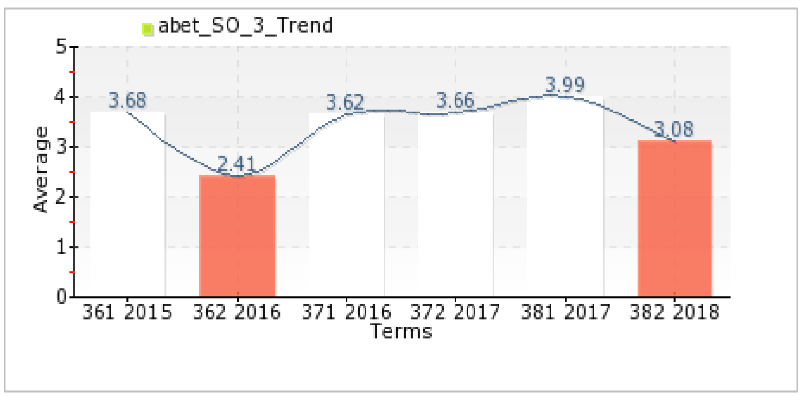


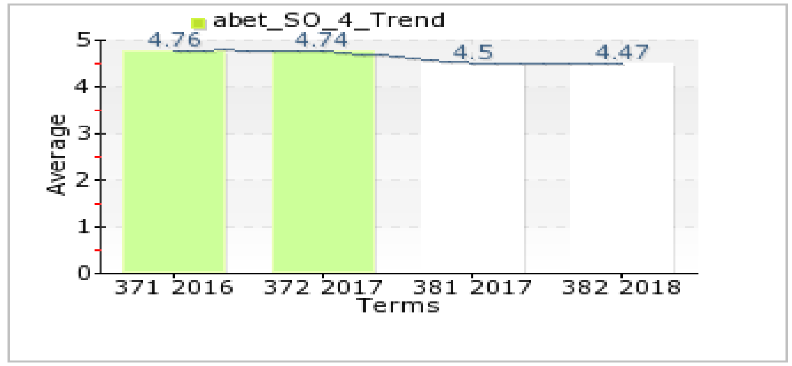
Figure J28. **Consolidated plot for EE program ABET SOs (a-k) multi-term trend analysis**

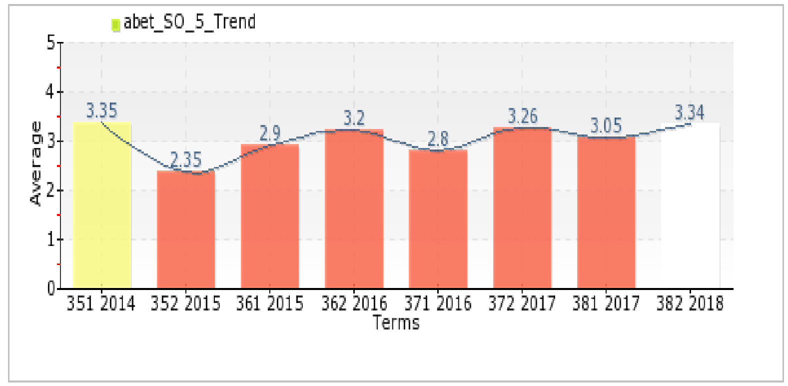
Multi-term Trend Analysis for CE program is shown in Figure J29 for 11 SOs (a-k) terms 351 to 382 (Fall 2014 to Spring 2018).

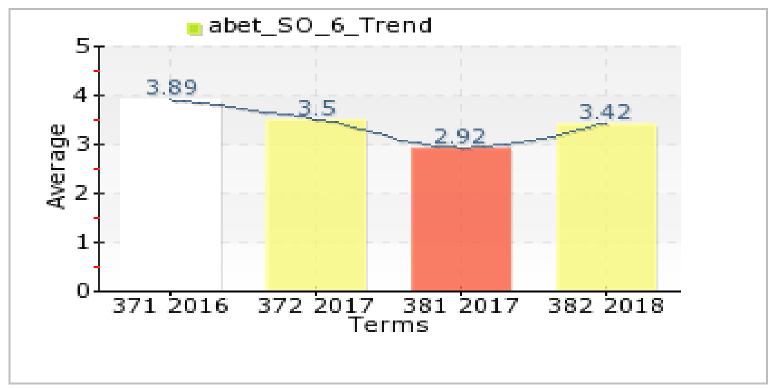


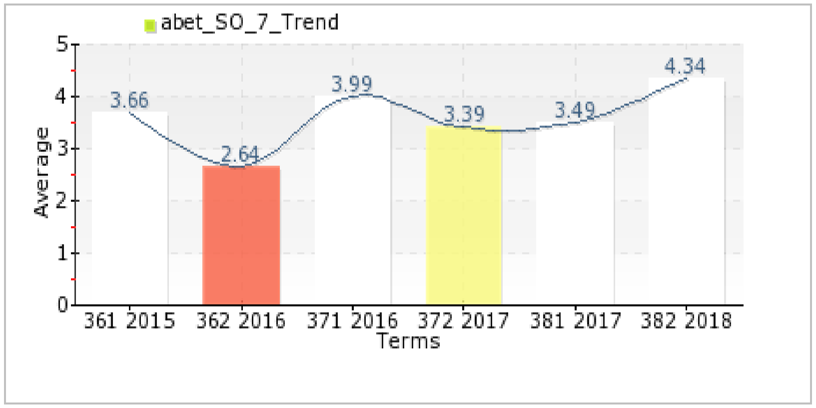


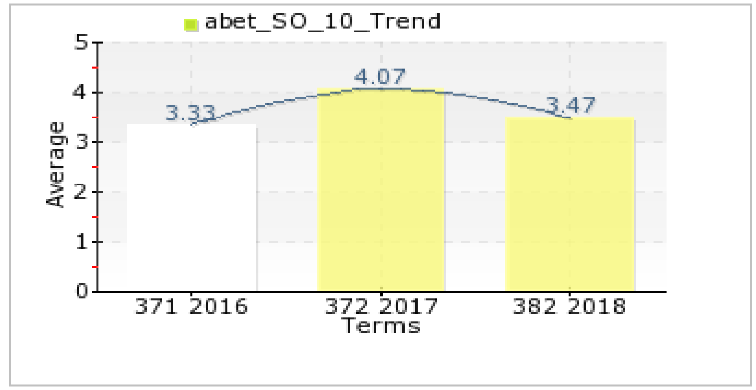


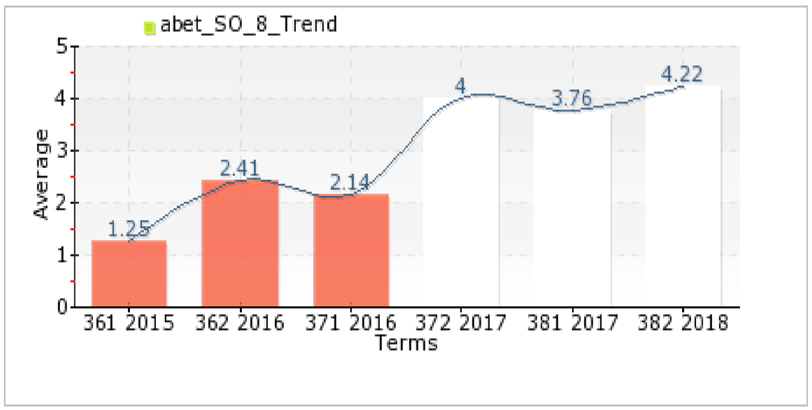


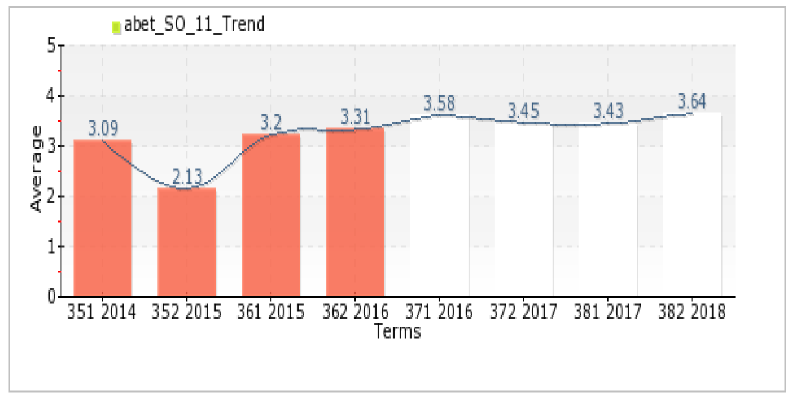












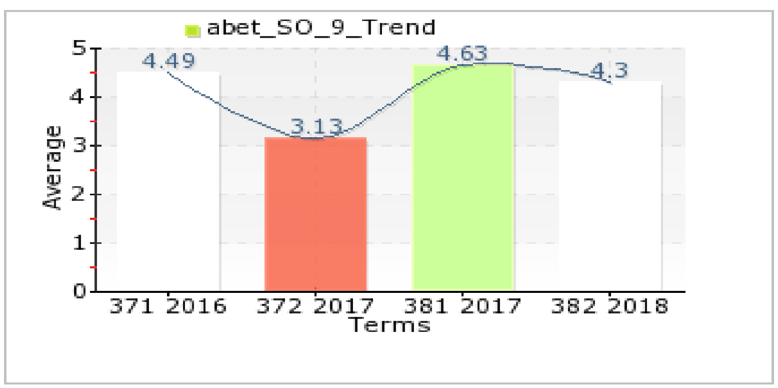


Figure J29. Consolidated plot for CE program ABET SOs (a-k) multi-term trend analysis

iv. PERFORMANCE CRITERIA FOR MULTI-TERM SOs TREND ANALYSIS

The Faculty of Engineering programs employ the performance criteria as shown in Table J22. A linear regression based trend analysis is employed to evaluate the multi-term trend performance of SOs (a-k). The next year's forecast for the SO performance is extrapolated from the linear trend using excel. This forecast is then compared with the average of SO values collected from the 351-382 terms to obtain the percentage increase. The SO's next year forecast value and percentage increase are compared to ranges as described in Table J22 to define seven case types and obtain the *Below, Meeting* and *Exceeding Expectations* review decisions for each SO.

Table J22. Performance criteria for multi-term SOs (A-K) trend analysis

Case#	Multi-term SO Trend Analysis Results	Review Decision	Recommended Action
1	Forecast after 1 year ≥ **4.0**	***Exceeding Expectations***	No action
2	Forecast after 1 year ≥ **3.0 AND** < **4.0** with > **0 AND** < **10%** increase compared to AVERAGE	***Meeting Expectations***	Need comments for SO based on term evaluations and create necessary action items
3	Forecast after 1 year ≥ **3.0 AND** < **4.0** with ≥ **10%** increase compared to AVERAGE	***Exceeding Expectations***	No action
4	Forecast after 1 year ≥ **3.0 AND** < **4.0** with < **0%** increase compared to AVERAGE	***Below Expectations***	Need comments for SO based on term evaluations and create action items, review SO change
5	Forecast after 1 year ≥ **2.5 AND** < **3.0** with ≥ **10%** increase compared to AVERAGE	***Meeting Expectations***	Need comments for SO based on term evaluations and create necessary action items
6	Forecast after 1 year ≥ **2.5 AND** < **3.0** with ≤ **10%** increase compared to AVERAGE	***Below Expectations***	Need comments for SO based on term evaluations and create necessary action items
7	Forecast after 1 year < **2.5**	***Below Expectations***	Review SO change, aggressive actions

1) OVERALL AVERAGE AND NEXT YEAR'S FORECAST FOR MULTI-TERM SOs TREND ANALYSIS

As shown in Table J23, SO 'a' (SO_1) average values obtained for ME program terms 351-382 are input as excel data and averaged to obtain the overall average. A linear regression based trend curve is then used to estimate the following year's forecasted SO 'a'value. Figure J30 shows the linear regression based trend curve obtained using excel for multi-term SO 'a' values. The percentage increase '% INCREASE' is computed by dividing the multi-term overall SO 'a' average value with the next year's forecasted SO 'a' value.

Table J23. Average calculation and next year forecast estimation for SO 'a' (SO_1)

TERM	**SNO.**	**SO_1 Results**
351	1	3.53
352	2	1.79
361	3	2.63
362	4	2.6
371	5	3.71
372	6	3.41
381	7	3.28
382	8	3.35
	AVERAGE	**3.04**
	FORECAST (NEXT YEAR)	**3.67**
	% INCREASE	**120.78**

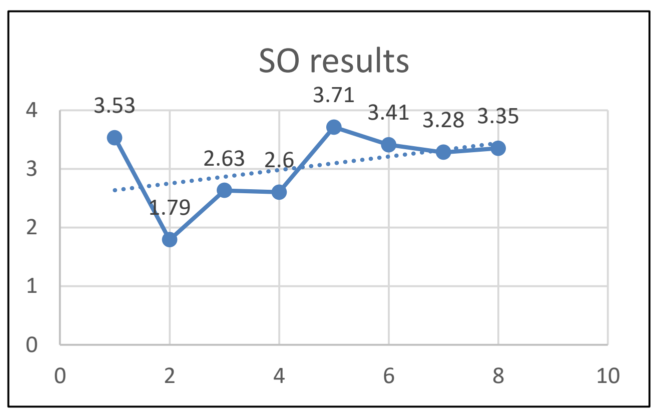


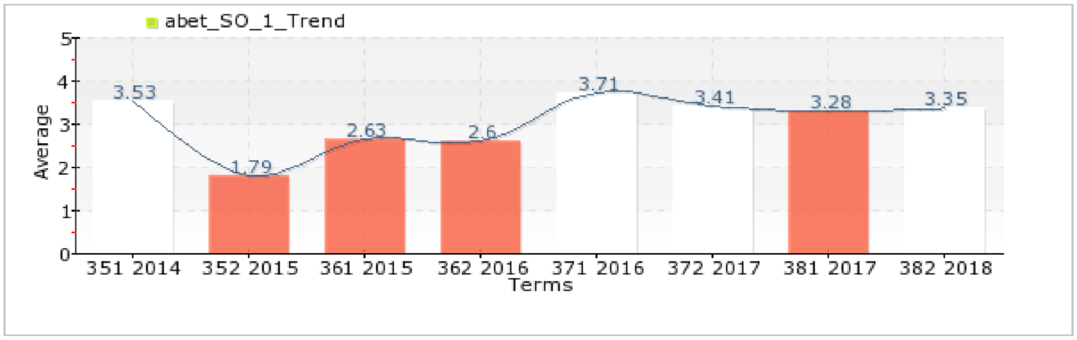
Figure J30. Trend Analysis based on linear regression for multi-term 351-382 SO 'a' values

2) MULTI-TERM SOs (a-k) TREND ANALYSIS EXECUTIVE SUMMARY REPORT

For brevity, a portion of the ME program's multi-term SOs (a-k) Trend Analysis Executive Summary Report for SO 'a' (SO_1) is shown in Table J24. The report indicates multi-term (351-382) SO 'a' (SO_1) data, trend curve, list of ME program reviewers, comments, corrective action, date of review and review decision of Exceeding Expectations for SO 'a' multi-term trend analysis.

Table J24. ME program trend analysis report for SO 'A' SO_1

abet_SO_1: an ability to apply knowledge of mathematics, science, and engineering



382 2018	**Avg**	3.35
	Classification	Meeting Expectations
381 2017	**Avg**	3.28
	Classification	Below Expectations
372 2017	**Avg**	3.41
	Classification	Meeting Expectations
371 2016	**Avg**	3.71
	Classification	Meeting Expectations
362 2016	**Avg**	2.60
	Classification	Below Expectations
361 2015	**Avg**	2.63
	Classification	Below Expectations
352 2015	**Avg**	1.79
	Classification	Below Expectations
351 2014	**Avg**	3.53
	Classification	Meeting Expectations

Classification: **Exceeding Expectations**
Discussion:

AVERAGE = 3.0375; FORECAST = 3.668690476; % INCREASE = 120.7799334;

According to multi-term SOs trend analysis performance criteria this is ***Case 3***: Forecast after 1 year ≥ 3.0 AND Ë, 4.0

with ≥ 10% increase compared to AVERAGE

The Review Decision for this SO is ***EXCEEDING EXPECTATIONS***

Action: No action

Reviewers:

Dr. KHT, Dr. MO, Dr. MA, Dr. AS, Dr. SZ, Dr. ERIM, Dr. MB, Mr. MF, Mr. YA, Mr. ANS, Mr. WH

Review Date:2018-09-03

v. SUMMARY OF RESULTS OF TREND ANALYSIS FOR ABET SOs (a-k) ME, CE AND EE PROGRAMS

The Multi-Term summary and trend reports involve a mixed methods review by Program and External Advisory Committees (EAC) every 3-5 years to:

1. Benchmark and adjust the existing performance criteria
2. Review coverage of SOs data coupled with faculty feedback of the validity/reliability of current assessment and evaluation data/process of individual SOs

3. Abrogate, modify or delete any SOs (refer to recommended actions for cases 4,6 and 7 mentioned in Table J22).
4. Based on the performance criteria shown in Figure 23 for the PDCA Quality Cycle Q5: *SOs Multi-Term Review Process Flow* the ME, CE and EE program committees made the following final review decisions for the ABET SOs (a-k) 5-year trend analysis [2014-18]:

(a) ME Program Final Review Decision:

Table J25 summarizes the ABET SOs (a-k) overall average, % increase, next year forecast, case type, review date and review decision data for the ME program.

Table J25. **ME program summary of ABET SOs (A-K) trend analysis data with review decisions**

ABET SOs	Overall Average	Forecast	% Increase	Case Type	Action	Review Date	Review Decision
SO_1 (SO 'a')	3.0375	3.67	120.78	3	None	2018-09-03	Exceeding Expectations
SO_2 (SO 'b')	3.90	3.82	98.18	4	Very marginal failure the program will continue with existing performance criteria and EAMU scales	2018-09-03	Below Expectations
SO_3 (SO 'c')	3.72	4.60	123.90	1	None	2018-09-03	Exceeding Expectations
SO_4 (SO 'd')	4.45	4.65	104.40	1	None	2018-09-03	Exceeding Expectations
SO_5 (SO 'e')	2.97	3.80	127.85	3	None	2018-09-03	Exceeding Expectations
SO_6 (SO 'f')	3.51	3.88	110.60	3	None	2018-09-03	Exceeding Expectations
SO_7 (SO 'g')	3.72	4.96	133.31	1	None	2018-09-03	Exceeding Expectations
SO_8 (SO 'h')	3.71	3.56	95.99	4	The program needs additional assessments to cover this SO in multiple courses; The performance criteria and EAMU scales will not be modified in the next cycle; This SO is merged with revised ABET SOs	2018-09-03	Below Expectations
SO_9 (SO 'i')	3.97	3.87	97.53	4	Very marginal failure. Concentrated focus on research skills and additional assessments are required in multiple courses; performance criteria and EAMU scales shall remain the same for the next cycle	2018-09-03	Below Expectations
SO_10 (SO 'j')	2.64	7.44	281.81	1	Need comprehensive assessments; this SO shall be merged with revised ABET SOs;	2018-09-03	Exceeding Expectations
SO_11 (SO 'k')	3.20	3.28	102.68	2	Need to concentrate on course level actions; performance criteria and EAMU scales shall remain the same in the next cycle; This SO is merged with revised ABET SOs	2018-09-03	Meeting Expectations
ME Program ABET SOs (a-k) Review Decision				8 out of 11 SOs Meeting or Exceeding Expectations [60-80%] Final Review Decision: **Meeting Expectations**			

Since 8 out of 11 SOs, 60-80% of SOs results were either *Exceeding* or *Meeting Expectations*, an overall review decision of *Meeting Expectations* was obtained. Figure 87 shows the meeting minutes for *Meeting ID ME:MTG:2018-09-03:V57* which indicate the ME program 's overall review decision for 11 SOs (a-k) multi-term (351-382) trend analysis is *Meeting Expectations*.

As mentioned in Table J22, based on trend forecast, achieved % increase, coverage of SOs data in several terms and faculty feedback, the following was observed:

1. The majority of SOs (a-k) performances just stabilized to *Meeting Expectations* in the last few terms towards 382 excepting for SO 'k' and therefore did not require any modifications to performance criteria. If *Meeting* or *Exceeding Expectations* results were observed in multiple terms for any of the SOs, then the minimum performance criteria would have been raised to increase the performance standards..
2. 8 out of the 11 SOs trends were positive with reasonable multi-term coverage and faculty feedback also indicated acceptable assessment and evaluation data/processes and did not necessitate any modifications to the 11 SOs

The overall multi-term results were therefore acceptable and the ME program's position to transition to revised 7 ABET SOs was reinforced.

Mechanical Engineering (ME) Committee Meeting Minutes

Meeting Code: ME:MTG:2018-09-03:V57

Location:

Meeting Schedule: 2018-09-03 13:00:00

Attended:

Excused:

Absent: -

1 Multi term SOs trend analysis (ABET)

Discussion:

Multi-term SOs trend analysis was carried out for the Mechanical Engineering Program.

8 out of the 11 SOs were found to be Meeting Expectations/Exceeding Expectations.

Decision:

Based on the analysis the ME program was found to be performing satisfactorily and meeting expectations in terms of SOs.

Figure J31. ME program meeting ID ME:MTG:2018-09-03:V57 review decision for SOs (a-k) multi-term trend analysis

(b) CE Program Final Review Decision:

Table J26 summarizes the ABET SOs (a-k) overall average, % increase, next year forecast, case type, review date and review decision data for the CE program.

Table J26. CE program summary of ABET SOs (A-K) trend analysis data with review decisions

ABET SOs	Overall Average	Forecast	% Increase	Case Type	Action	Review Date	Review Decision
SO_1 (SO 'a')	3.34	4.35	130.19	1	None	2018-09-04	Exceeding Expectations
SO_2 (SO 'b')	3.77	4.99	132.39	1	None	2018-09-04	Exceeding Expectations
SO_3 (SO 'c')	3.41	3.64	106.72	2	Need to concentrate on course level actions; performance criteria and EAMU scales shall remain the same in the next cycle;	2018-09-04	Meeting Expectations
SO_4 (SO 'd')	4.6175	4.23	91.59	1	None	2018-09-04	Exceeding Expectations
SO_5 (SO 'e')	3.03	3.30	108.88	2	None	2018-09-04	Meeting Expectations
SO_6 (SO 'f')	3.43	2.74	79.71	6	Need to identify additional course topics and assessments; performance criteria and EAMU scales shall remain the same in the next cycle; This SO is merged with revised ABET SOs	2018-09-04	Below Expectations
SO_7 (SO 'g')	3.59	4.27	119.19	1	None	2018-09-04	Exceeding Expectations
SO_8 (SO 'h')	2.96	5.63	190.07	1	None	2018-09-04	Exceeding Expectations
SO_9 (SO 'i')	4.02	5.78	143.66	1	None	2018-09-04	Exceeding Expectations
SO_10 (SO 'j')	3.62	3.83	105.80	2	None	2018-09-04	Meeting Expectations
SO_11 (SO 'k')	3.23	3.97	123.06	3	None	2018-09-04	Exceeding Expectations
CE Program ABET SOs (a-k) Review Decision					10 out of 11 SOs Meeting or Exceeding Expectation >80% Final Review Decision: **Exceeding Expectations**		

Since 10 out of 11 SOs, >80% of SOs results were either Exceeding or Meeting Expectations, an overall review decision of *Exceeding Expectations* was obtained. Figure J32 shows the meeting minutes for *MEETING_ID CE:MTG:2018-09-04:V49* which indicate the CE program‘s overall review decision for 11 SOs (a-k) multi-term (351-382) trend analysis is ***Exceeding Expectations.***

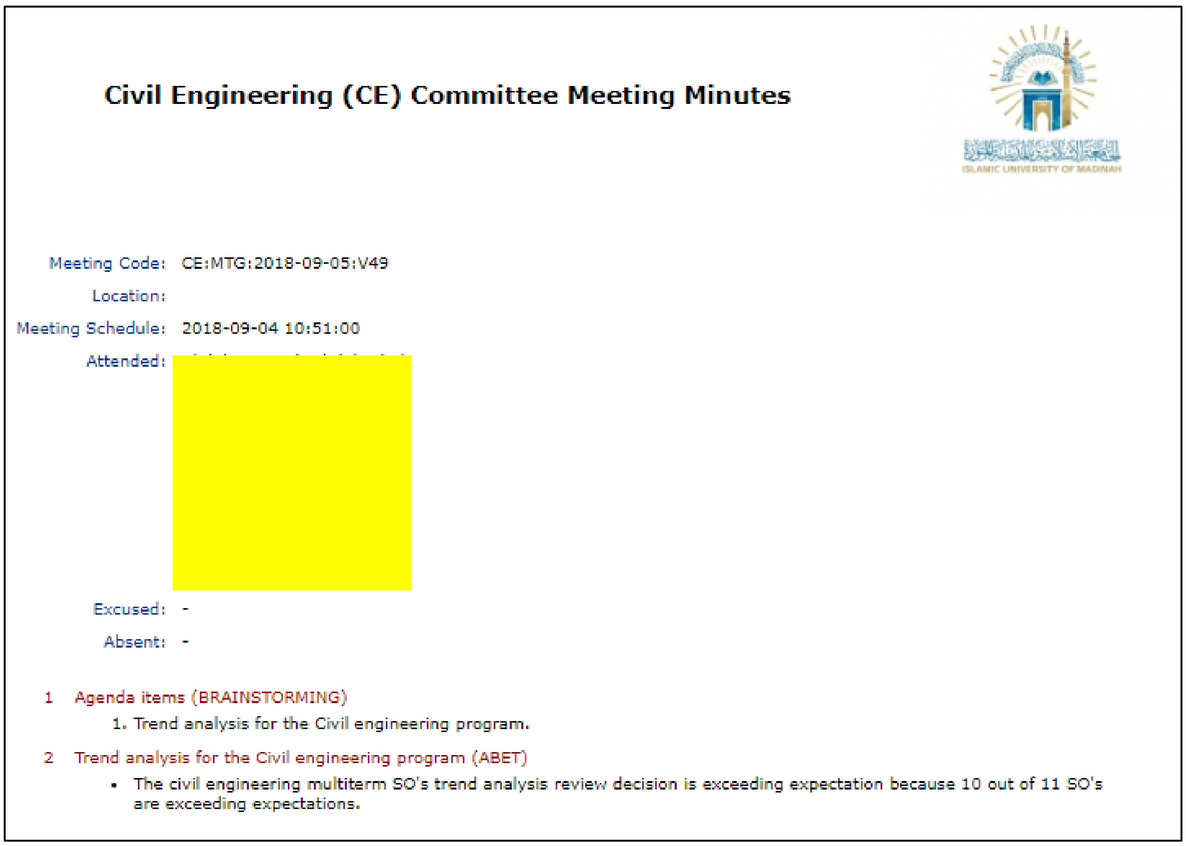
As mentioned in Table J22, based on trend forecast, achieved % increase, coverage of SOs data in several terms and faculty feedback, the following was observed:

1. The majority of SOs (a-k) performances just stabilized to *Meeting Expectations* in the last few terms towards 382 excepting for SO ‘c’ and therefore did not require any modifications to performance criteria. If *Meeting* or *Exceeding Expectations* results were observed in multiple terms for any of the SOs, then the minimum performance criteria would have been raised to increase the performance standards.
2. 10 out of 11 SOs trends were positive with reasonable multi-term coverage and faculty feedback also indicated acceptable assessment and evaluation data/processes and did not necessitate any modifications to the 11 SOs

The overall multi-term results were therefore acceptable and the CE program’s position to transition to revised 7 ABET SOs was reinforced.

(c) EE Program Final Review Decision:

Table J27 summarizes the ABET SOs (a-k) overall average, % increase, next year forecast, case type, review date and review decision data for the EE program.



Civil Engineering (CE) Committee Meeting Minutes

ISLAMIC UNIVERSITY OF MADINAH

Meeting Code: CE:MTG:2018-09-05:V49
Location:
Meeting Schedule: 2018-09-04 10:51:00
Attended:
Excused: -
Absent: -

1 Agenda items (BRAINSTORMING)
1. Trend analysis for the Civil engineering program.

2 Trend analysis for the Civil engineering program (ABET)
- The civil engineering multiterm SO's trend analysis review decision is exceeding expectation because 10 out of 11 SO's are exceeding expectations.

Figure J32. **CE program meeting ID CE:MTG:2018-09-04:V49 review decision for SOs (a-k) multi-term trend analysis**

Since 8 out of 11 SOs, 60-80% of SOs results were either *Exceeding* or *Meeting Expectations*, an overall review decision of *Meeting Expectations* was obtained. Figure J33 shows the meeting minutes for *MEETING_ID EE:MTG:2018-09-03:V60,* which indicate the EE program ‘s overall review decision for 11 SOs (a-k) multi-term (351-382) trend analysis is ***Exceeding Expectations.***

As mentioned in Table J22, based on trend forecast, achieved % increase, coverage of SOs data in several terms and faculty feedback, the following was observed:

1. 8 out of 11 SOs (a-k) performances just stabilized to *Meeting Expectations* in the last few terms towards 382 excepting for SOs ‘a’, ‘e’ and ‘j’, and therefore did not require any modifications to performance criteria. If *Meeting* or *Exceeding Expectations* results

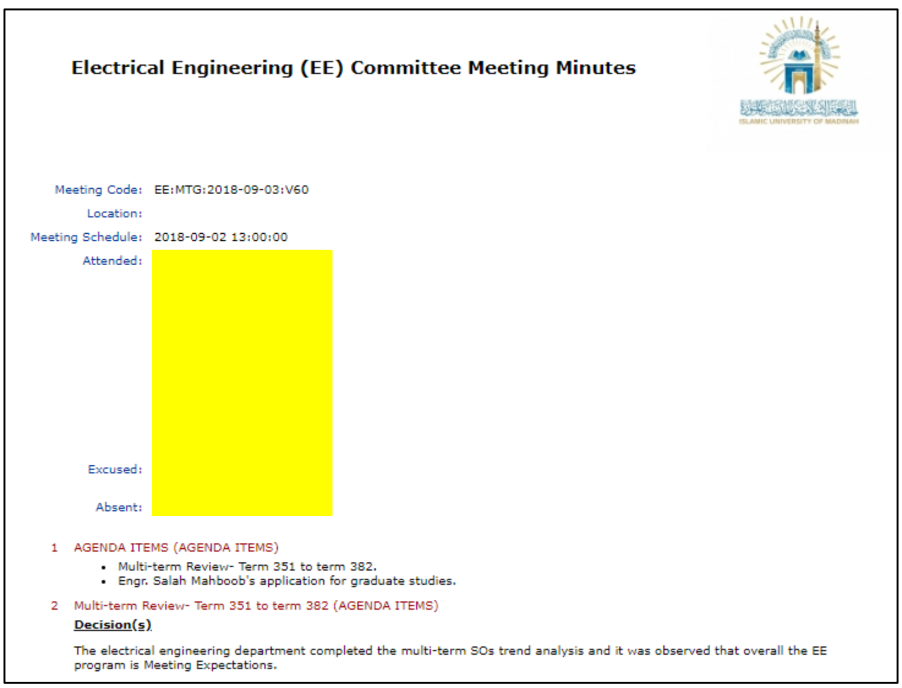
were observed in multiple terms for any of the SOs, then the minimum performance criteria would have been raised to increase the performance standards.

2. 8 out of 11 SOs trends were positive with reasonable multi-term coverage and faculty feedback also indicated acceptable assessment and evaluation data/processes and did not necessitate any modifications to the 11 SOs

Table J27. EE program summary of ABET SOs (A-K) trend analysis data with review decisions

ABET SOs	Overall Average	Forecast	% Increase	Case Type	Action	Review Date	Review Decision
SO_1 (SO 'a')	2.46	2.88	117.18	5	In general, SO 'a' is improving in overall trend performance so the performance criteria and EAMU levels are satisfactory and the program can continue employing the same performance criteria for this SO.	2018-09-02	Meeting Expectations
SO_2 (SO 'b')	3.77	4.12	109.27	1	None	2018-09-02	Exceeding Expectations
SO_3 (SO 'c')	2.96	4.52	152.87	1	None	2018-09-02	Exceeding Expectations
SO_4 (SO 'd')	3.56	5.66	158.87	1	None	2018-09-02	Exceeding Expectations
SO_5 (SO 'e')	2.65	2.76	104.15	6	This SO is modified as per the revised ABET SOs (1-7); Course actions have to be followed; performance criteria and EAMU values are to remain the same.	2018-09-02	Below Expectations
SO_6 (SO 'f')	3.05	4.35	142.61	1	None	2018-09-02	Exceeding Expectations
SO_7 (SO 'g')	3.28	5.49	166.87	1	None	2018-09-02	Exceeding Expectations
SO_8 (SO 'h')	3.19	5.27	165.60	1	None	2018-09-02	Exceeding Expectations
SO_9 (SO 'i')	4.11	3.55	86.39	3	The overall average is greater than 4.0 comprehensive assessments to be planned in courses and continued monitoring of this SO in the next cycle. The performance criteria and EAMU values to remain the same.	2018-09-02	Below Expectations
SO_10 (SO 'j')	2.85	2.67	93.68	6	Need comprehensive assessments in multiple courses and performance criteria, EAMU values to remain the same.	2018-09-02	Below Expectations
SO_11 (SO 'k')	2.63	3.82	145.07	3	None	2018-09-02	Exceeding Expectations
EE Program ABET SOs (a-k) Review Decision				10 out of 11 SOs Meeting or Exceeding Expectation >80% Final Review Decision: **Exceeding Expectations**			

The overall multi-term results were therefore acceptable and the EE program's position to transition to revised 7 ABET SOs was reinforced



Electrical Engineering (EE) Committee Meeting Minutes

Meeting Code: EE:MTG:2018-09-03:V60
Location:
Meeting Schedule: 2018-09-02 13:00:00
Attended:
Excused:
Absent:

1 AGENDA ITEMS (AGENDA ITEMS)
- Multi-term Review- Term 351 to term 382.
- Engr. Salah Mahboob's application for graduate studies.

2 Multi-term Review- Term 351 to term 382 (AGENDA ITEMS)
Decision(s)

The electrical engineering department completed the multi-term SOs trend analysis and it was observed that overall the EE program is Meeting Expectations.

Figure J33. EE program meeting ID EE:MTG:2018-09-03:V60 review decision for SOs (a-k) multi-term trend analysis

6. *PDCA QUALITY CYCLE Q6: PEOs 5-YEARS REVIEW PROCESS*

A Saudi educational institution with universal message, dealing with education, scientific research and community service in the sciences of Shari'ah, Arabic language and other sciences with global standards and technologies and high-quality output contributing to spreading the eternal message of Islam from the city of the Messenger of Allah (PBUH) to serve the local and global community

Figure J34. Islamic University mission statement, highlighting key phrases

Table J28. Relationship between ME, CE and EE PEOs and Islamic University mission statement

Key Components of Islamic University Mission Statement	PEO1	PEO2	PEO3	PEO4
Education with global standards, technology and high-quality output	√	√	√	
Scientific research with global standards, technology and high-quality output		√		√
Community Service with high-quality output to serve the local and global community		√		√
A Saudi educational institution contributing to spread the eternal message of Islam	√			√

Table J29. ME, CE and EE PEOs statements

ME department's program educational objectives:

PEO1	Successfully integrate the fundamentals of engineering knowledge, skills, tools, experimentation and design to develop innovative solutions related to mechanical engineering problems within a context of economical, societal, ethical and environmental constraints.
PEO2	Advance their career by assuming increasing levels of responsibility and entrepreneurial activities through effective communication, ability to work in multi-disciplinary and multi-cultural teams and leadership.
PEO3	Participate in life-long learning to acquire new expertise, as measured by continued education and qualifications such as licensure and membership with professional societies.
PEO4	Contribute to the development of the national and international society through professional/ community service, applied and basic research with integrity and sensitivity to global societal issues guided by Islamic values.

CE department's program educational objectives:

PEO1	Successfully integrate the fundamentals of civil engineering, skills, tools and design practices to develop innovative solutions to complex technological problems within a context of economical, societal, ethical and environmental constraints.
PEO2	Advance their careers as measured by leadership, communication skills, ability to work with multi-disciplinary and multi-cultural teams, promotions, salaries, career satisfaction, awards, recognitions, entrepreneurial activities, development of products or processes, patents, and/or publications.
PEO3	Participate in life-long learning to acquire new expertise, as measured by post-graduate education, continuing education and/or licensure, registration with professional societies.
PEO4	Contribute to local, national and international societies by providing professional, community and research services with integrity and sensitivity to global societal issues within the context of Islamic values

EE department's program educational objectives:

PEO1	Successfully integrate the fundamentals of electrical engineering, skills, tools and design practices to develop innovative solutions to complex technological problems within a context of economical, societal, ethical and environmental constraints.
PEO2	Advance their careers as measured by leadership, communication skills, ability to work with multi-disciplinary and multi-cultural teams, promotions, salaries, career satisfaction, awards, recognitions, entrepreneurial activities, development of products or processes, patents, and/or publications.
PEO3	Participate in life-long learning to acquire new expertise, as measured by post-graduate education, continuing education and/or licensure, registration with professional societies.
PEO4	Contribute to the society, profession and economic development of the local and global community/industry as measured by professional/ community service, applied and basic research, recognition in their chosen fields for leadership, integrity and sensitivity to global societal issues within the context of Islamic values.

Internal review of meeting the PEOs

To assess whether educational practices prepare students for reaching the intended program educational objectives, the first step is to examine how the programs' SOs are mapped to the PEOs as shown in Table J30. This relationship was previously reviewed by the programs' faculty members in February 2015 and most recently reviewed in August 2018. After much discussion, no changes were made. Table J31 shows correlation of PEOs to the revised ABET SOs (1-7).

Table J30. Correlation between PEOs and ABET SOs (a-k)

1 ABET Student Outcomes

	Outcomes	PEO1	PEO2	PEO3	PEO4
SO1	an ability to apply knowledge of mathematics, science, and engineering	☑	☐	☐	☐
SO2	an ability to design and conduct experiments, as well as to analyze and interpret data	☑	☐	☐	☐
SO3	an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	☑	☑	☐	☑
SO4	an ability to function on multidisciplinary teams	☐	☑	☐	☑
SO5	an ability to identify, formulate, and solve engineering problems	☑	☐	☐	☐
SO6	an understanding of professional and ethical responsibility	☑	☐	☐	☑
SO7	an ability to communicate effectively	☐	☑	☐	☑
SO8	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	☑	☑	☑	☐
SO9	a recognition of the need for, and an ability to engage in life-long learning	☐	☑	☑	☑
SO10	a knowledge of contemporary issues	☐	☐	☑	☑
SO11	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	☑	☐	☐	☑

Table J31. Correlation between PEOs and revised ABET SOs (1-7)

1 ABET Student Outcomes

	Outcomes	PEO1	PEO2	PEO3	PEO4
SO1	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	☑	☐	☐	☐
SO2	an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	☑	☐	☐	☑
SO3	an ability to communicate effectively with a range of audiences	☐	☑	☑	☑
SO4	an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	☐	☑	☑	☑
SO5	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	☐	☑	☐	☑
SO6	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	☑	☐	☐	☐
SO7	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	☐	☑	☑	☑

External Review of Meeting the PEOs

For the question of "How well are the programs' graduates really doing in the workforce?" alumni provide the primary input for the external view of meeting the PEOs. The main tool used is the alumni survey. However, despite ABET's reduction of requirements, the Faculty of Engineering conducted remote employer surveys using the EvalTools ® survey suite to evaluate student performances during vocational training.

Expected Level of Attainment for PEOs: Table J32 presents a rubric for assessing the expected level of attainment for the CE program's PEOs. For each PEO, the criteria for exceeding expectations, meeting expectations, or below expectations is clearly defined. For data such as alumni comments that are qualitative in nature, the rubric shown in Table J32 provides guidelines for quantifying the attainment of the corresponding PEO. Since the PEOs are assessed from two different perspectives, one from the alumni survey and the other from student outcomes attainment, a numeric scale is also used to indicate attainment of quantitative data. For example, on the scale of 5.0 (i.e., x in Table J32), if the quantitative value is 3.5, we will conclude meeting expectations as a result. However, if the numeric results were aggregated from the scale of 3.0 (i.e., y in Table J32), with 3 for exceeding expectations, 2 for meeting expectations, and 1 for below expectations, then the aggregated value between 2.0 and 2.5 would be considerd as meeting expectations.

Table J32. Rubric to assess Levels of attainment for CE PEOs

PEO	EXCEEDING EXPECTATIONS (x >= 4.0) (y >= 2.5)	MEETING EXPECTATIONS (3.0 <= x < 4.0) (2.0 <= y < 2.5)	BELOW EXPECTATIONS (x < 3.0) (y < 2.0)
1	**Excellent** integration of fundamentals of civil engineering, skills, tools and design practices to develop innovative solutions to complex technological problems within a context of economical, societal, ethical and environmental constraints.	**Satisfactory** integration of fundamentals of civil engineering, skills, tools and design practices to develop innovative solutions to complex technological problems within a context of economical, societal, ethical and environmental constraints.	**Unsatisfactory** integration of fundamentals of civil engineering, skills, tools and design practices to develop innovative solutions to complex technological problems within a context of economical, societal, ethical and environmental constraints.
2	**Several evidences** that exhibit an **exceptional level** of career growth as measured by leadership, communication skills, ability to work with multi-disciplinary and multi-cultural teams, promotions, salaries, career satisfaction, awards, recognitions, entrepreneurial activities, development of products or processes, patents, and/or publications	**Moderate number of evidences** that exhibit an **above average level** of career growth as measured by leadership, communication skills, ability to work with multi-disciplinary and multi-cultural teams, promotions, salaries, career satisfaction, awards, recognitions, entrepreneurial activities, development of products or processes, patents, and/or publications	**Low number of evidences** that exhibit **below average level** of career growth as measured by leadership, communication skills, ability to work with multi-disciplinary and multi-cultural teams, promotions, salaries, career satisfaction, awards, recognitions, entrepreneurial activities, development of products or processes, patents, and/or publications
3	**Several evidences** that exhibit an **exceptional level** of participation in life-long learning to acquire new expertise, as measured by post-graduate education, continuing education and/or licensure, registration with professional societies.	**Moderate number of evidences** that exhibit an **above average level** of participation in life-long learning to acquire new expertise, as measured by post-graduate education, continuing education and/or licensure, registration with professional societies.	**Low number of evidences** that exhibit **below average level** of participation in life-long learning to acquire new expertise, as measured by post-graduate education, continuing education and/or licensure, registration with professional societies.
4	**Several evidences** that exhibit an **exceptional level** of contribution to the local, national and international societies by providing professional, community and research services with integrity and sensitivity to global societal issues within the context of Islamic values	**Moderate number of evidences** that exhibit an **above average level** of contribution to the local, national and international societies by providing professional, community and research services with integrity and sensitivity to global societal issues within the context of Islamic values	**Low number of evidences** that exhibit **below average level** of contribution to the local, national and international societies by providing professional, community and research services with integrity and sensitivity to global societal issues within the context of Islamic values

Documentation of Results

The Faculty of Engineering uses EvalTools® 6 for tracking and documenting data for its PEOs assessment processes. The following data are documented and tracked by EvalTools®:

- Alumni survey—deployed using EvalTools®; data was tracked and saved in the EvalTools® database.
- Employer survey—deployed using EvalTools®; data was tracked and saved in the EvalTools® database.
- Senior Exit survey—deployed using EvalTools®; data was tracked and saved in the EvalTools® database.
- EAC meeting minutes—a Word document that keeps records of discussion for the EAC review on PEOs. An administrative committee called "External Advisory Committee" was created in EvalTools®. The documents tab of this committee acts as a place holder to keep copies of meeting minutes in its respective meeting folder.
- Performance Indicators and Student Outcomes Evaluation results—EvalTools® provides features to track course outcomes assessment using FCAR and the roll-up data from all FCARs for each student outcome. All student outcomes assessment results are tracked in EvalTools® and can be generated or produced in hard copy when needed.

Faculty members are given access to EvalTools® for the data and results mentioned above.

i. RELEVANCY OF THE PEOs TO THE INDUSTRY NEEDS

The ME, CE and EE program PEOs were established in Fall 2014 following a program level meeting and were accordingly implemented in the assessment and CQI process.

The Faculty Engineering programs conducted a comprehensive 5 point likert survey in September 2018 with a body of 7 EAC members for each program to review the appropriateness of the PEOs, SOs and alignment to the curriculum and teaching/learning. CQI processes were also reviewed by the survey. Questionnaires specifically targeted the language of PEOs, Students' knowledge and skill sets and whether PEOs align with the university mission, curriculum, and support CQI processes.

Table J33 presents some detail on the questionnaire, summary of results and decision based on rubrics shown in Table J32. Overall feedback received was either *Exceeding* or *Meeting expectations* and reinforced the qualification of the status of standards for theoretical frameworks, educational process and CQI systems implemented at the Faculty of Engineering programs.

Table J33. **General Survey: EAC Approval CE**

Response Rate 6/7 (CE); 7/7 (ME); 6/7 (EE)

PEOs: Graduate Attributes and Program Development In this section, EAC members provided opinions regarding the appropriateness of language used in PEOs to reflect the desired graduate attributes and using these as a metric to evaluate program effectiveness

	Questions	ME Mean(5)	*ME sd*	EE Mean(5)	*EE sd*	CE Mean(5)	CE sd
1	PEO1: 'Successfully integrate the fundamentals of civil engineering knowledge, skills, tools, testing and design practices to provide innovative solutions for infrastructural development and improvement with context of economical, societal, sustainability and environmental constraints' properly reflects essential graduate attributes and is appropriate for the development of the program	4.0	0.00	4.5	0.35	4.5	0.35
2	PEO2: 'Advance their careers as measured by leadership, communication skills, ability to work with multi-disciplinary and multi-cultural teams, promotions, awards, entrepreneurial activities, patents, and/or publications' properly reflects essential graduate attributes and is appropriate for the development of the program	4.0	0.00	3.5	0.35	4.5	0.35
3	PEO3: 'Participate in life-long learning to acquire new expertise, as measured by post-graduate and continuing education, membership with professional societies and license' properly reflects essential graduate attributes and is appropriate for the development of the program	4.0	0.00	4.5	0.35	4.5	0.35
4	PEO4: 'Contribute to local, national and international societies by providing professional, community and research services with integrity and sensitivity to global societal issues within the context of Islamic values' properly reflects essential graduate attributes and is appropriate for the development of the program	4.3	0.31	5.0	0.00	3.5	0.35
	Total Response:	4.1	0.08	4.4	0.27	4.2	0.35
	Results based on rubrics	Exceeding Expectations		Exceeding Expectations		Exceeding Expectations	

Student Outcomes: Students' Knowledge and Skills
In this section, EAC members provided opinions regarding the appropriateness of language used in student outcomes to reflect necessary engineering knowledge and skills and using these as a metric to evaluate the program's teaching, learning and assessment process

	Questions	ME Mean(5)	*ME sd*	EE Mean(5)	*EE sd*	CE Mean(5)	CE sd
1	SO 'a': 'an ability to apply knowledge of mathematics, science, and engineering' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	4.3	0.31	4.5	0.35	4.5	0.35
2	SO 'b': 'an ability to design and conduct experiments, as well as to analyze and interpret data' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	4.0	0.47	5.0	0.00	3.5	0.35
3	SO 'c': 'an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	3.7	0.31	4.5	0.35	3.5	0.35
4	SO 'd': 'an ability to function on multidisciplinary teams' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	4.0	0.47	3.5	1.06	4.0	0.71
5	SO 'e': 'an ability to identify, formulate, and solve engineering problems' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	4.3	0.31	5.0	0.00	4.5	0.35
6	SO 'f': 'an understanding of professional and ethical responsibility' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	4.0	0.00	4.5	0.35	4.0	0.71
7	SO 'g': 'an ability to communicate effectively' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	4.0	0.00	4.5	0.35	4.0	0.00
8	SO 'h': 'the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context' properly reflects necessary engineering knowledge and skills and is	3.7	0.31	4.5	0.35	4.5	0.35

	appropriate for effective teaching, learning, assessment and improvement efforts						
9	SO 'i': 'a recognition of the need for, and an ability to engage in life-long learning' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	3.7	0.31	5.0	0.00	3.5	0.35
10	SO 'j': 'a knowledge of contemporary issues' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	4.0	0.00	1.5	0.35	4.0	0.00
11	SO 'k': 'an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice' properly reflects necessary engineering knowledge and skills and is appropriate for effective teaching, learning, assessment and improvement efforts	3.7	0.31	3.5	0.35	4.5	0.35
	Total Response:	3.9	0.26	4.2	0.32	4.0	0.35
	Results based on rubrics	Meeting Expectations		Exceeding Expectations		Exceeding Expectations	

PEOs: Alignment and Continuous Improvement Efforts
In this section, EAC members provided opinions regarding the alignment of PEOs with the Islamic University Mission, student outcomes and program curriculum. They also indicated whether this alignment helps in effectively integrating the PEOs, SOs with all levels of curriculum delivery to support effective Continuous Quality Improvement.

	Questions	ME Mean(5)	*ME sd*	EE Mean(5)	*EE sd*	CE Mean(5)	CE sd
1	The PEOs align perfectly with the values, goals and scope of the Islamic University mission statement: A Saudi educational institution with universal message, dealing with education, scientific research and community service in the sciences of Shari ah, Arabic language and other sciences with global standards and technologies and high-quality output contributing to spreading the eternal message of Islam from the city of the Messenger of Allah (PBUH) to serve the local and global community	3.7	0.31	2.0	0.00	4.5	0.35
2	The PEOs align perfectly with the values, goals and scope of the CE program mission statement: Graduate highly competent civil engineers able to lead the construction industry, promote environmental sustainability pursue higher studies and innovative researches to serve the people of Madinah locally and to contribute to the welfare of mankind globally by their acquired Islamic moral values, professional skills, creative thinking and human intelligence	3.7	0.31	3.5	0.35	5.0	0.00
3	The graduates attributes mentioned in PEOs are attainable using the (a-k) student outcomes	4.0	0.00	3.5	1.06	3.0	0.00
4	The curriculum adequately covers all the PEOs and SOs while fulfilling necessary National Qualification Frameworks and Accreditation standards	4.0	0.00	3.5	1.06	4.0	0.00
5	The Continuous Quality Improvement processes evaluate program effectiveness by adequately integrating PEOs and SOs information	4.3	0.31	4.0	0.71	4.5	0.35
6	The Capstone Design courses and projects comprehensively assess the SOs and significantly help students attain the desired PEOs	4.0	0.47	4.0	0.00	4.0	0.00
7	The vocational training courses help students apply fundamental engineering theory to practical field work and prepare students for much of the soft skills mentioned in PEOs	4.0	0.00	5.0	0.00	4.0	0.00
8	The PEOs adequately represent the latest regional and international engineering graduate attributes to fully meet current needs, align with emerging technology and market trends and fulfill required entrepreneurship skills sets as per the national 2030 vision	4.0	0.00	2.5	0.35	4.0	0.00
	Total Class Response:	4.0	0.18	3.5	0.44	4.1	0.09
	Results based on rubrics	Exceeding Expectations		Meeting Expectations		Exceeding Expectations	

ii. PEOs ASSESSMENT DATA

Internal Review of Meeting the PEOs – Multi-term Direct Assessments SOs (a-k)

Tables J18, J19, and J20 in *Section 5.i* showing the multi-term review ABET SOs (a-k) results from terms 351 to 382 [2014-18] was presented to the EAC. *Section IV.D 1 FCAR and PVT* provides details of how the student outcomes direct assessment results are obtained. The section below illustrates how to roll these results up to Level 1 PEOs assessment. Each student outcome is rated at *Exceeding Expectations, Meeting Expectations* or *Below Expectations*. Using the relationship between PEOs and SOs shown in Table J30, the SOs aggregate results from term 382 are utilized to compute the roll-up data for the CE, ME, and EE PEOs as shown in Tables J34, J35 and J36. The final review decisions for all the PEOs for the CE, ME, and EE programs are either *Meeting* or *Exceeding Expectations*. Therefore, the direct SOs assessment results provide a strong indication that the programs' students are well-prepared for the intended PEOs.

Table J34. Direct assessments roll-up results to PEOs CE program Term 382 (Spring 2018)

Student Outcomes	PEO1	PEO2	PEO3	PEO4
SO1: Ability to apply knowledge of mathematics, science, and engineering	3.89	-	-	-
SO2: Ability to design and conduct experiment, as well as to analyze and interpret data	4.73	-	-	
SO3: Ability to design a system, component, or process to meet desired needs	3.08	3.08	-	3.08
SO4: Ability to function on multi-disciplinary teams	-	4.47	-	4.47
SO5: Ability to identify, formulate, and solve engineering problem	3.34	-	-	-
SO6: Understanding of professional and ethical responsibility	3.42	-	-	3.42
SO7: Ability to communicate effectively	4.34	4.34	-	4.34
SO8: Broad education necessary to understand the impact of engineering solutions in a global and societal context	4.22	4.22	4.22	-
SO9: Recognition of the need for, and an ability to engage in life-long learning	-	4.3	4.3	4.3
SO10: knowledge of contemporary issues	-	-	3.47	3.47
SO11: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	3.64	-	-	3.64
Average scale of 5:	**3.8**	**4.1**	**4.0**	**3.8**
Decision based on Rubrics	**Meeting Expectations**	**Exceeding Expectations**	**Exceeding Expectations**	**Meeting Expectations**

Table J35. Direct assessments roll-up results to PEOs ME program Term 382 (Spring 2018)

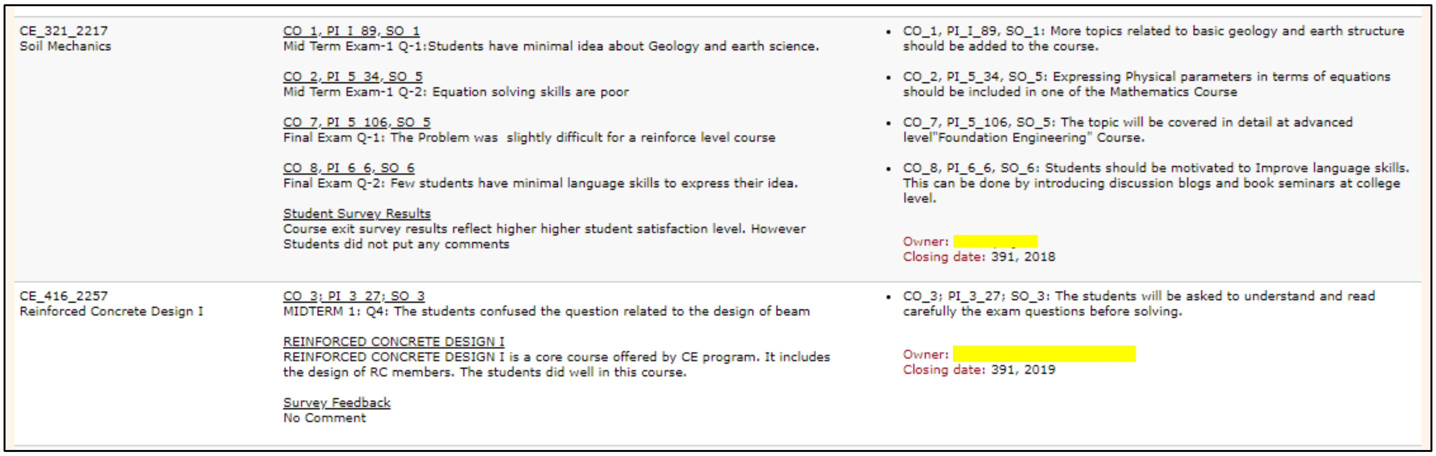
Student Outcomes	PEO1	PEO2	PEO3	PEO4
SO1: Ability to apply knowledge of mathematics, science, and engineering	3.89	-	-	-
SO2: Ability to design and conduct experiment, as well as to analyze and interpret data	4.73	-	-	
SO3: Ability to design a system, component, or process to meet desired needs	3.08	3.08	-	3.08
SO4: Ability to function on multi-disciplinary teams	-	4.47	-	4.47
SO5: Ability to identify, formulate, and solve engineering problem	3.34	-	-	-
SO6: Understanding of professional and ethical responsibility	3.42	-	-	3.42
SO7: Ability to communicate effectively	4.34	4.34	-	4.34
SO8: Broad education necessary to understand the impact of engineering solutions in a global and societal context	4.22	4.22	4.22	-
SO9: Recognition of the need for, and an ability to engage in life-long learning	-	4.3	4.3	4.3
SO10: knowledge of contemporary issues	-	-	3.47	3.47
SO11: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	3.64	-	-	3.64
Average scale of 5:	**3.8**	**4.2**	**3.9**	**3.9**
Decision based on Rubrics	**Meeting Expectations**	**Exceeding Expectations**	**Meeting Expectations**	**Meeting Expectations**

Table J36. Direct assessments roll-up results to PEOs EE program Term 382 (Spring 2018)

Student Outcomes	PEO1	PEO2	PEO3	PEO4
SO1: Ability to apply knowledge of mathematics, science, and engineering	2.71	-	-	-
SO2: Ability to design and conduct experiment, as well as to analyze and interpret data	4.40	-	-	
SO3: Ability to design a system, component, or process to meet desired needs	3.47	3.47	-	3.47
SO4: Ability to function on multi-disciplinary teams	-	4.69	-	4.69
SO5: Ability to identify, formulate, and solve engineering problem	2.97	-	-	-
SO6: Understanding of professional and ethical responsibility	4.29	-	-	4.29
SO7: Ability to communicate effectively	4.12	4.12	-	4.12
SO8: Broad education necessary to understand the impact of engineering solutions in a global and societal context	3.46	3.46	3.46	-
SO9: Recognition of the need for, and an ability to engage in life-long learning	-	4.23	4.23	4.23
SO10: knowledge of contemporary issues	-	-	2.8	2.8
SO11: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	3.58	-	-	3.58
Average scale of 5:	**3.6**	**3.9**	**3.5**	**3.9**
Decision based on Rubrics	**Meeting Expectations**	**Meeting Expectations**	**Meeting Expectations**	**Meeting Expectations**

Internal Review – Indirect Assessments Course Exit Surveys

At the Faculty of Engineering, course exit surveys are officially conducted in the last week of the term prior to the final exams. Lecturers and administrative staff regulate and monitor on campus survey feedback sessions. The surveys are conducted online using the EvalTools® 6 platform. The students who fail to attend these on campus survey sessions are encouraged to provide their feedback remotely prior to stipulated time frames. Programs' faculty members are able to access student feedback from course exit surveys after final exams. Since the reliability of student surveys is generally low, a greater emphasis is laid on the feedback comments. The faculty members study the feedback comments and provide reflections plus generate corrective actions for legitimate concerns raised by students. Figure J35 shows an example of such reflections and/or actions provided by the faculty.



CE_321_2217 Soil Mechanics	CO_1, PI_I_89, SO_1 Mid Term Exam-1 Q-1:Students have minimal idea about Geology and earth science. CO_2, PI_5_34, SO_5 Mid Term Exam-1 Q-2: Equation solving skills are poor CO_7, PI_5_106, SO_5 Final Exam Q-1: The Problem was slightly difficult for a reinforce level course CO_8, PI_6_6, SO_6 Final Exam Q-2: Few students have minimal language skills to express their idea. Student Survey Results Course exit survey results reflect higher higher student satisfaction level. However Students did not put any comments	• CO_1, PI_I_89, SO_1: More topics related to basic geology and earth structure should be added to the course. • CO_2, PI_5_34, SO_5: Expressing Physical parameters in terms of equations should be included in one of the Mathematics Course • CO_7, PI_5_106, SO_5: The topic will be covered in detail at advanced level"Foundation Engineering" Course. • CO_8, PI_6_6, SO_6: Students should be motivated to Improve language skills. This can be done by introducing discussion blogs and book seminars at college level. Owner: Closing date: 391, 2018
CE_416_2257 Reinforced Concrete Design I	CO_3; PI_3_27; SO_3 MIDTERM 1: Q4: The students confused the question related to the design of beam REINFORCED CONCRETE DESIGN I REINFORCED CONCRETE DESIGN I is a core course offered by CE program. It includes the design of RC members. The students did well in this course. Survey Feedback No Comment	• CO_3; PI_3_27; SO_3: The students will be asked to understand and read carefully the exam questions before solving. Owner: Closing date: 391, 2019

Figure J35. Samples of course reflections and AIs showing survey feedback

Internal Review – Indirect Assessments Senior Exit Surveys (Terms 381, 382, 391 and 392)

The remote *Senior Exit Survey* feedback using EvalTools® 6 web-based survey module was requested from senior level students in terms 381, 382, 391 and 392 (Fall 2017 to Spring 2019). The format of the survey is indicated in Table J37 below. Questions of the survey included sections related to *Islamic University Education and Environment, Department/Program Education, Student Learning Outcomes* and *General Questions*. The questions of the survey section titled *Student Learning Outcomes* are aligned to the ABET SOs (a-k) for terms 381, 382 and SOs (1-7) for terms 391, 392 to facilitate easy analysis and evaluation of the *Senior Exit Survey*.

Table J37. CE Senior exit survey

Senior-Exit Survey

General Instructions/Comments:

Senior Exit Survey

The Senior Exit Survey is designed to assist school in discovering valuable information about graduating seniors career preparedness. Graduating seniors report their perceptions of quality of education related to preparing them for future plans, strengths of and interferences with their education, and their educational aspirations indicated by plans for college, expected educational degree, and career field.

Goals

Results of this survey will be used to determine if changes are needed in acheiving a better quality of education.

Confidentiality

All responses to this survey will remain confidential. Please take a few moments to complete the survey.

Senior-Exit Survey: CESeniorExit

Response Rate : **0/0**

Islamic University Education and Environment
Please rate the following according to your best knowledge

Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**

1	Do you feel your education at the Islamic University has helped you to understand the Islamic ethical responsibilities for your life roles and professional career?								
2	Do you feel your education at the Islamic University offered sufficient opportunities for professional development?								
3	The Islamic University administration is committed to providing the best education possible for all students.								
4	The atmosphere at the Islamic University emphasizes the academic program and encourages intellectual development.								
5	How well has your education at the Islamic University prepared you to appreciate other cultures or societies?								
6	Did the Islamic University provide sufficient support and services related to career counseling or search for employment opportunities?								
	Total Class Response:								

Department/Program Education
Please rate the following according to your college experience

	Questions	*Very Satisfied*	*Satisfied*	*No experience*	*Dissatisfied*	*Very dissatisfied*	*N.A.*	Mean(5)	**sd**
1	Quality of faculty instruction, assessment, feedback and alignment to student outcomes								
2	Availability of faculty outside the class and attitude towards students								
3	Department e-learning, web based learning management systems, outcomes assessment systems								
4	Academic advising by department advisors/staff								
5	Overall quality of department facilities such as class rooms, labs, library, recreational centers, computers, software, other learning resources etc.								
6	Extra curricular activities arranged by the department								
	Total Class Response:								

Student Learning Outcomes
Please rate the following according to your overall college experience

	Questions	*Excellent*	*Average*	*Poor*	*N.A.*	Mean(3)	**sd**
1	How well did your educational training prepare you to apply engineering theory, fundamentals of math and science to practical engineering problems and applications?						
2	How well did your educational training prepare you to design and conduct experiments?						
3	How well do you feel your educational training has prepared you to analyze and interpret experimental data?						
4	How well do you feel your training has prepared you to design a system, component or process to meet specific task needs?						
5	As you graduate, how confident do you feel in your ability to function effectively in a multidisciplinary team?						
6	How well has your educational training helped to develop your leadership skills?						
7	How well has your educational training prepared you to identify, formulate and solve engineering problems?						
8	Do you feel your educational training has helped you to understand the ethical responsibilities of your profession?						
9	How well has your educational training prepared you to write technical reports, other written communications and make effective oral presentations?						
10	Do you feel your educational training was broad enough to give you a perspective on how a particular engineering solution might impact society, environment, culture or economy?						
11	How well do you feel your educational training has prepared you for adapting to changes in technology?						
12	Do you feel your educational training made you aware of contemporary issues (such as environmental, safety, health, security, sustainability) facing your profession?						
13	Do you feel you have sufficiently learned how to use effectively the most modern engineering tools and techniques necessary for your profession?						
	Total Class Response:						

General Questions

1 Please list what you feel are your most important professional accomplishments as a student
2 What are your long term professional goals following graduation
3 Do you have any further comments you would like to make concerning the effectiveness of your professional training
4 What are the 3 most positive aspects of attending this college
5 Please provide any other comments below

Performance criteria shown in Table J38 was applied for evaluating the feedback results obtained in the Senior Exit Survey. As shown in Tables J39, J40, J41, J42, J43 and J44 the CE, ME, and EE program committee decisions for the Senior Exit Survey (Terms 381, 382) results were mostly *Exceeding* or *Meeting Expectations*. The level of attainment indicated in Tables J39 to J44 is abbreviated as follows: EE:Exceeding Expectations; ME:Meeting Expectations; and BE:Below Expectations

Table J38. Survey evaluation performance criteria

Levels of Attainment	General Performance Criteria Description
Below Expectations (x < 3.0) (y<2.0)	when there are: (1) any red or yellow flags raised in the final year of data, or (2) multiple red flags are raised prior to the final year of data, or (3) a majority of red and yellow flags are raised prior to the final year of data
Exceeding Expectations (x >= 4.0) (y >= 2.5)	when there are a majority of green flags raised
Meeting Expectations (3.0 <= x < 4.0) (2.0 <= y < 2.5)	the default condition when the application of the heuristic rules does not fall into either of the Below Expectations or Exceeding

Table J40. CE program committee decisions for ABET SOs (1-7) based on senior exit survey results Term 391 (Fall 2018) Response Rate: 17/21; Term 392 (Spring 2019) Response Rate: 5/5

ABET SOs	392 (3 scale) (3.0 Scale)	392 (5 scale) (5.0 Scale)	391 (3 scale) (3.0 Scale)	391 (5 scale) (5.0 Scale)	Annual Result (x)	Level of Attainment*
1	2.70	4.50	3.00	5.00	4.75	Exceeding Expectations
2	2.60	4.33	2.80	4.67	4.50	Exceeding Expectations
3	2.60	4.33	2.40	4.00	4.17	Exceeding Expectations
4	2.80	4.67	2.80	4.67	4.67	Exceeding Expectations
5	2.70	4.50	2.80	4.67	4.58	Exceeding Expectations
6	2.67	4.44	2.87	4.78	4.61	Exceeding Expectations
7	2.60	4.33	3.00	5.00	4.67	Exceeding Expectations

Table J41. CE program committee decisions for ABET SOs (A-K) based on senior exit survey results Term 381 (Fall 2017) Response Rate: 9/10; Term 382 (Spring 2018) Response Rate: 2/4

ABET SOs	Term 382 (3.0 Scale)	Term 382 (5.0 Scale)	Term381 (3.0 Scale)	Term381 (5.0 Scale)	Annual result (5.0 Scale)	Level of attainment
1	2.3	3.83	2	3.33	3.58	Meeting Expectations
2	2.25	3.75	2.5	4.17	3.96	Meeting Expectations
3	2.2	3.67	2.5	4.17	3.92	Meeting Expectations
4	2.2	3.67	2.5	4.17	3.92	Meeting Expectations
5	2.4	4.00	2.5	4.17	4.08	Exceeding Expectations
6	2.4	4.00	2.5	4.17	4.08	Exceeding Expectations
7	2	3.33	2	3.33	3.33	Meeting Expectations
8	2.6	4.33	2	3.33	3.83	Meeting Expectations
9	2.4	4.00	2.5	4.17	4.08	Exceeding Expectations
10	2.3	3.83	2	3.33	3.58	Meeting Expectations
11	2.3	3.83	2.5	4.17	4.00	Exceeding Expectations

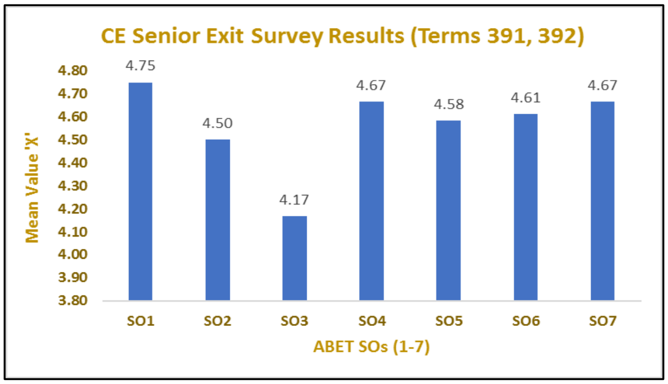


Figure J36. CE senior exit survey results (Terms 391, 392)

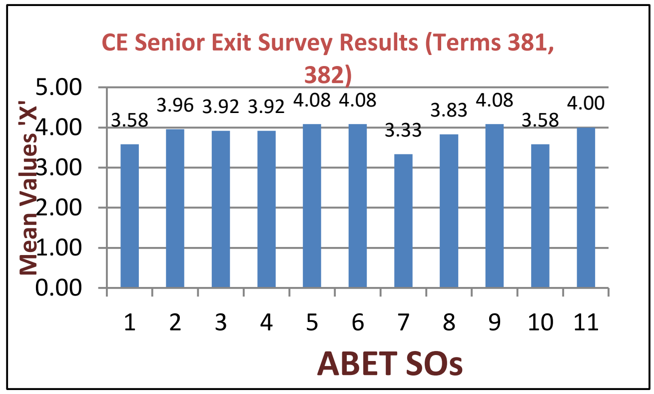


Figure J37. CE senior exit survey results (Terms 381, 382)

Table J42. ME program committee decisions for ABET SOs (1-7) based on senior exit survey results Term 391 (Fall 2018) Response Rate: 6/8; Term 392 (Spring 2019) Response Rate: 11/13

ABET SOs	Term 391		Term 392		Annual Average (X)	Level of attainment
	(3.0 Scale)	(5.0 Scale)	(3.0 Scale)	(5.0 Scale)	(5.0 Scale)	
1	2.75	4.58	2.70	4.50	4.54	Exceeding Expectations
2	2.80	4.67	2.50	4.17	4.42	Exceeding Expectations
3	2.60	4.33	2.50	4.17	4.25	Exceeding Expectations
4	2.77	4.61	2.57	4.28	4.44	Exceeding Expectations
5	2.70	4.50	2.60	4.33	4.42	Exceeding Expectations
6	2.60	4.33	2.60	4.33	4.33	Exceeding Expectations
7	2.60	4.33	2.50	4.17	4.25	Exceeding Expectations

Table J43. ME program committee decisions for ABET SOs (A-K) based on senior exit survey results Term 382 (Spring 2018) Response Rate: 5/5

ABET SOs	Term 382		Annual Average (X)	Level of attainment
	(3.0 Scale)	(5.0 Scale)	(5.0 Scale)	
1	2.4	4.00	4.54	Meeting Expectations
2	2.6	4.33	4.42	Exceeding Expectations
3	2.8	4.67	4.25	Exceeding Expectations
4	2.5	4.17	4.44	Exceeding Expectations
5	2.6	4.33	4.42	Exceeding Expectations
6	2.8	4.67	4.33	Exceeding Expectations
7	2.8	4.67	4.25	Exceeding Expectations
8	3	5.00	4.54	Exceeding Expectations
9	2.4	4.00	4.42	Meeting Expectations
10	2.8	4.67	4.25	Exceeding Expectations
11	2.4	4.00	4.44	Meeting Expectations

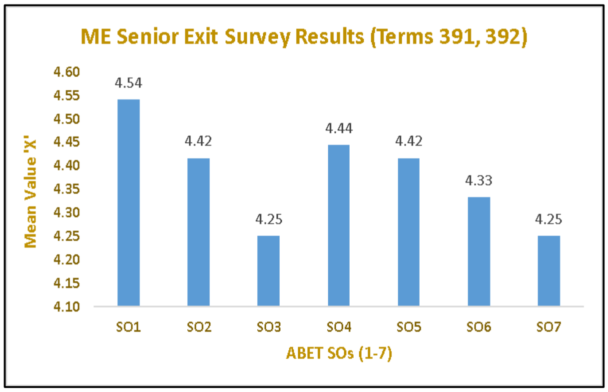


Figure J38. ME Senior Exit Survey Results Terms 391, 392 (Spring Fall 2018)

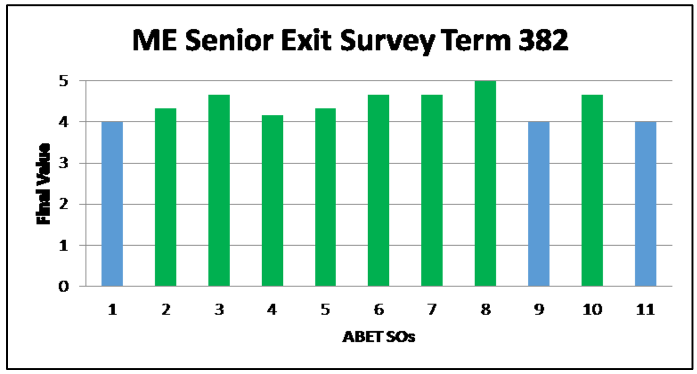


Figure J39. ME Senior Exit Survey Results Terms 382 (Spring Fall 2018)

Table J44. EE program committee decisions for ABET SOs (1-7) based on senior exit survey results Term 391 (Fall 2018) Response Rate: 8/8; Term 392 (Spring 2019) Response Rate: 7/7

ABET SOs	Term 392 (3.0 Scale)	Term 392 (5.0 Scale)	Term 391 (3.0 Scale)	Term 391 (5.0 Scale)	Annual result	Level of attainment
1	2.40	4.00	3.00	5.00	4.50	Exceeding Expectations
2	2.60	4.33	2.80	4.67	4.50	Exceeding Expectations
3	2.40	4.00	2.40	4.00	4.00	Exceeding Expectations
4	2.60	4.33	2.80	4.67	4.50	Exceeding Expectations
5	2.40	4.00	2.80	4.67	4.33	Exceeding Expectations
6	2.53	4.22	2.87	4.78	4.50	Exceeding Expectations
7	2.60	4.33	3.00	5.00	4.67	Exceeding Expectations

Table J45. EE program committee decisions for ABET SOs (A-K) based on senior exit survey results Term 381 (FalL 2017) Response Rate: 2/4; Term 382 (Spring 2018) Response Rate: 8/8

ABET SOs	Term 382 (3.0 Scale)	Term 382 (5.0 Scale)	Term 381 (3.0 Scale)	Term 381 (5.0 Scale)	Annual result	Level of attainment
1	2.3	3.83	2.4	4.00	3.92	Meeting Expectations
2	2.2	3.67	2.15	3.58	3.63	Meeting Expectations
3	2.2	3.67	2.4	4.00	3.83	Meeting Expectations
4	2.4	4.00	2.45	4.08	4.04	Exceeding Expectations
5	2.3	3.83	2.5	4.17	4.00	Meeting Expectations
6	2.4	4.00	2.2	3.67	3.83	Meeting Expectations
7	2.7	4.50	2.2	3.67	4.08	Exceeding Expectations
8	2.6	4.33	2.2	3.67	4.00	Meeting Expectations
9	2.4	4.00	2.2	3.67	3.83	Meeting Expectations
10	2.4	4.00	2.4	4.00	4.00	Meeting Expectations
11	2.1	3.50	2.4	4.00	3.75	Meeting Expectations

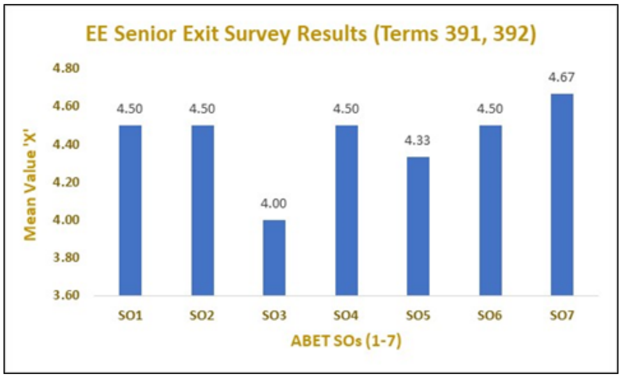


Figure J40. EE senior exit survey results Terms 391, 391 (Spring Fall 2018)

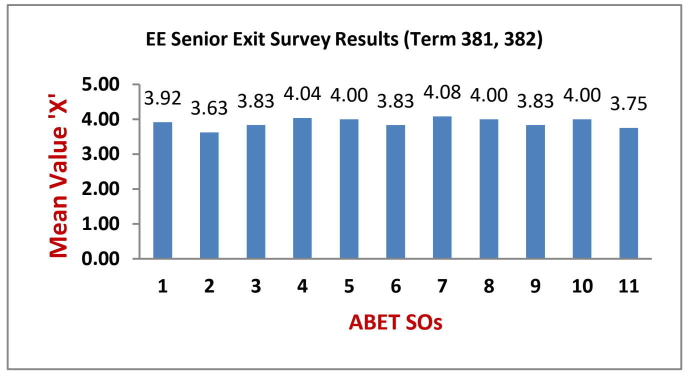


Figure J41. EE senior exit survey results Terms 381, 382 (Spring Fall 2018)

Graduating students corresponding to cohorts for the years 2017-2019 responded to the senior exit survey questionnaire by exhibiting high levels of satisfaction with the *Islamic University Education and Environment, Department/Program Education, Student Learning Outcomes* and *General Questions*. The results of the feedback received through the senior exit surveys qualify the CE, ME, and EE programs for delivery of necessary knowledge and skill sets required to attain the PEOs.

External Review of Meeting the PEOs – Alumni Surveys

The remote Alumni Survey using EvalTools® 6 web-based survey module was deployed to fulfill the external component of the PEOs review process. It was requested from CE, ME and EE graduates of the 2017 and 2018 years cohorts respectively. The future iteration of implementing the alumni surveys (ABET SOs 1-7) will be in 2020 for the alumni who graduated in the 2019 and 2020 academic years. The format of the survey is indicated in Table J45. All the questions of the survey are aligned to the ABET SOs (a-k) facilitating easy analysis and evaluation.

Table J46: CE, ME and EE programs' alumni survey format

Alumni Survey: Alumni CE/EE/ME

General Instructions/Comments:

Alumni Survey

We are conducting a survey of all alumni to help improve the programs. Your response will help us to understand the strengths and weaknesses of the program so that we can adapt the program to better serve current and future students. When answering these questions consider your experiences in other courses and activities including internships and student societies.

Goals

Results of this survey will be used to determine if changes are needed in acheiving a better quality of education.

Confidentiality

All responses to this survey will remain confidential. Please take a few moments to complete the survey.

Response Rate : **0/0**

ABET SO 'a'
Please rate the following according to your best knowledge

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	sd
1	Your educational training helped you to develop the ability to apply technical knowledge or engineering theory for the solution of specific work-related problems?								
2	Your education provided essential learning in all areas of technical engineering knowledge, concepts, fundamentals and other necessary theory to adequately equip you with comprehensive understanding necessary for practical engineering work								
	Total Class Response:								

ABET SO 'b'
Please rate the following according to your college experience

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	sd
1	Your educational training adequately prepared you to design and conduct experiments								

2	Your educational training provided the necessary exposure to most experimental and test equipment that you continue to use for completing field work								
	Total Class Response:								

ABET SO 'c'

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Your educational training has adequately prepared you to design a system, component or process to meet specific customer needs while fulfilling realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability								
	Total Class Response:								

ABET SO 'd'

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	You are confident in your ability to function effectively on a team of people from disciplines other than engineering								
2	You have learnt essential team work skills during your education like leadership, communication, fulfillment of team roles, conflict resolution etc.								
	Total Class Response:								

ABET SO 'e'

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Your educational training adequately prepared you to acquire skills to accurately identify, formulate and solve engineering problems								
	Total Class Response:								

ABET SO 'f'

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Your education provided sufficient understanding of the importance of engineering standards, codes and regulations								
2	Your education provided ample opportunity and resources to practice professional responsibility and principles of engineering ethics								
	Total Class Response:								

ABET SO 'g'

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	The course projects presentations helped you learn technical presentation and public speaking skills								
2	The Capstone courses viva, presentation and poster display activities provided ample opportunity and resources to gain experience in interactive discussions								
3	Your technical writing and report preparation experiences during education significantly helped you prepare critical engineering reports at work								
	Total Class Response:								

ABET SO 'h'

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	The knowledge of the impact of engineering on societal, economic and environmental aspects learnt during education significantly helped to broaden your understanding of the actual scope of real life engineering solutions								
	Total Class Response:								

ABET SO 'i'

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Your educational training has prepared you to conduct thorough literature review of engineering topics, analyze and interpret research data								
2	Your education encouraged self-motivated learning and meta-cognition skills								
	Total Class Response:								

ABET SO 'j'

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	You were adequately exposed to real issues related to contemporary engineering solutions during your vocational field experience								
2	Your education provided comprehensive understanding of the limitations of current engineering solutions in various applications								
	Total Class Response:								

ABET SO 'k'
Please rate the following according to your overall college experience

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Your education has provided you with ample opportunity and resources to gain proficiency in tools, techniques and skills necessary for engineering practice								
2	The vocational experience provided sufficient exposure to the operation, functioning and application of various software, engineering equipment and tools that helped you to prepare for practical field work								
	Total Class Response:								

Qualitative Section

1 Please list what you feel are your most important professional accomplishments

2 Which aspects of your education and experiences have been most valuable to you since you graduated?

3 Do you have any further comments you would like to make concerning the effectiveness of your professional training?

4 What kind of activities would you like to see for alumni in your region that would serve alumni interests and strengthen the relationships among alumni and the college?

5 Please provide any other comments below

CE Alumni survey: The CE alumni survey was conducted in the spring of 2018 for alumni who graduated from the CE program in the years 2017 and 2018. Table J47 provides the results of responses to questionnaire aligned with the ABET SOs (a-k) and regarding how graduates meet the intended PEOs. 4 responses out of 9 were received.

Table J47. CE alumni survey responses on PEOs

Survey questions related to SOs	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	NA	Mean
SO1	25.0	62.5	12.5	0.0	0.0	0.0	4.1
SO2	50.0	12.5	12.5	25.0	0.0	0.0	3.9
SO3	50.0	50.0	0.0	0.0	0.0	0.0	4.5
SO4	62.5	12.5	12.5	0.0	0.0	12.5	4.6
SO5	25.0	50.0	25.0	0.0	0.0	0.0	4.0
SO6	50.0	25.0	25.0	0.0	0.0	0.0	4.2
SO7	33.3	25.0	25.0	16.7	0.0	0.0	3.8
SO8	25.0	75.0	0.0	0.0	0.0	0.0	4.2
SO9	37.5	37.5	25.0	0.0	0.0	0.0	4.1
SO10	25.0	50.0	12.5	12.5	0.0	0.0	3.9
SO11	25.0	50.0	25.0	0.0	0.0	0.0	4.0
Total Class Response:	**37.1**	**40.9**	**15.9**	**4.9**	**0.0**	**1.1**	**4.1**

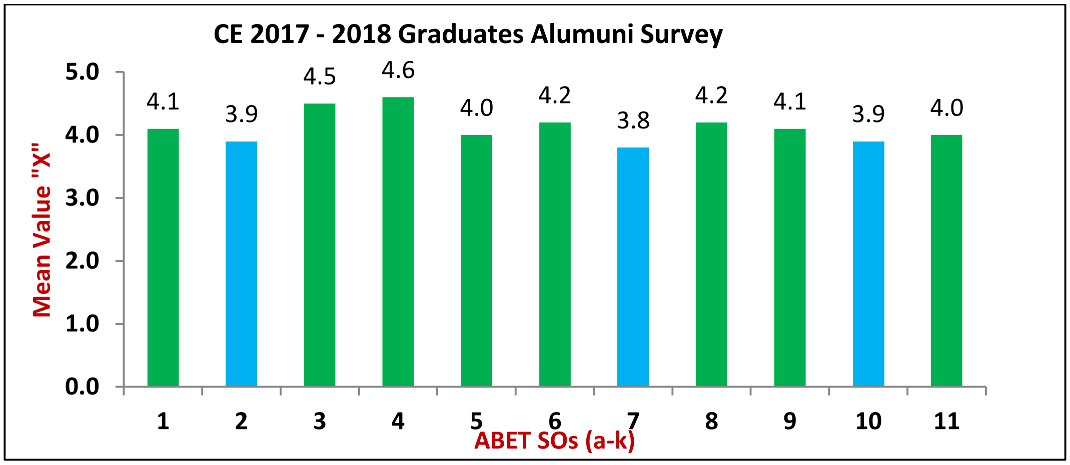


Figure J42. CE alumni survey results (2017-18)

ME Alumni survey: The ME alumni survey was conducted in the spring of 2018 for alumni who graduated from the ME program in the years 2017 and 2018. Table J48 provides the results of responses to questionnaire aligned with the ABET SOs (a-k) and regarding how graduates meet the intended PEOs. A total of 11 responses out of 17 were received.

Table J48. ME alumni survey responses on PEOs

Survey questions related to SOs	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	NA	mean
SO1	27.3	63.6	9.1	0.0	0.0	0.0	**4.2**
SO2	18.2	45.5	22.7	9.1	0.0	4.5	**3.8**
SO3	27.3	63.6	0.0	0.0	9.1	0.0	**4.0**
SO4	22.7	68.2	9.1	0.0	0.0	0.0	**4.1**
SO5	36.4	63.6	0.0	0.0	0.0	0.0	**4.4**
SO6	27.3	59.1	13.6	0.0	0.0	0.0	**4.1**
SO7	27.3	66.7	3.0	3.0	0.0	0.0	**4.2**
SO8	18.2	72.7	9.1	0.0	0.0	0.0	**4.1**
SO9	22.7	50.0	22.7	4.5	0.0	0.0	**3.9**
SO10	22.7	63.6	9.1	0.0	0.0	4.5	**4.1**
SO11	27.3	50.0	4.5	9.1	0.0	9.1	**4.1**
Total Class Response:	**25.22**	**60.60**	**9.35**	**2.34**	**0.83**	**1.65**	**4.09**

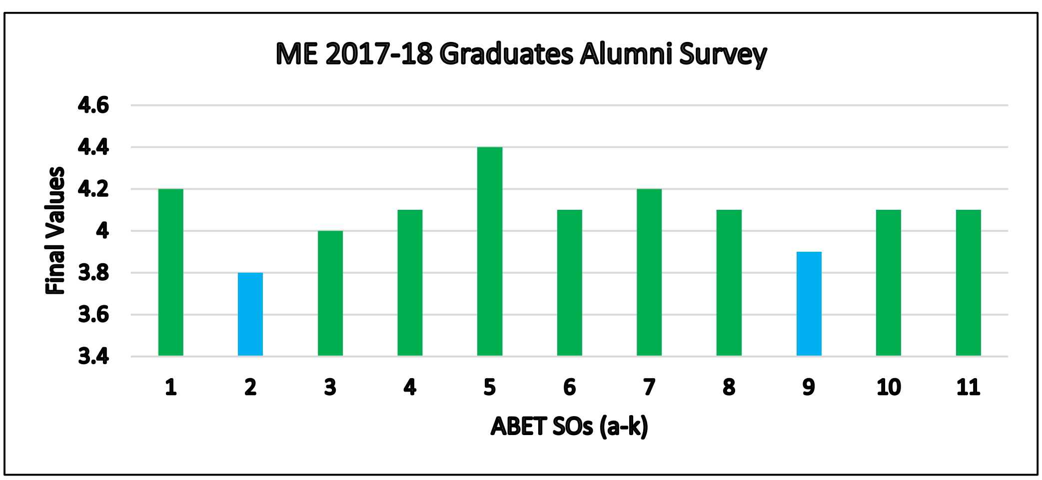


Figure J43. ME alumni survey results (2017-18)

EE Alumni survey: The EE alumni survey was conducted in the spring of 2018 for alumni who graduated from the EE program in the years 2017 and 2018. Table J49 provides the results of responses to questionnaire aligned with the ABET SOs (a-k) and regarding how graduates meet the intended PEOs. 13 responses out of 17 were received.

Table J49. EE alumni survey responses on PEOs

Survey questions related to SOs	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	NA	Mean
SO1	26.9	53.8	15.4	3.8	0.0	0.0	4.0
SO2	26.9	57.7	11.5	3.8	0.0	0.0	4.1
SO3	7.7	61.5	23.1	7.7	0.0	0.0	3.7
SO4	26.9	50.0	15.4	0.0	0.0	7.7	4.1
SO5	30.8	46.2	15.4	7.7	0.0	0.0	4.0
SO6	11.5	69.2	11.5	3.8	0.0	3.8	3.9
SO7	20.5	56.4	17.9	5.1	0.0	0.0	3.9
SO8	23.1	46.2	30.8	0.0	0.0	0.0	3.9
SO9	15.4	53.8	23.1	3.8	3.8	0.0	3.7
SO10	19.2	38.5	34.6	3.8	3.8	0.0	3.7
SO11	11.5	50.0	34.6	3.8	0.0	0.0	3.7
Total Class Response:	**20.0**	**53.0**	**21.2**	**3.9**	**0.7**	**1.0**	**3.9**

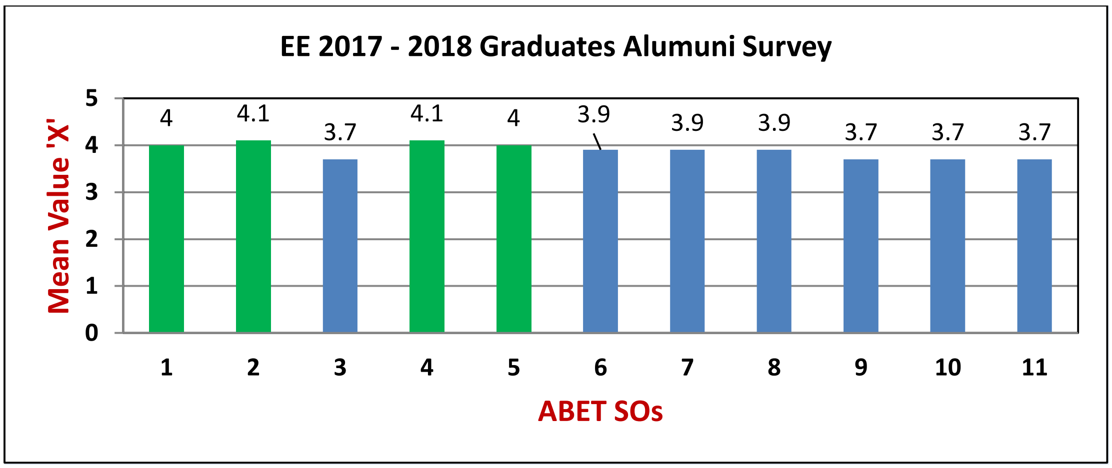


Figure J44. EE alumni survey results (2017-18)

Based on the SOs (a-k) relationship to PEOs shown in Table J30, alumni survey SOs (a-k) data are rolled up for CE, ME and EE programs to compute the corresponding PEOs information as shown in Tables J50, J51 and J52. Based on rubrics the review decision for all the PEOs extracted for external review from alumni surveys is either *Exceeding* or *Meeting Expectations*.

Table J50. CE alumni survey responses data roll-up results to PEOs

Student Outcomes	PEO1	PEO2	PEO3	PEO4
SO1: Ability to apply knowledge of mathematics, science, and engineering	4.1	-	-	-
SO2: Ability to design and conduct experiment, as well as to analyze and interpret data	3.9	-	-	-
SO3: Ability to design a system, component, or process to meet desired needs	4.5	4.5	-	4.5
SO4: Ability to function on multi-disciplinary teams		4.6	-	4.6
SO5: Ability to identify, formulate, and solve engineering problem	4.0	-	-	-
SO6: Understanding of professional and ethical responsibility	4.2	-	-	4.2
SO7: Ability to communicate effectively		3.8	-	3.8
SO8: Broad education necessary to understand the impact of engineering solutions in a global and societal context	4.2	4.2	4.2	-
SO9: Recognition of the need for, and an ability to engage in life-long learning	-	4.1	4.1	4.1
SO10: knowledge of contemporary issues	-	-	3.9	3.9
SO11: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	4.0	-	-	4.0
Average scale of 5: 4.15	**4.1**	**4.2**	**4.1**	**4.2**
Decision based on Rubrics	**Exceeding Expectations**	**Exceeding Expectations**	**Exceeding Expectations**	**Exceeding Expectations**

Table J53. ME alumni survey responses data roll-up results to PEOs

Student Outcomes	PEO1	PEO2	PEO3	PEO4
SO1: Ability to apply knowledge of mathematics, science, and engineering	4.2	-	-	-
SO2: Ability to design and conduct experiment, as well as to analyze and interpret data	3.8	-	-	-
SO3: Ability to design a system, component, or process to meet desired needs	4.0	4.0	-	4.0
SO4: Ability to function on multi-disciplinary teams	-	4.1	-	4.1
SO5: Ability to identify, formulate, and solve engineering problem	4.4	-	-	-
SO6: Understanding of professional and ethical responsibility	4.1	-	-	4.1
SO7: Ability to communicate effectively	-	4.2	-	4.2
SO8: Broad education necessary to understand the impact of engineering solutions in a global and societal context	4.1	4.1	4.1	-
SO9: Recognition of the need for, and an ability to engage in life-long learning	-	3.9	3.9	3.9
SO10: knowledge of contemporary issues	-	-	4.1	4.1
SO11: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	4.1	-	-	4.1
Average scale of 5: 4.07	**4.1**	**4.1**	**4.0**	**4.1**
Decision based on Rubrics	**Exceeding Expectations**	**Exceeding Expectations**	**Exceeding Expectations**	**Exceeding Expectations**

Table J54. EE alumni survey responses data roll-up results to PEOs

Student Outcomes	PEO1	PEO2	PEO3	PEO4
SO1: Ability to apply knowledge of mathematics, science, and engineering	4.0	-	-	-
SO2: Ability to design and conduct experiment, as well as to analyze and interpret data	4.1	-	-	-
SO3: Ability to design a system, component, or process to meet desired needs	3.7	3.7	-	3.7
SO4: Ability to function on multi-disciplinary teams		4.1	-	4.1
SO5: Ability to identify, formulate, and solve engineering problem	4.0	-	-	-
SO6: Understanding of professional and ethical responsibility	3.9	-	-	3.9
SO7: Ability to communicate effectively		3.9	-	3.9
SO8: Broad education necessary to understand the impact of engineering solutions in a global and societal context	3.9	3.9	3.9	-
SO9: Recognition of the need for, and an ability to engage in life-long learning	-	3.7	3.7	3.7
SO10: knowledge of contemporary issues	-	-	3.7	3.7
SO11: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	3.7	-	-	3.7
Average scale of 5: 3.85	**3.9**	**3.9**	**3.8**	**3.8**
Decision based on Rubrics	**Meeting Expectations**	**Meeting Expectations**	**Meeting Expectations**	**Meeting Expectations**

The qualitative data from external alumni surveys and quantitative data from internal direct assessments of SOs (a-k) are combined in Tables J55, J56 and J57 to obtain a comprehensive evaluation review of the CE, ME and EE PEOs. In general, the ratings from external alumni surveys are better than those from the internal view of meeting the PEOs. From the combined qualitative and quantitative results we can clearly infer that the qualification of the programs based on PEOs evaluation process is comprehensively reinforced.

Table J55. Results of CE PEOs for direct and indirect assessments

PEOs	Direct Assessments	Result	Indirect Assessments (Alumni Survey)	Result
PEO1	3.8	Meeting Expectations	4.1	Exceeding Expectations
PEO2	4.1	Exceeding Expectations	4.2	Exceeding Expectations
PEO3	4.0	Meeting Expectations	4.1	Exceeding Expectations
PEO4	3.8	Meeting Expectations	4.2	Exceeding Expectations

Table J56. Results of ME PEOs for direct and indirect assessments

PEOs	Direct Assessments	Result	Indirect Assessments (Alumni Survey)	Result
PEO1	3.8	Meeting Expectations	4.1	Exceeding Expectations
PEO2	4.2	Exceeding Expectations	4.1	Exceeding Expectations
PEO3	3.9	Meeting Expectations	4.0	Meeting Expectations
PEO4	3.9	Meeting Expectations	4.1	Exceeding Expectations

Table J57. Results of EE PEOs for direct and indirect assessments

PEOs	Direct Assessments	Result	Indirect Assessments (Alumni Survey)	Result
PEO1	3.6	Meeting Expectations	3.9	Meeting Expectations
PEO2	3.9	Meeting Expectations	3.9	Meeting Expectations
PEO3	3.5	Meeting Expectations	3.8	Meeting Expectations
PEO4	3.9	Meeting Expectations	3.8	Meeting Expectations

External Review of Meeting the PEOs – Employer Surveys

The remote Employer Survey using EvalTools® 6 web-based survey module was requested from several summer training employers in the summer Terms 363 (2016), 373 (2017) and 383 (2018). Feedback was received from summer training employers for 100 students during the three years 2016-18 as per the program wise distribution given in Table J58.

Table J58. Summer training employers and program committee review decisions

	EE Program	ME Program	CE Program
Employer Survey [2016-2018]	2018: SOs (1-7) Response Rate: 3/3 Exceeding Expectations	2018: SOs (1-7) Response Rate: 6/6 Exceeding Expectations	2018: SOs (1-7) Response Rate: 19/19 Exceeding Expectations
Employer Survey [2016-2018]	2017: SOs (a-k) Response Rate: 4/4 Exceeding Expectations	2017: SOs (a-k) Response Rate: 13/13 Exceeding Expectations	2017: SOs (a-k) Response Rate: 9/9 Exceeding Expectations
Employer Survey [2016-2018]	2016: SOs (a-k) Response Rate: 20/20 Exceeding Expectations	2016: SOs (a-k) Response Rate: 18/18 Exceeding Expectations	2016: SOs (a-k) Response Rate: 8/8 Exceeding Expectations

In the section below are shown results from the terms 363, 373 and 383 (Summer 2016, 2017 and 2018). The format of the survey is indicated in the Table J59 below. The questions of the survey are aligned to the ABET SOs (a-k) for Terms 373 and 363 and ABET SOs (1-7) for Term 383 facilitating easy analysis and evaluation of the Employer Surveys.

Table J59. CE/ME/EE Employer Survey (Terms 383, 373, 363)

Employer Survey: SUMMER TRAINING - Total Intern's Results

Response Rate : **0/0**
ABET SO1: Applying Theory and Problem Solving

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	sd
1	Comfortably apply conceptual knowledge of Maths, Science and Engineering principles to complete assigned tasks with minimal supervision.								
2	Pose questions to identify and define given problems related to specific engineering processes..								
3	Use the techniques, skills and modern engineering equipment or tools necessary to complete assigned tasks..								
	Total Class Response:								

ABET SO2: Design System/Component/Process

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	sd
1	Participate in tasks such as modelling, simulation, drawing (AutoCAD/ Manual), assembly etc. to support final engineering design solutions..								
	Total Class Response:								

ABET SO3: Communicate Effectively

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	sd

	Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N.A.	Mean(5)	sd
1	Communicate on time and effectively with the concerned stake holders using oral and written means in the form of presentations, technical reports, diagrammatic representations using electronic or other media.								
	Total Class Response:								

ABET SO4: Safety Regulations, Professional Ethics, Engineering Standards and Contemporary Issues

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Implement company/industry quality standards for assigned processes.								
2	Fulfill Implementation of safety and health requirements in assigned processes as per required company/industry standards or regulations.								
3	Inquire of the benefits or drawbacks of engineering solutions on society and environment..								
4	Inquire of the modern social, economic and cultural issues to derive company's policies/regulations.								
	Total Class Response:								

ABET SO5: Team Work

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Listen to given instructions, complete assigned tasks in timely manner								
2	Effectively coordinate tasks with other team members								
3	Punctual attendance of regular meetings								
4	Communicate effectively with assigned supervisors, team members and other stake holders								
	Total Class Response:								

ABET SO6: Experimentation

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Participate in assigned experiments, observe and record measurements, operation of appropriate test and experimental equipment's, analyse and interpret data.								
	Total Class Response:								

ABET SO7: Lifelong Learning and Professional Development

	Questions	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N.A.*	Mean(5)	**sd**
1	Locate requested technical information using the internet, company provided or external resources; gather and integrate this information in the implementation of engineering solutions..								
	Total Class Response:								

Performance criteria shown in Table J38 were applied for evaluating the feedback results obtained in the Employer Survey. As shown in the Tables J60,J61,J62,J63, J64 and J65, the CE, ME and EE programs committee decisions for the results of the Employer Survey (Terms 363, 373) aligned to ABET SOs (a-k) and Employer Survey (Term 383) aligned to ABET SOs (1-7) were mostly *Exceeding* or *Meeting Expectations*

Table J60. CE program committee decisions for ABET SOs (A-K) based on employer survey results Term 363 (Summer 2016) Response Rate: 8/8; Term 373 (Summer 2017) Response Rate: 9/9

SOs	Term 363	Term 373	Average (3.0)	Final average (5.0)	Level of attainment
SO a	2.8	2.7	2.75	4.58	Exceeding Expectations
SO b	3	2.8	2.9	4.83	Exceeding Expectations
SO c	3	2.7	2.85	4.75	Exceeding Expectations
SO d	3	2.8	2.9	4.83	Exceeding Expectations
SO e	2.9	2.8	2.85	4.75	Exceeding Expectations
SO f	3	2.8	2.9	4.83	Exceeding Expectations
SO g	3	2.8	2.9	4.83	Exceeding Expectations
SO h	2.8	2.6	2.7	4.50	Exceeding Expectations
SO i	3	2.6	2.8	4.67	Exceeding Expectations
SO j	3	2.6	2.8	4.67	Exceeding Expectations
SO k	3	2.7	2.85	4.75	Exceeding Expectations

Table J61. CE program committee decisions for ABET SOs (1-7) based on employer survey results Term 383 (Summer 2018) Response Rate: 19/19

ABET SOs	Term 383 Average (3.0)	Final average (5.0)	Level of attainment
SO 1	2.76	4.6	Exceeding Expectations
SO 2	2.76	4.6	Exceeding Expectations
SO 3	2.88	4.8	Exceeding Expectations
SO 4	2.82	4.7	Exceeding Expectations
SO 5	2.88	4.8	Exceeding Expectations
SO 6	2.76	4.6	Exceeding Expectations
SO 7	2.82	4.7	Exceeding Expectations

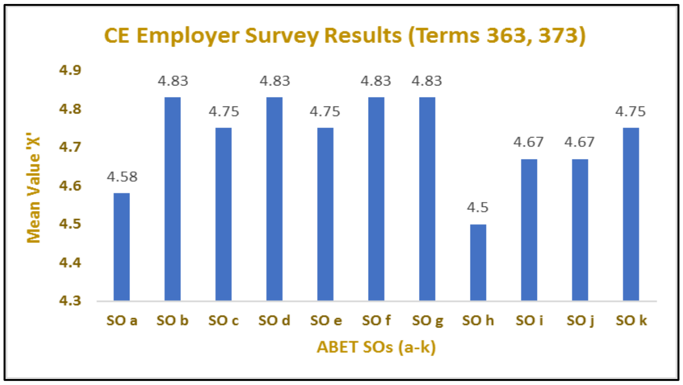


Figure J45. CE Employer Survey results terms 363, 373 (Summer 2016-17)

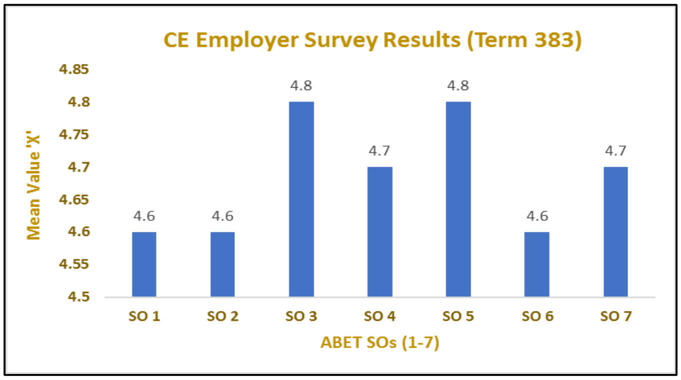


Figure J46. CE Employer survey results term 383 (Summer 2018)

Table J62. ME program committee decisions for ABET SOs (A-K) based on employer survey results Term 363 (Summer 2016) Response Rate: 18/18; Term 373 (Summer 2017) Response Rate: 13/13

ABET SOs	Term 373		Term 363		Final Result	Level of attainment
	Scale (3.0)	Scale (5.0)	Scale (3.0)	Scale (5.0)		
1	2.80	4.67	2.80	4.67	4.67	Exceeding Expectations
2	2.70	4.50	2.80	4.67	4.58	Exceeding Expectations
3	2.90	4.83	2.90	4.83	4.83	Exceeding Expectations
4	2.80	4.67	2.80	4.67	4.67	Exceeding Expectations
5	2.80	4.67	2.90	4.83	4.75	Exceeding Expectations
6	2.90	4.83	2.80	4.67	4.75	Exceeding Expectations
7	2.70	4.50	2.80	4.67	4.58	Exceeding Expectations
8	2.60	4.33	2.70	4.50	4.42	Exceeding Expectations
9	2.80	4.67	2.90	4.83	4.75	Exceeding Expectations
10	2.60	4.33	2.50	4.17	4.25	Exceeding Expectations
11	2.80	4.67	2.80	4.67	4.67	Exceeding Expectations

Table J63. ME program committee decisions for ABET SOs (1-7) based on employer survey results Term 383 (Summer 2018) Response Rate: 6/6

ABET SOs	Term 383		Level of attainment
	Scale (3.0)	Scale (5.0)	
1	2.88	4.80	Exceeding Expectations
2	2.88	4.80	Exceeding Expectations
3	3.00	5.00	Exceeding Expectations
4	2.94	4.90	Exceeding Expectations
5	2.94	4.90	Exceeding Expectations
6	2.88	4.80	Exceeding Expectations
7	2.70	4.50	Exceeding Expectations

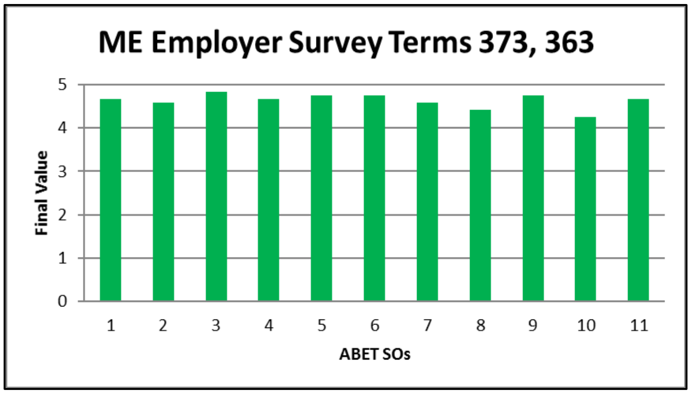


FIGURE J46. ME employer survey results Terms 363, 373 (Summer 2016-17)

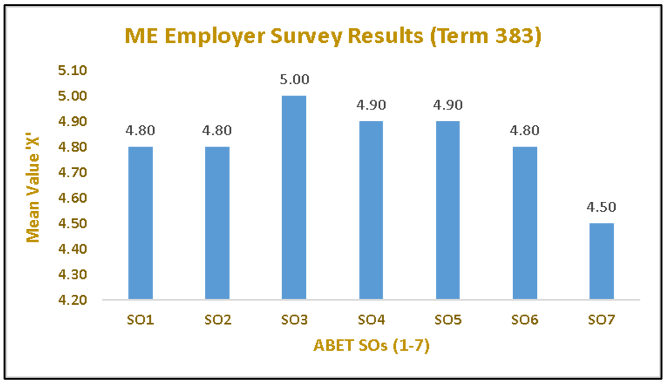


Figure J47. ME employer survey results Term 383 (Summer 2018)

Table J64. EE program committee decisions for ABET SOs (A-K) based on employer survey results Term 363 (Summer 2016) Response Rate: 20/20; Term 373 (Summer 2017) Response Rate: 4/4

Outcomes	Term 363	Term 373	Average (3.0)	Final average (5.0)	Level of attainment
SO a	2.8	2.8	2.8	4.67	Exceeding Expectations
SO b	2.8	2.8	2.8	4.67	Exceeding Expectations
SO c	2.8	2.7	2.7	4.50	Exceeding Expectations
SO d	3	2.8	2.6	4.33	Exceeding Expectations
SO e	2.7	2.8	2.2	3.67	Meeting Expectations
SO f	2.5	2.8	2.3	3.83	Meeting Expectations
SO g	2.6	2.8	2.5	4.17	Exceeding Expectations
SO h	2.8	2.6	2.2	3.67	Meeting Expectations
SO i	2.8	2.6	3	5.00	Exceeding Expectations
SO j	2.6	2.6	2	3.33	Meeting Expectations
SO k	2.7	2.7	2.8	4.67	Exceeding Expectations

Table J65. EE program committee decisions for ABET SOs (1-7) based on employer survey results Term 383 (Summer 2018) Response Rate: 3/3

ABET SOs	Term 383 Average (3.0)	Final average (5.0)	Level of attainment
SO 1	2.88	4.8	Exceeding Expectations
SO 2	2.82	4.7	Exceeding Expectations
SO 3	2.58	4.3	Exceeding Expectations
SO 4	2.88	4.8	Exceeding Expectations
SO 5	2.94	4.9	Exceeding Expectations
SO 6	3	5	Exceeding Expectations
SO 7	3	5	Exceeding Expectations

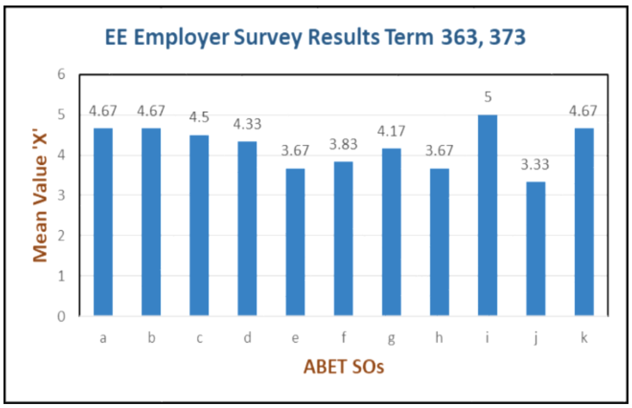


Figure J48. EE employer survey results terms 363, 373 (Summer 2016-17)

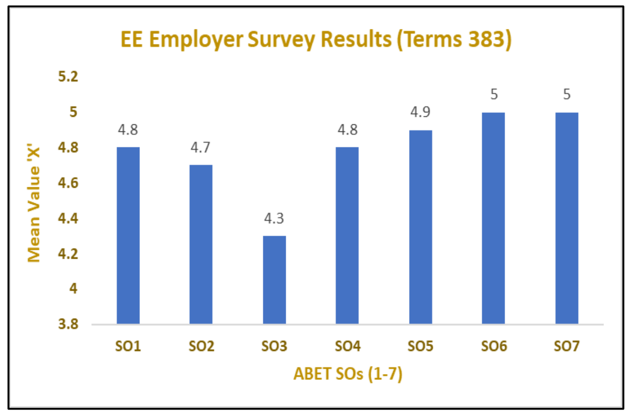


Figure J49. EE employer survey results term 383 (Summer 2018)

iii. EAC REVIEW MEETING

The EAC review meeting invovles a qualitative and quantitative review of relevant data to gauge the attainment of SOs, relevancy of PEOs and status of several key aspects of the education and CQI process. The first meeting of the EAC was conducted on Dec 05, 2018 at the Islamic University. The objectives of the meeting of the EAC were the following:

a) Introducing the Faculty of Engineering to EAC members
b) Elaborate on the importance, role and expectations of the EAC
c) Agenda items for discussion

The committee discussed six agenda items in the meeting:

a) Approval of the Vision, Mission, Objectives and the Strategic Plan of the Faculty.
b) Approval of the Vision, Mission and Program educational objectives of the EE, ME and CE programs of the Faculty of Engineering
c) Approval of adoption of ABET's revised 7 SOs for the EE, ME and CE programs and their relevance with the needs of the labor market.
d) Study of the EE, ME and CE curriculum and alignment with the program SOs
e) Report of Senior Design Projects, Summer Training and exploring entrepreneurship opportunities and cooperation with industry and employers.

f) Scheduling future EAC meetings, mode of communication and work.

Kingdom of Saudi Arabia
Ministry of Education
The Islamic University in Madinah
(032)
External Advisory Committee

المملكة العربية السعودية
وزارة التعليم
الجامعة الإسلامية بالمدينة المنورة
(٠٣٢)
المجلس الاستشاري بكلية الهندسة

The EAC members reviewed the PEOs data for the quality cycle 2014-2018 and elaborated in detail on the content of the PEOs for each program and their alignment with the vision and mission. In summary, the EAC were satisfied with the language of the PEOs and approved the same for the three programs.

c. Approval of adoption of ABET's revised 7 SOs for the EE, ME and CE programs and their relevance with the needs of the labor market.

The Faculty of Engineering, EE, ME and CE programs adopted in term 383 2018 the ABET EAC 7 SOs as listed below:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

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External Advisory Committee

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وزارة التعليم
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The multi-term SOs (a-k) data terms 351-382 was presented to the EAC. The EAC members were impressed with the positive trends in student learning for all the 11 SOs (a-k) for all the three programs. All the EAC members unanimously endorsed transition to the revised 7 ABET SOs and agreed that the revised SOs comprehensively cover the required skills and knowledge areas for the engineering students of the Islamic University. The various aspects related to problem solving, design, team work, communication, experimentation, lifelong learning etc. adequately align with the much needed 21st century skills and confirm the fulfilment of the criteria set by the NCAAA and Ministry of Education according to the Vision 2030 of the country.

The Dean also confirmed the fact that all the programs outcomes are measured and reviewed at the end of each semester. The Vice Dean elaborated on the Continuous Quality Improvement process of programs which involved conducting end of term meetings to review any shortcomings of measured outcomes and create corrective actions to remediate failures.

Prof. Mirghani Ahmed explained the software "Evaltools" used by the Faculty of Engineering, a high quality integrated learning management system that has flexible program modules to meet the needs of the faculty in education by providing required student academic information to facilitate learning management and student advising. This software is popular with accreditation agency such as ABET Inc.

A number of other points were discussed and listed as below:

1) Prof. Amro Al-qutub praised the software "Evaltools" used and stressed on the importance of having a backup copy of all the stored files, documents and data in order to preserve it to avoid the loss of this valuable information.

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Figure J50. Relevant pages of EAC meeting minutes indicating review of PEOs, SOs, curriculum, multi-term SOs (a-k) data and CQI processes

APPENDIX K: *Meta-analyses Results*

Table K1. MMTBIE at Faculty of Engineering programs according to Bronfenbrenner's Model [97]

Bronfenbrenner's Level	Detail of Level	Context and Standards*	Quantiatitive (QN) & Qualitative (QL) Evaluations
Micro-MMTBIE	Applied to cohorts enrolled in courses within an engineering program; COs and PIs used to evaluate students;	1. NCAAA course specific performance indicators 2. Washington graduate attributes and profiles 3. ABET SOs 4. ABET CR9: Program Criteria 5. Islamic University educational objectives	1. PDCA (Q_1,Q_2): Course evaluation (QN & QL) 2. PDCA (Q_1,Q_2): Student evaluation (QN & QL) For details of evaluation refer sections: 7.1 (Q_1) and 7.2 (Q_2)
Meso-MMTBIE	Applied to engineering programs to evaluate attainment of program level SOs and coverage of curricular requirements.	1. NCAAA course and curricular requirements 2. Washington graduate attributes and profiles 3. ABET SOs 4. ABET CR5: curricular requirements 5. ABET CR9: program criteria 6. Islamic University educational objectives	1. PDCA (Q_3): SOs Evaluation (QN & QL) 2. PDCA (Q_3): PIs Evaluation(QN & QL) 3. PDCA (Q_3): Learning Domains Evaluation (QN & QL) 4. PDCA (Q_4): Multi-term PIs review (QN & QL) For details of evaluation refer sections: 7.3 (Q_3) and 7.4 (Q_4)
Exo-MMTBIE	Applied to cohorts enrolled in summer training courses within an engineering program; COs and PIs used to evaluate students; Employers evaluate student performances.	1. NCAAA field traning experience requirements 2. Washington graduate attributes and profiles 3. ABET SOs 4. Industrial sites' professional work and ethics requirements	1. PDCA (Q_1,Q_2): Course evaluation (QN & QL) 2. PDCA (Q_1,Q_2): Student evaluation (QN & QL) 3. PDCA (Q_2,Q_6): Employer evaluation (QL) For details of evaluation refer sections: 7.1 (Q_1), 7.2 (Q_2) and 7.6 (Q_6)
Macro-MMTBIE	Applied to graduates of engineering programs few years after employment; alumni provide feedback related to attainment of PEOs; External advisory committee review attainment of PEOs;	1. Engineering program's PEOs 2. NCAAA course and curricular requirements 3. Washington graduate attributes and profiles 4. ABET SOs 5. ABET CR5: curricular requirements 6. ABET CR9: program criteria 7. Islamic University educational objectives 8. Regional job market knowledge and skills requirements 9. Spady's Transformational OBE – life performance roles 10. Summer training industrial employers feedback	1. PDCA (Q_6): PEOs analysis and review (QN & QL) 2. PDCA (Q_5): Multi-term SOs trend analysis (QN & QL) 3. PDCA (Q_6): External Advisory Committee feedback (QL) 4. PDCA (Q_6): Alumni feedback (QL) 5. PDCA (Q_2,Q_6): Employer feedback (QL) 6. PDCA (Q_6): Senior exit feedback (QL) For details of evaluation refer sections: 7.2 (Q_2), 7.5 (Q_5) and 7.6 (Q_6)

* Obtained by a thorough qualitative literature review of regional (NCAAA, Islamic University, local employers training plans, local job market requirements) and international (Washington Accord, ABET, international employers training plans) informational resources

Table K2. Relevant frameworks, constructs and variables for MMTBIE of Faculty of Engineering EE, CE and ME programs

Framework	Construct(s) of Interest	Variables	Sectional References
Theoretical	OBE Model	Fulfillment of paradigm, premises and principles or lack of fulfillment	IV.A.1
Conceptual - Models	Selecting learning Models	Bloom's Mastery Learning Model or other valid model	IV.B.1
	Mapping model from goals to PIs	Design Down implemented or inaccurate model	IV.B.2
	Ideal Learning Distribution	Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology or other valid grouping methdology	IV.B.3
	Assessment model	1. ABET assessment model or inaccurate model 2. Incorporation of ABET accreditation criteria for CR2: PEOs review or deficient 3. Assessment and evaluation plan facilitate comprehenisive attainment of ABET SOs using PIs or deficient 4. Incorporation of ABET accreditation criteria for CR4 : Continuous Improvement or deficient	IV.B.4
Conceptual – Techniques & Methods	Embedded Assessments using FCAR, EAMU Performance Vector Methodology	Unique assessments or NOT Aligned to COs, PIs and SOs or NOT EAMU performance criteria and heuristic rules or other scientifically defined and clear performance criteria Structured template integrating direct and indirect assessments or deficient Facilitate accurate course reflections and actions available or NOT	IV.C.1
	Design rules for COs and PIs	1. Follow Mager's essential principles for outcomes statements or NOT 2. Follow Adelman's strcuture of outcomes statements or NOT 3. PIs tightly aligned to COs, ABET SOs and learning activity or NOT 4. Cover all learning domains of Bloom's learning model or all learning domains of other valid learning model or NOT 5. Cover major course topics or NOT 6. Achieve Ideal course learning distribution or NOT	IV.C.2
	Rubrics	1. Use analytic topic specific hybrid rubrics or use vague generic rubrics or lacking rubrics 2. Rubrics tightly aligned to PIs, SOs and learning activity or NOT 3. Rubrics development incorporates OBE principles or NOT	IV.C.3
	Weighting factors	Apply scientific wieighting factors for aggregating assessment and skill types or apply deficient weighting factors or lacking any kind of weighting factors	IV.C.4
Practical – Digital Platform EvalTools ®	FCAR and PVT	1. Unique assessments or NOT 2. Aligned to outcomes or NOT 3. EAMU performance criteria and heuristic rules or other scientifically defined and clear performance criteria 4. Apply scientific wieighting factors for aggregating assessment and skill types or NOT 5. Provide course level learning distribution and assessment counts information for 3 learning domains of Bloom's model or NOT 6. Sample size assesses all students enrolled in class or random small or other selective sample size 7. Structured template integrating direct and indirect assessments or deficient 8. Detailed quantitative diagnostics showing composite COs, PIs, SOs evaluation plots 9. Facilitate accurate course reflections and actions available or NOT	IV.D.1
	Specific PIs database	1. Accurate alignment to SOs or NOT 2. Accurately classified to Bloom's 3 domains and learning levels or inaccurate classfication 3. Database linked with hybrid rubrics or NOT	IV.D.2
	Hybrid rubrics	1. Accurate alignment to PIs, SOs and assessments or NOT 2. Provide detailed steps with scoring information or lack information 3. Provide detailed descriptors for all EAMU scale or lack information 4. Available in digital database for student and instructor view or NOT	IV.D.3
	SOs and PIs evaluations	1. Present accurate SOs data using scientific and clear performance criteria or NOT 2. Incorporate scientific weighting factors scheme to aggregate skills from all courses in given term or NOT 3. Provide root cause failure analysis search features or NOT 4. Present comments features for reviewers or NOT 5. Provide digital reports for executive summary, course and program level actions or NOT	IV.D.4
	Learning domains evaluations	1. Provide overall learning distribution and assessment counts information for 3 learning domains of Bloom's model or NOT 2. Provide learning distribution and assessment counts information for all ABET SOs or NOT 3. Provide learning distribution and assesment counts information for individual learning domains of Bloom's model or NOT 4. Present comments features for reviewers or NOT 5. Provide digital reports for executive summary, corrective actions or NOT	IV.D.5
	Advising based on outcomes	1. Provide outcomes data with diagnostics for every individual enrolled student or NOT 2. Provide state of the art features to facilitate advising based on outcomes or NOT 3. At least 2 years advising records based on outcomes available or NOT	IV.D.6
	CIMS	1. Provide meeting minutes history for administrative committees CQI work or NOT 2. Provide task lists with time stamps, status of actions, priority, ownership information for administrative committees CQI work or NOT 3. Provide documentation folders for administrative committees CQI work or NOT 4. Provide latest member and moderator lists for all administrative committees	IV.D.7

Table K3. Conditions and evaluation questions for Phase-3 of Meta-Framework for MMTBIEs

Conditions[1]	Conditions Fulfillment
a) Causal chain links inputs to outcomes and impacts	Figure 18 in *Section VI: Integrated Quality Management Systems – 6 PDCA Quality Cycles* clearly indicates a systematic and logical flow of CQI process from *Q1: COs, PIs and hybrid rubrics development* to final cycle *Q6: PEOs 5-year review*. Specific details of each phase's inputs, process are provided exhaustively in the sub sections *VI.A* to *VI.F*.
b) Causal chain should be based on some form of theory—evaluation theory, social science theory, and/or program theory	▸ Figure 1 displays how various elements of the theoretical, conceptual and practical frameworks are based on social science, evaluation and program theory respectively; ▸ Social science theory: authentic OBE theory (refer *Section IV.A.1 OBE Model*) ▸ Evaluation theory: ABET assessment model and assessment best practices (refer *Section IV.B Conceptual Framework-Models* and *Section IV.C Conceptual Framework – Techniques, Methods*) ▸ Program theory: practical framework (refer *Section IV.D Practical Framework – Digital Platform EvalTools* ® and its subsections *IV.D.1* to *IV.D.7* and implementation of Q1-Q6 PDCA quality cycles (refer *Section VI Integrated Quality Management Systems – 6 PDCA Quality Cycles* and its subsections *VI.A* to *VI.F*.)
c) Causal link should be directional and not bi-directional	The CQI process flow shown in Figure 18 in *Section F*. It is essentially unidirectional flowing from course work to PEOs with Q1-Q6 quality cycles consisting of continuously processing loops, thereby indicating that inputs, processes result in the final impact and outcomes of the intervention and not vice versa.
d) Causal chain reflects inputs from the local experts, stake holders and project members	As shown in Table K4 and also referred to in *Section VI.F.2 PDCA Quality Cycle Q6: PEOs 5-Years Review Process – Program Constituencies*, the causal links extensively integrate inputs into every phase of the CQI process from local OBE and assessment experts, several stakeholders such as alumni, students, industry and faculty, local (NCAAA) and international (Washington Accord, ABET) accreditation agencies.
Evaluation Questions[2]	**Responses**
a) What are all the specific elements (e.g., services, activities) that underlie the intervention, treatment, program, or policy?	As shown in Figure 18 in *Section VI*, the Integrated Quality Management System comprises 6 PDCA quality cycles, their inputs and outputs.
b) What is the cost (e.g., financial, time, resources, labor) of delivering each element (e.g., service, activity)?	Table 11 shows detailed information related to frequency, time spent, ownership, some process details for various CQI activities related to the implementing the Integrated Quality Management System
c) What are the expected short-term and long-term outcomes of each element?	Short term outcomes are provided in Sections *VI.A* to *VI.E* for each PDCA quality cycle Q1-Q5. Long term outcomes are to contribute in implementation of an Integrated Quality Managment System which positively impacts the education process to improve SOs and eventually attain PEOs as mentioned in Section *VI.F PDCA Quality Cycle Q6: PEOs 5-Years Review Process.* The PEOs target technical and transversal skills, professional achievments, community service and instill Islamic ethics.
d) How is each element (e.g., service, activity) operationalized?	Sections *VI.A* to *VI.F* provide details of operations for each PDCA quality cycle Q1-Q6
e) What are the quantitative and qualitative data sources for each output?	Table K4 lists the distribution of quantitative and qualitative data sources for PDCA quality cycles Q1-Q6
f) Who, how, when, and where will each data source be collected?	Table 11 shows detailed information related to frequency, time of year, ownership, process details for various CQI activities related to quantitative and qualitative data sources for PDCA quality cycles Q1-Q6
g) How many data points will be collected and how often?	Sections *VI.A* to *VI.F* provide detailed answers for data points to be collected for each PDCA quality cycle Q1-Q6
h) What is the performance target for each element (e.g., service, activity)? i) What is the potential range for the performance target for each element (e.g., service, activity)?	Table 6 shows peformance criteria and heuristic rules for COs, SOs and PIs evaluations; Table J32 shows rubrics for evaluating attainment of PEOs; Table J38 shows rubrics for evaluating survey responses; *Section VI.E.4* Table J22 shows the performance criteria for Multi-term SOs evaluation and trend analysis
j) For whom, when, where, under what context/conditions, why, and how is each activity most likely to be optimal?	Sections *VI.A* to *VI.F* provide details of conditions or requirements for optimal operations in each PDCA quality cycle Q1-Q6

1- Requirements White (2009) model applied to complete process

2- Evaluation questions to be answered to the fullest extent (James Bell Associates, 2008)

Table K4. **Qualitative and quantitative measures for Phase-4 of Meta-Framework for MMTBIEs**

PDCA Quality Cycle	Qualitative	Quantitative	Sectional References
Q_1: COs, PIs and hybrid rubrics development	1. Analysis of COs and PIs statements for fulfillment of Mager's and Adelman's models 2. Analyis of alignment of COs, PIs to major course topics, student learning activity, assessments and SOs. 3. Analysis of descriptors for various steps and EAMU scales of hybrid rubrics. 4. Analysis of alignment of rubrics to learnng activity in assessments	1. Analyis of Ideal course learning dsitribution 2. Analysis of scoring mechanism for hybrid rubrics and alignment of scoring to assessments 3. Analysis of course level weighting factors based on course format, type of assessments and grading scale	1. *Section IV.B.3* Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology; Ideal Learning Distribution 2. *Section IV.C.2* Design rules COs and PIs 3. *Section IV.C.3* Hybrid rubrics 4. *Section IV.C.4* Weighting factors 5. *Section VI.A* PDCA cycle Q1: COs, PIs and hybrid rubrics development
Q_2: Course evaluation, feedback and improvement	1. Course exit survey 2. Semantic analysis of language of failing COs, PIs 3. Analysis of failing assessments 4. Items 4,5,6,7,8,9 of FCAR checklist 5. Self evaluation	1. Analysis of COs, PIs and SOs histogram plots 2. Analysis of EAMU vector assessment and CO distributions 3. Analysis of learning distribution 4. Syllabi checklist 5. Items 1,2,3,10,11,12,13,14,15,16,17, 18 of FCAR checklist 6. EOT checklist	*Section VI.B* PDCA Quality Cycle Q2: Syllabi Checklist, FCAR Checklist, End of Term (EOT) Checklist
Q_3: Program term review	1. Semantic analysis of langauge of failing PIs 2. Root cause failure analysis by investigating assessments 3. Review of course level actions	1. Analysis of program level weighting factors 2. SOs evaluation 3. PIs evaluation 4. Learning domains evaluation 5. Review of past term SO assessment plan	1. *Section IV.D.1* Practical Framework – Digital Platform EvalTools ® - FCAR and PVT 2. *Section IV.D.4* SOs and PIs evaluations 3. *Section IV.D.5* Learning Domains evaluations 4. *Section VI.C* PDCA Quality Cycle Q3: Program Term Review – Learning Domains, PIs and SOs Evaluation
Q_4: PIs 3-year multi-term review	1. Analysis of PIs database for inaccurate content 2. Analysis of PIs database for futuristic content 3. Analysis of PIs database for incorrect alignment to SO and therefore moved to appropriate SO 4. Analysis of PIs database for too basic content.	Analysis of PIs database for redundancy	*Section VI.D* PDCA Quality Cycle Q4: PIs 3 Year Multi-Term Review
Q_5: SOs Multi-term review	1. Analysis of coverage of SOs based on PIs and history of assessment details and reviewer feedback 2. Final decision on SOs trend analysis based on reviewer feedback 3. Final decision on updating performance criteria based on reviewer feedback of trend analysis results 4. Analysis of multi-term executive summary report based on reviewer feedback and corrective actions generated	1. Analysis of multi-term SOs average values and benchmarking 2. Linear regression of SO multi-term data to obtain overall average and forecasted values for trend analysis	*Section VI.E* PDCA Quality Cycle Q5: SOs Multi-Term Review
Q_6: PEOs 5-year review	1. Program faculty review PEOs alignment to Islamic University mission. 2. EAC feedback for approval of PEOs, alignment of SOs to curriculum and CQI system and processes 3. EAC review and approval of Capstone design project process 4. EAC review and approval of curriculum 5. EAC review and approval of Industrial training course and employers 6. EAC feedback on industry knowledge and skills requirements 7. EAC review and feedback for multi-term SOs results 8. EAC review and feedback for multi-term executive summary 9. Alumni feedback on SOs and PEOs 10. Senior exit survey on SOs and PEOs 11. Employer feedback on training students' SOs	1. Analysis of multi-term SOs data 2. Estimation of PEOs from direct assessment results 3. Evaluation for attainment of PEOs based on rubrics and performance criteria	*Section VI.F* PDCA Quality Cycle Q6: PEOs 5-Years Review Process

Table K5. Quality of statistical data for MMTBIEs of the Faculty of Engineering programs

Statistical Analysis	Type	Sample size (Planned vs. Actual)	Course /Program Level	Data and Theoretical Saturation	Statistical Power	Response Rate	Generalizability & Transferability	Sustainability*
COs Evaluation	Quantitative	Same; All students enrolled in courses for the term	Course	N/A	High	N/A	COs data statistically generalizable externally with course cohorts for given term; and case to case transferable to following term course offerings for comparison of performances in previously failing COs	Automated Sustainable
SOs Evaluation	Quantitative	Same; All students enrolled in programs for the term	Program	N/A	High	N/A	SOs data statistically generalizable externally with all cohorts enrolled in program for given term; and case to case transferable to following term SOs evaluations for comparison of performances in previously failing SOs	Automated Sustainable
PIs Evaluation	Quantitative	Same; All students enrolled in programs for the term	Program	N/A	High	N/A	PIs data statistically generalizable externally with all cohorts enrolled in program for given term; and case to case transferable to following term PIs evaluations for comparison of performances in previously failing PIs	Automated Sustainable
Learning Domains Evaluation	Quantitative	Same; All students enrolled in programs for the term	Program	N/A	High	N/A	Learning domains distribution data statistically generalizable extenally with all cohorts in courses at specific learning level either mastery, reinforced or introductory; and case to case transferable to following term for SO assessment plan improvement	Automated Sustainable
Multi-term SOs	Quantitative	Same; All students enrolled in programs for years covered	Program	N/A	High	N/A	SOs data statistically generalizable externally with all cohorts enrolled in program for given term	Automated Sustainable
PEOs Review (EAC)	Mixed: ‣ Quantitative: multiterm SOs; ‣ Qualitative: Alumni, EAC, Senior Exit survey and EAC review	Quantitative: same; Qualitative: depends upon size of cohorts being covered by survey; depends upon number of participants of EAC	Program	Data and theoretical saturation achieved	High	> 70%	Quantitative data is externally generalizable to all cohorts enrolled in the programs during preiod covered by the PEOs review; Qualitative student survey data is internally generalizable to the cohorts enrolled in the programs for the years covered by the survey; Qualitative EAC review yields naturalistic generalization of any review data.	Review once every 5 years; All reports automated; Sustainable
EAC Survey	Qualitative 5-likert survey	Same; depends upon size of cohorts being covered by survey	Program	Data and theoretical saturation achieved	N/A	> 70%	Qualitative EAC survey data is internally generalizable to the cohorts enrolled in progams for the years covered by the quality cycle Q6 being evaluated;	Remote survey Sustainable

Alumni Survey	Qualitative 5-likert survey	Acceptable response rate; depends upon size of cohorts being covered by survey	Program	Data and theoretical saturation achieved	N/A	> 70%	Qualitative alumni survey data is case to case transferable to the cohorts enrolled in programs for the same academic year of conducting the survey;	Remote survey Sustainable
Employer Survey	Qualitative 5-likert survey	Same; depends upon size of cohorts being covered by survey	Course	Data and theoretical saturation achieved	N/A	> 70%	Qualitative employer survey data is internally generalizable to the cohorts related with the survey;	Remote survey Sustainable
Senior Exit Survey	Qualitative 5-likert survey	Same; depends upon size of cohorts being covered by survey	Program	Data saturation is partial	N/A	> 70%	Qualitative student survey data is internally generalizable to the cohorts related with the survey;	Remote survey Sustainable
Course Exit Survey	Qualitative 5-likert survey	Response rate is acceptable but students need training and motivation for providing credible responses; depends upon size of cohorts being covered by survey	Course	Data saturation not Achieved	N/A	> 70%	Qualitative student survey data is internally generalizable to the cohorts related with the survey;	Remote survey Sustainable

*Refer *Section VII* Sustainability of Course and Program Level CQI Processes

Table K6. Process analysis for PDCA quality cycles Q_1 to Q_6 for MMTBIEs conducted at Faculty of Engineering programs

PDCA Quality Cycle Q1: COs, PIs and Hybrid Rubrics Development

Inputs	Qualitative Analyses	Quantitative Analyses	Outputs	Framework	Constructs of Interest	Comments/Observations
1. Course Topics 2. Target Learning Activity 3. Target Assessments	1. Analysis of COs and PIs statements for fulfillment of Mager's and Adelman's models 2. Analyis of alignment of COs, PIs to major course topics, student learning activity, assessments and SOs. 3. Analysis of descriptors for various steps and EAMU scales of hybrid rubrics. 4. Analysis of alignment of rubrics to learnng activity in assessments	1. Analyis of Ideal course learning dsitribution 2. Analysis of scoring mechanism for hybrid rubrics and alignment of scoring to assessments. 3. Analysis of course level weighting factors based on course format, type of assessments and grading scale.	1. CO, PIs and SOs for course delivery 2. Course curriculum delivery plan 3. Hybrid rubrics 4. Sample of target assessments aligned to hybrid rubrics	Theoretical	OBE model	Fulfillment of paradigm, premises and principles
				Conceptual - Models	Selecting learning models	Bloom's Mastery Learning Model implemented
					Mapping model from goals to Pis	Design Down implemented
					Ideal learning distribution	Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology implemented

PDCA Quality Cycle Q2: Syllabi Checklist, FCAR Checklist and End of Term (EOT) Checklist

Inputs	Qualitative Analyses	Quantitative Analyses	Outputs	Framework	Constructs of Interest	Comments/Observations
1. Course Syllabi 2. CO, PIs and SOs for course delivery 3. Course curriculum delivery plan 4. Hybrid rubrics 5. Sample of target assessments aligned to hybrid rubrics	1. Course exit survey 2. Semantic analysis of language of failing COs, PIs 3. Analysis of failing assessments 4. Items 4,5,6,7,8,9 of FCAR checklist 5. Self evaluation	1. Analysis of COs, PIs and SOs histogram plots 2. Analysis of EAMU vector assessment and CO distributions 3. Analysis of learning distribution 4. Syllabi checklist 5. Items 1,2,3,10,11,12,13, 14,15,16,17, 18 of FCAR checklist 6. EOT checklist	1. Course work for all courses offered in a given term: ▸ Lessons ▸ SOs, PIs Assessments ▸ Rubrics applied to major course activity ▸ L,M, H student work samples ▸ Completed FCAR ▸ Old corrective actions ported, completed and status closed ▸ Grade book 2. FCAR checklist 3. EOT checklist 4. Supervisor QD approval	Theoretical	OBE model	Fulfillment of paradigm, premises and principles
				Conceptual - Models	Selecting learning models	Bloom's Mastery Learning Model implemented
					Mapping model from goals to Pis	Design Down implemented
					Ideal learning distribution	Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology implemented

				Conceptual – Techniques & Methods	Embedded Assessments using FCAR, EAMU Performance Vector Methodology	1. Unique assessments implemented 2. Aligned to COs, PIs and SOs 3. EAMU performance criteria and heuristic rules 4. Structured template integrating direct and indirect assessments 5. Accurate course reflections and actions available and completed
					Design rules for COs and Pis	1. Followed Mager's essential principles for outcomes statements 2. Followed Adelman's strcuture of outcomes statements 3. PIs tightly aligned to COs, ABET SOs and learning activity 4. Covered all learning domains of Bloom's learning model 5. Covered major course topics 6. Achieved Ideal course learning distribution
					Rubrics	1. Used analytic topic specific hybrid rubrics 2. Rubrics tightly aligned to PIs, SOs and learning activity 3. Rubrics development incorporates OBE principles
					Weighting factors	Apply scientific wieighting factors for aggregating assessment and skill types
PDCA Quality Cycle Q3: Program Term Review						
Inputs	**Qualitative Analyses**	**Quantitative Analyses**	**Outputs**	**Framework**	**Constructs of Interest**	**Comments/Observations**
1. Course work for all courses offered in a given term: ‣ Lessons ‣ SOs, PIs Assessments ‣ Rubrics applied to major course activity ‣ L,M, H student work samples ‣ Completed FCAR ‣ Old corrective actions ported, completed and status closed ‣ Grade book 2. FCAR checklist	1. Semantic analysis of langauge of failing PIs 2. Root cause failure analysis by investigating assessments 6. Review of course level actions	1. Analysis of program level weighting factors 2. SOs evaluation 3. PIs evaluation 4. Learning domains evaluation 4. Review of past term SO assessment plan	1. SO executive summary report 2. Detailed SO/PI executive summary report 3. SO/PI Performance Vector Table PVT summary report 4. Course reflections/ action items 5. Learning domains evaluation report 6. Updated and improved SOs assessment plan 7. Updated curriculum maps	Theoretical	OBE model	Fulfillment of paradigm, premises and principles
				Conceptual - Models	Selecting learning models	Bloom's Mastery Learning Model implemented
					Mapping model from goals to Pis	Design Down model implemented
					Ideal learning distribution	Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology implemented

3. EOT checklist 4. Supervisor QD approval				Practical – Digital Platform EvalTools ®	FCAR and PVT	1. Unique assessments implemented 2. Aligned to outcomes 3. EAMU performance criteria and heuristic rules 4. Apply scientific wieighting factors for aggregating assessment and skill types 5. Provide course level learning distribution and assessment counts information for 3 learning domains of Bloom's model 6. Sample size assesses all students enrolled in class 7. Structured template integrating direct and indirect assessments 8. Detailed quantitative diagnostics showing composite COs, PIs, SOs evaluation plots Accurate course reflections and actions available and completed
					SOs and PIs evaluations	1. Presented accurate SOs data using scientific and clear performance criteria 2. Incorporated scientific weighting factors scheme to aggregate skills from all courses in given term 3. Provided root cause failure analysis search features 4. Presented comments features for reviewers 5. Provided digital reports for executive summary, course and program level actions
					Learning domains evaluations	1. Provided overall learning distribution and assessment counts information for 3 learning domains of Bloom's model 2. Provided learning distribution and assessment counts information for all ABET SOs 3. Provided learning distribution and assesment counts information for individual learning domains of Bloom's model 4. Presented comments features for reviewers 5. Provided digital reports for executive summary, corrective actions
					CIMS	1. Provided meeting minutes history for administrative committees CQI work 2. Provided task lists with time stamps, status of actions, priority, ownership information for administrative committees CQI work 3. Provided documentation folders for administrative committees CQI work 4. Provide latest member and moderator lists for all administrative committees
PDCA Quality Cycle Q4: PIs 3-Year Multi-term Review						
Inputs	**Qualitative Analyses**	**Quantitative Analyses**	**Outputs**	**Framework**	**Constructs of Interest**	**Comments/Observations**

Multi-term reports covering period [2014-2018]: 1. SO executive summary report 2. Detailed SO/PI executive summary report	1. Analysis of PIs database for inaccurate content 2. Analysis of PIs database for futuristic content 3. Analysis of PIs database for incorrect alignment to SO and therefore moved to appropriate SO 7. Analysis of PIs database for too basic content.	1. Analysis of PIs database for redundancy	1. Updated and accurate database of specific and generic PIs 2. Updated database of corrected hybrid rubrics	Theoretical	OBE model	Fulfillment of paradigm, premises and principles
				Conceptual - Models	Selecting learning models	Bloom's Mastery Learning Model implemented
					Mapping model from goals to PIs	Design Down model implemented
					Ideal learning distribution	Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology implemented
				Practical – Digital Platform EvalTools ®	Specific PIs database	1. Accurate alignment to SOs or NOT 2. Accurately classified to Bloom's 3 domains and learning levels or inaccurate classfication Database linked with hybrid rubrics or NOT
					Hybrid rubrics	1. Accurate alignment to PIs, SOs and assessments or NOT 2. Provide detailed steps with scoring information or lack information 3. Provide detailed descriptors for all EAMU scale or lack information Available in digital database for student and instructor view or NOT

PDCA Quality Cycle Q5: SOs Multi-Term review

Inputs	**Qualitative Analyses**	**Quantitative Analyses**	**Outputs**	**Framework**	**Constructs of Interest**	**Comments/Observations**
Multi-term reports covering period [2014-2018]: 1. SO executive summary report 2. Detailed SO/PI executive summary report 3. SO/PI Performance	1. Analysis of coverage of SOs based on PIs and history of assessment details and reviewer feedback 2. Final decision on SOs trend analysis based on	1. Analysis of multi-term SOs average values and benchmarking 2. Linear regression of SO multi-term data to obtain overall average and forecasted values for trend analysis	Program committee review and decision of *Meeting Expectations* for ME, EE programs and *Exceeding Expectations* for CE program for attainment of SOs [a-k] 1. Majority of SOs (a-k) performances just stabilized to Meeting Expectations in the last few terms towards 382	Theoretical	OBE model	Fulfillment of paradigm, premises and principles
				Conceptual - Models	Selecting learning models	Bloom's Mastery Learning Model implemented

Vector Table PVT summary report 4. Course reflections/ action items 5. Learning domains evaluation report 6. Updated and improved SOs assessment plan 7. Updated curriculum maps	reviewer feedback 3. Final decision on updating performance criteria based on reviewer feedback of trend analysis results 8. Analysis of multi-term executive summary report based on reviewer feedback and corrective actions generated		excepting for SO 'k' and therefore did not require any modifications to performance criteria. If Meeting or Exceeding Expectations were observed for any of the SOs for multiple terms, then the minimum performance criteria would have been raised to increase the performance standards. 2. 8 out of the 11 SOs (EE, ME) and 10 out of 11 SOs (CE) trends were positive with reasonable multi-term coverage and faculty feedback also indicated acceptable assessment and evaluation data/processes and did not necessitate any modifications to the 11 SOs 3. The overall multi-term results were therefore acceptable and the CE, EE and ME programs' position to transition to revised 7 ABET SOs was reinforced.		Mapping model from goals to PIs	Design Down model implemented
					Ideal learning distribution	Bloom's 3 Domains Taxonomic Learning Model and 3-Skills Grouping Methodology implemented
				Practical – Digital Platform EvalTools ®	FCAR and PVT	1. Unique assessments implemented 2. Aligned to outcomes 3. EAMU performance criteria and heuristic rules 4. Apply scientific wieighting factors for aggregating assessment and skill types 5. Provide course level learning distribution and assessment counts information for 3 learning domains of Bloom's model 6. Sample size assesses all students enrolled in class 7. Structured template integrating direct and indirect assessments 8. Detailed quantitative diagnostics showing composite COs, PIs, SOs evaluation plots Accurate course reflections and actions available and completed
					SOs and PIs evaluations	1. Presented accurate SOs data using scientific and clear performance criteria 2. Incorporated scientific weighting factors scheme to aggregate skills from all courses in given term 3. Provided root cause failure analysis search features 4. Presented comments features for reviewers Provided digital reports for executive summary, course and program level actions
					Learning domains evaluations	1. Provided overall learning distribution and assessment counts information for 3 learning domains of Bloom's model 2. Provided learning distribution and assessment counts information for all ABET SOs 3. Provided learning distribution and assesment counts information for individual learning domains of Bloom's model 4. Presented comments features for reviewers 5. Provided digital reports for executive summary, corrective actions
					CIMS	1. Provided meeting minutes history for administrative committees CQI work 2. Provided task lists with time stamps, status of actions, priority, ownership information for administrative committees CQI work 3. Provided documentation folders for administrative committees CQI work 4. Provide latest member and moderator lists for all administrative committees

Table K7. Process and product analysis for PDCA quality cycles of the MMTBIE of the Faculty of Engineering EE, ME and CE programs

Process Analysis – PDCA Quality Cycles Q1 to Q5					
CQI Activity	**Qualitative Analyses**	**Quantitative Analyses**	**Audited by**	**Period**	**Result**
PDCA cycle Q_1: Development of: 1. CO, PIs and SOs for course delivery 2. Course curriculum delivery plan 3. Hybrid rubrics 4. Sample of target assessments aligned to hybrid rubrics	1. Analysis of COs and PIs statements for fulfillment of Mager's and Adelman's models 2. Analysis of alignment of COs, PIs to major course topics, student learning activity, assessments and SOs. 3. Analysis of descriptors for various steps and EAMU scales of hybrid rubrics. 4. Analysis of alignment of rubrics to learnng activity in assessments	1. Analyis of Ideal course learning dsitribution 2. Analysis of scoring mechanism for hybrid rubrics and alignment of scoring to assessments. 3. Analysis of course level weighting factors based on course format, type of assessments and grading scale.	1. Instructor 2. Program committee 3. QA office 4. QD Supervisor	Every term [2014-20]	EE, CE and ME programs' course materials, curriculum and delivery plan approved
PDCA cycle Q_2: Course work items completion audit for all courses offered in a given term: ‣ Lessons ‣ SOs, PIs Assessments ‣ Rubrics applied to major course activity ‣ L,M, H student work samples ‣ Completed FCAR ‣ Old corrective actions ported, completed and status closed ‣ Grade book	1. Semantic analysis of langauge of failing PIs 2. Root cause failure analysis by investigating assessments 3. Review of course level actions	1. Analysis of program level weighting factors 2. SOs evaluation 3. PIs evaluation 4. Learning domains evaluation 5. Review of past term SO assessment plan	1. Instructor 2. Program committee 3. QA office 4. QD Supervisor	Every term [2014-20]	EE, CE and ME programs' FCAR checklist and EOT form approved and programs cleared for conducting program term reviews
PDCA cycle Q_3: EE, ME and CE program term reviews 1. Learning domains evaluation 2. PIs evaluation 3. SOs Evaluation	1. Semantic analysis of langauge of failing PIs 2. Root cause failure analysis by investigating assessments 3. Review of course level actions	1. Analysis of program level weighting factors 2. SOs evaluation 3. PIs evaluation 4. Learning domains evaluation 5. Review of past term SO assessment plan	1. Program committee 2. QA office 3. QD Supervisor	Every term [2014-20]	1. EE, CE and ME programs reports approved by QD and submitted to Course and Curriculum Committee: ‣ SO executive summary report ‣ Detailed SO/PI executive summary report ‣ SO/PI Performance Vector Table PVT summary report ‣ Course reflections/ action items ‣ Learning domains evaluation report 2. Updated and improved SOs assessment plan and updated curriculum maps submitted to program committee for implementation
PDCA Cycle Q_4: Review of PIs database	1. Analysis of PIs database for inaccurate content 2. Analysis of PIs database for futuristic content 3. Analysis of PIs database for incorrect alignment to SO and therefore moved to appropriate SO 4. Analysis of PIs database for too basic content.	Analysis of PIs database for redundancy	1. Program committee 2. QA office 3. QD Supervisor	Every three years. Last conducted Spring 2018	Updated and improved PIs database with corrections for some hybrid rubrics

PDCA cycle Q_5: Multi-term SOs summary review and trend analysis	1. Analysis of coverage of SOs based on PIs and history of assessment details and reviewer feedback 2. Final decision on SOs trend analysis based on reviewer feedback 3. Final decision on updating performance criteria based on reviewer feedback of trend analysis results 4. Analysis of multi-term executive summary report based on reviewer feedback and corrective actions generated	1. Analysis of multi-term SOs average values and benchmarking 2. Linear regression of SO multi-term data to obtain overall average and forecasted values for trend analysis	1. Program committee 2. QA office 3. QD Supervisor	Every three years. Last conducted Fall 2018	Program committee review and decision of *Meeting Expectations* for ME, EE and *Exceeding Expectations* for CE program for attainment of SOs [a-k]
Process Analysis – PDCA Quality Cycle Q6					
CQI Activity	**Qualitative Analyses**	**Quantitative Analyses**	**Audited by**	**Period**	**Result**
Review of Mission and Vision of programs	1. EAC 5-likert survey feedback 2. EAC committee review	N/A	1. Program Committee 2. QA office 3. QD Supervisor 4. External Advisory Committee	▲ Survey: September 2018 ▲ EAC review: December 2018	Approved with discussions EAC meeting minutes Dec 05, 2018: 1. Mission and Vision of programs 2. PEOs 3. EE, CE and ME programs' SOs (a-k) 4. EE, ME and CE programs' curriculum 5. Capstone design course syllabi, hybrid rubrics, assessement instruments and course data 6. Industrial training courses syllabi, training plan, employer pool, and SOs, PIs data 7. CQI systems, processes and PDCA quality cycles
Review of Definition of PEOs and alignment to University Mission		N/A	1. Program Committee 2. QA office 3. QD Supervisor 4. External Advisory Committee		
Review of EE, CE and ME programs' SOs (a-k)		N/A	1. Program Committee 2. QA office 3. QD Supervisor 4. External Advisory Committee		
Review of alignment of EE, ME and CE programs' curriculum to SOs and PEOs		N/A	1. Program Committee 2. QA office 3. QD Supervisor 4. External Advisory Committee		
Review of the Capstone design course syllabi, hybrid rubrics, assessement instruments and course data		External Advisory Committee review of capstone design courses COs, PIs and SOs data	1. Instructor 2. Program Committee 3. QA office 4. QD Supervisor 5. External Advisory Committee		
Review of industrial training courses syllabi, training plan, employer pool, and SOs, PIs data		External Advisory Committee review of Industrial training courses COs, PIs and SOs data	1. Instructor 2. Program Committee 3. QA office 4. QD Supervisor 5. External Advisory Committee		
Review of CQI systems, processes and PDCA quality cycles		N/A	1. Program Committee 2. QA office 3. QD Supervisor 4. External Advisory Committee		
Outcomes Analysis – PDCA Quality Cycle Q6					
CQI Activity	**Qualitative Analyses**	**Quantitative Analyses**	**Audited by**	**Period**	**Result**
Review of EE, ME and CE programs' multi-term SO executive summary report covering period [2014-2018]	N/A	External Advisory Committee review and comments on multi-term SOs summarized data	1. Program Committee 2. QA office 3. QD Supervisor 4. External Advisory Committee	Fall 2014 to Spring 2018	▸ Program committee review and decision of *Meeting Expectations* for ME, EE programs and *Exceeding Expectations* for CE program for attainment of SOs [a-k] ▸ Majority of SOs (a-k) performances just stabilized to Meeting Expectations in the last few terms towards 382 excepting for SO 'k' and therefore did not require
Review of EE, ME and CE programs' multi-term detailed SO/PI	External Advisory Committee review of program committee	N/A			

executive summary report covering period [2014-2018]	discussions and comments in SO/PI executive summary report				any modifications to performance criteria. If Meeting or Exceeding Expectations were observed for any of the SOs for multiple terms, then the minimum performance criteria would have been raised to increase the performance standards.
Review of EE, ME and CE programs' multi-term SO/PI Performance Vector Table (PVT) summary report covering period [2014-2018]	N/A	External Advisory Committee review and comments on SO/PI PVT summarized data			
Review of EE, ME and CE programs' multi-term course reflections/ action items report covering period [2014-2018]	External Advisory Committee review of program committee and insructor discussions, comments and status of actions	N/A			
Review of EE, ME ad CE programs' multi-term learning domains evaluation report covering period [2014-2018]	External Advisory Committee review of program committee discussions and comments in learning domains evaluation report	External Advisory Committee review and comments on overall and individual domains learning distribution data			
EE, ME and CE programs' multi-term SOs trend analysis and forecasting	N/A	External Advisory Committee review and comments on EE, ME and CE programs' multi-term SOs trend analysis and forecasting			▸ 8 out of the 11 SOs (EE, ME) and 10 out of 11 SOs (CE) trends were positive with reasonable multi-term coverage and faculty feedback also indicated acceptable assessment and evaluation data/processes and did not necessitate any modifications to the 11 SOs ▸ The overall multi-term results were therefore acceptable and the CE, EE and ME programs' position to transition to revised 7 ABET SOs was reinforced.
Review of alumni feedback on EE, ME and CE PEOs	External Advisory Committee review of responses and statistical data related to alumni feedback on PEOs	N/A		2017-18 cohorts	SOs and PEOs attainment is *Meeting/Exceeding expectations* for CE, ME and EE programs (refer Tables J60, J61, J62, J63, J64, J65)
Review of senior exit feedback on EE, ME and CE PEOs	External Advisory Committee review of responses and statistical data related to senior exit feedback on PEOs	N/A		2016-18 cohorts	SOs and PEOs attainment is *Meeting/ Expectations* for EE, CE and ME programs (refer Tables J40, J41, J42, J43, J44, and J45)
Review of employer feedback on EE, ME and CE programs' industrial training SOs data	External Advisory Committee review of responses and statistical data related to employer feedback on SOs collected for industrial training courses	N/A		2016-2018 cohorts	SOs and PEOs attainment is *Exceeding expectations* for CE, ME and EE programs (refer Table J58)

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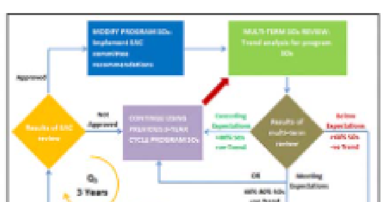

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Impact Evaluations of Engineering Programs Using ABET Student Outcomes

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ABSTRACT Engineering programs worldwide collect and report student learning outcomes data to conduct program evaluations for quality assurance and accreditation purposes. Accreditation agencies such as ABET typically mandate that at least two years of program evaluation data be provided and for institutions to show how this data has been used for continuous quality improvement. Engineering programs rarely evaluate interventions using multi-term student outcomes information over several years, since this quantitative data generally lacks accuracy and statistical power. The quality of outcomes data is affected by obsolete assessment methods and lack of digital access and technical analysis. In this study, we present essential elements of an authentic outcome based assessment model that used web-based software and embedded assessment technology to collect and report accurate cohort outcomes for credible multi-term evaluations. A non-experimental approach employing regression analyses were used to identify trends in student outcomes and evaluate the impact for three engineering programs. Detailed rubrics provide criteria to accurately classify multi-year student outcomes. The findings of this study present practical steps for engineering programs to effectively collect and report accurate cohort outcomes data and perform credible evaluations of program interventions based on multi-year outcomes data.

INDEX TERMS ABET, outcomes, assessment, OBE, performance indicators, continuous quality improvement (CQI), program evaluation.

I. INTRODUCTION

Engineering accreditation standards as defined by the International Engineering Alliance's (IEA) Washington Accord [1] are derived from the philosophy, paradigm and principles of the Outcome Based Education (OBE) model [2]–[10]. As per Spady, the premise of OBE is that every component of an educational system should be based on essential outcomes [2]–[6]. Students should achieve the essential or culminating outcomes after every learning experience. All aspects of learning such as instructional strategy, assessments, evaluations, feedback, and advising should help students attain the intended outcomes. This model helps engineering programs adopt a student centered approach by focusing on attainment of culminating outcomes of student learning experiences rather than the quality of the offered curriculum [2]–[6]. Additionally, accreditation bodies require that engineering programs maintain well established and sustainable CQI processes based on outcomes [1], [11]–[16]. An exhaustive review of literature shows that collecting and reporting massive amounts of Continuous Quality Improvement (CQI) data for accreditation audits using manual methods is one of the most challenging tasks for engineering programs [19], [21]–[24], [26], [30], [31], [34]–[41], [44], [45], [54], [76]. Specifically, to fulfill international quality standards of the Accreditation Board of Engineering and Technology (ABET), engineering programs are required to maintain CQI processes based on an OBE model and prepare self-study reports with multiple years of evidentiary data for review in an audit visit. ABET requires engineering programs to fulfill 9 accreditation criteria. The most significant criteria with respect to CQI are the *Program Educational Objectives* (PEOs), *Student Outcomes* (SOs), *Program Criteria* and *Continuous Improvement* [11].

Most programs in the US and internationally, state that the most difficult criteria to fulfill for ABET accreditation was

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criteria 4, for CQI [19], [21]–[24], [26], [30], [31], [34]–[41], [44], [45], [54], [76]. The CQI criteria 4 requires programs to track quality improvement resulting from corrective actions for students' performance failures extracted from assessment and evaluation of outcomes at the course and program level. ABET's evaluators require programs to implement 6 years of quality cycles with at least 2 years of well documented data as display material during audit visits. The general advice provided to programs is to be very selective in using assessment for measuring ABET SOs to minimize overburdening faculty and program efforts for accreditation [11], [36], [40], [45], [56]. This is acceptable from the accreditation criteria fulfillment standpoint, but from the OBE model student centered point of view, it does not facilitate CQI. These assessments tend to become summative and not formative, since educational assessment refers to all activities which provide information to be used as feedback to revise and improve instruction and learning strategies [27], [28]. Programs using manual CQI systems tend to consider relatively small student sample sizes for assessment of SOs data which consequently fulfill minimal accreditation requirements [22], [24], [26], [28], [29], [36], [39], [40], [43], [45], [56], [60]–[63], [72], [76]. Additionally, most engineering programs rarely classify learning outcomes data in all the three learning domains with corresponding learning evels of the revised Bloom's taxonomy [7], [20], [23], [24], [26], [30], [31], [40], [48], [52]–[54], [58]. Courses within a program are]generally classified into three levels: *Introductory*, *Reinforced*, and *Mastery*, with outcomes data assessed at *Mastery Level* for streamlining the documentation and reporting efforts needed for effective program evaluations. However, collecting performance information at just the *Mastery* level represents the final phase of a typical quality cycle and is too late for remediation. Data sampling following such an approach presents a major deficiency for CQI in student-centered OBE models. In fact, SOs and performance criteria progressing from the elementary to advanced levels should be assessed at the course level for all courses spanning the entire curriculum [26], [30], [31], [36], [39], [41], [56]. A holistic approach for a CQI model would require a systematic measurement of Performance Indicators (PIs) in all three of Bloom's domains of learning and their corresponding learning levels for all course levels of a program. Manual CQI models have been increasingly cited in literature as being deficient with several issues such as deficient standards of language of learning outcomes statements, generic and vague performance criteria, lack of use of accurate topic specific analytic rubrics, lack of reliable and valid assessment and evaluation criteria, random or ad hoc sampling of outcomes information, lack of proper alignment of learning activities with outcomes, inability to achieve comprehensive coverage of Bloom's three domains of learning, lengthy and impractical quality cycles, inability to implement real-time learning improvements in enrolled cohorts etc. [23], [29], [39], [40], [42]–[45], [48], [53], [54], [56] [58], [61], [62], [76].

Engineering programs can adopt an authentic OBE philosophy for implementing quality learning outcome statements, specific performance criteria and analytic rubrics that are all aligned to assess student knowledge and skills in all three domains and their learning levels. Only after implementing a coherent learning model that aligns assessment to learning outcomes, can data collection be effective for evaluating impact of programs. Onwuegbuzie and Hitchcock (2017) emphasized the need for rigorous evaluations of impact of programs around the world so that trustworthy evidence of change can be used for future decision making [49]. According to them, a vast majority of impact evaluations across various fields including education, have involved the use of quantitative experimental, quasi-experimental and non-experimental methods [49]. The impact evaluations based on data collected for learning outcome assessments and accreditation requirements would be non-experimental since the use of control groups in educational settings dealing with delivery of curriculum is an impractical exercise which could not be managed institutionally. However, engineering programs can conduct non-experimental impact evaluations which use *difference in differences models* with actual comparison groups or *regression models* that do not explicitly use comparison groups. Manual CQI systems that collect continuous data by employing authentic OBE and assessment methodology are required to incorporate appropriate sample sizes in their study design to achieve satisfactory statistical power for data related to all the ABET SOs.

Impact evaluations estimate the effects on outcomes by comparing a sample from intervention and control or comparison groups. It is more likely that a larger sample would be a more accurate representation of the population from which it is taken. The probability of an evaluation identifying a significant impact when there is actually one, is called statistical power. The impact of interventions is mostly evaluated using cluster designs in which data is collected from several subunits. The impact of interventions may be assigned to institutions, but outcomes are assessed individual students and for cohorts [51], [72]. This approach has significant implications for sampling methods and sizes, which are often not adequately recognized or calculated in impact evaluation studies [73]. In the case of program evaluations based on student outcomes, for achieving enhanced statistical power, the program would need to sample a relatively large number of students from courses spanning all levels of the curriculum. The statistical power of the design is determined by the number of clusters in the study rather than the number of treated units. This means that the example would need a reasonably large number of contributing courses. However, cluster designs require larger sample size than simple random sampling to have equivalent statistical power. Power is higher the more heterogeneous the units are within a cluster [72].

For engineering programs employing manual CQI systems, power calculations need to be performed to determine the sample size for a study that is sufficient for finding statistically significant intervention effects. If the sample size is too small then the study would be "underpowered," with the risk that the evaluation would not find a significant impact even though there was one. It would be higly probable to have implications for false positive or negative results with too small of an outcomes assessment sample. Too large a sample would mean that the study would require larger than affordable effort and resources for data collection and reporting. Apparently, small samples can save time and financial resources, but this comes at the cost of reducing accuracy when finding significant intervention effects. In the case of underpowered evaluations, they may offer little or no useful information since it would be impossible to acurrately determine whether an intervention is actually working or the findings do not indicate any impact due to the study being underpowered [51], [72].

A succinct statement of research findings made by the Evaluation Gap Working Group (2006) clearly sums up a general state of current program interventions, "*Of the hundreds of evaluation studies conducted in recent years, only a tiny handful were designed in a manner that makes it possible to identify program impact*" (p. 17) [50]. Engineering program evaluations that utilize manual CQI systems, despite implementing some authentic OBE and assessment practices, are commonly underpowered for the following reasons [56]:

a) Program chairs or assessment teams simply select what they think is an appropriate sample size generally from a final phase of an education process without performing appropriate power calculations.
b) Clustering of interventions is not considered, which means multiple cohorts for various sections of the same or multiple course(s) are not sampled.
c) Lack of consideration of the degree of homogeneity or heterogeneity of the student population within each course or multi-course sample(s).
d) The outcomes data is not evaluated over a realistic period of time (multiple years) to actually assess the full effect of a program intervention but concluded prematurely.
e) Outcomes data is not sampled from all three domains of Bloom's learning model.
f) Sample sizes are variant and insufficient with some SOs assessments using appropriate sizes and others being too small.
g) The study may be powered sufficiently to estimate the average treatment effect, but not for any subgroup analysis. So there would be no heterogeneity in impact of outcomes data between seniors or freshmen, mastery courses or introductory, higher order or lower order skills, formative or summative assessments etc.
h) There is attrition in the study design, such that data are actually collected from a smaller sample than originally planned.

Paper-free web-based digital systems with user friendly interfaces can encourage faculty participation and employ embedded assessment technology that can solve many issues related to achieving desired statistical power for accurate impact evaluations. The indispensable necessity of digital solutions to automate and streamline outcomes assessment for accreditation is explained in many research papers [22], [26], [34]–[39], [44], [56]. State-of-the-art digital technology-based outcomes assessment systems would definitely help fulfill accreditation standards and achieve excellent CQI results as well. Several digital solutions have been proposed recently to alleviate the aforementioned issues with manual CQI systems [21], [22], [26], [34]–[41], [45]–[47], [54], [56], [72], [76]. Considering the latest ground breaking developments related to digital automation of CQI processes, several accreditation bodies such as ABET have incorporated special language in their accreditation policy to accommodate engineering programs that choose to maintain digital display materials for accreditation audits [11].

In this study, we present essential elements of an authentic outcome based assessment model implemented using web-based software EvalTools® [45], [47] and embedded assessment technology employing the Faculty Course Assessment Report (FCAR) and Performance Vector Table (PVT) methodology [40], [45], [68] to effectively collect and report accurate cohort outcomes data scientifically aggregated from all courses in a program for credible multi-term evaluations. A non-experimental approach employing linear regression methods is used to perform SOs trend analyses for Electrical Engineering (EE), Mechanical Engineering (ME) and Civil Engineering (CE) programs' impact evaluations at the Islamic University of Madinah. Detailed rubrics provide qualifying criteria to accurately classify multi-year SOs performances. The trend analyses enable credible impact evaluations for program interventions. The findings of this study present implications for practical steps for engineering programs to collect and report accurate cohort outcomes data effectively and perform credible evaluations of program interventions based on multi-year outcomes data.

II. PURPOSE OF STUDY

The driving force behind this research is to examine the benefits and limitations of application of essential theory of the authentic OBE model for the implementation of a holistic and comprehensive educational process that maximizes opportunities for the attainment of successful student learning. The objective is to conduct effective non-experimental impact evaluations using multi-year (2014-20) SOs trend analyses for EE, ME and CE program interventions employing state of the art Integrated Quality Management Systems (IQMS).

In particular, the researchers sought to answer the following research questions:

1. What are some common issues that affect the statistical power of quantitative outcomes data collected by many engineering programs?

2. What are some essential elements of best assessment practice and available automated digital technology that help attain valid and reliable outcomes data?

3. Can multi-year SOs data be used to conduct credible impact evaluations? If so, what are some essential

requirements to ensure the validity and reliability, and statistical power of SOs data?

III. RESEARCH FRAMEWORK

A. METHODOLOGY

This research involves an OBE theory based qualitative analysis of SOs data for manual CQI systems obtained through a selective literature review covering accreditation topics in relevant engineering education and education psychology research literature. An indepth description of the theoretical, conceptual and practical frameworks are followed with quality management details of the PDCA quality cycle Q_5 regarding multi-term ABET SOs (a-k) reviews. Results of the study include review of various sections of detailed executive summary reports regarding SOs attainment, PI evaluations, trend plots and program committee actions. Finally, we apply a non-experimental approach employing regression methods to perform multi-year (2014-18) trend analyses of ABET SOs (a-k) for the EE, ME and CE programs' impact evaluations at the Islamic University of Madinah. Detailed rubrics provide qualifying criteria to accurately classify multi-year SOs performances. Results of trend analyses following this approach enable credible impact evaluations for program interventions without the explicit use of comparison groups. We show how the process flow for PDCA quality cycle Q_5 is applied to summarized results of SOs (a-k) trend analyses for the three programs thereby helping program committees to arrive at final review decisions for their respective impact evaluations The findings of this study present practical steps for engineering programs to collect and report accurate cohort outcomes data effectively and perform credible evaluations of program interventions based on multi-year ABET SOs data.The application of essential elements of authentic OBE assessment methdology and digital embedded assessment technology provide practical gudelines for the automation of collection and reporting of multi-term ABET SOs (a-k) data for quality assurance and accreditation purposes. Using regression methods to analyze valid and reliable multi-year SOs data with high statistical power can enable credible impact evaluations.

B. PARTICIPANTS

The non-experimental impact evaluation of the Faculty of Engineering EE, CE and ME programs from 2014 to 2018 involved 39 faculty members and 672 students from multiple cohorts of the 4-year bachelor of science programs.

C. SOs DATA FOR MANUAL CQI SYSTEMS– A QUALITATIVE ANALYSIS

A selective literature review related to engineering program evaluations for accreditation was completed to conduct an effective OBE theory based qualitative analysis of SOs data for manual CQI systems. We primarily considered research on accreditation topics in popular engineering education and educational psychology journals and conference proceedings

TABLE 1. Qualitative analysis of SOs data for manual CQI systems.

VALIDITY & RELIABILITY	Several fundamental aspects of authentic OBE theory are either not targeted nor achieved [17,21,23-24,26,30-31,41,45,48,52,56]
	Learning models are not understood and applied comprehensively as a basis for CQI efforts [4,20,41,48,52,56]
	Alignment of actual learning activities and language of Course Outcomes (COs) and associated PIs are deficient [4,20,30-31,41,48,52-54,56]
	PIs are used to assess SOs and are mostly generic thereby lack the required specificity for valid and reliable assessment and evaluation [20,23,25-26,28,30-31,36,39-41,45,48,56,57,58]
	Most rubrics are generic and vague using simplistic language and lack technical details to accurately assess several hundred complex engineering activities [20,23,26,41,56,57,58]
	Generic rubrics are applied by independent raters to score past course portfolios [36,40-41,45,56,59,61,63]
STATISTICAL POWER	Assessment plans mostly measure cognitive learning while learning in the psychomotor and affective domains is not assessed [7,20,23-24,26,30-31,39-41,45,48,52,54,56-58]
	Most quality systems do not collect, document and report outcomes and CQI information for all enrolled students because the sample size is too large to handle manually [6,21,24,26,28,30-31,36,39-43,50]
	Most program evaluations incorporate ad hoc or random sampling representing a small set of student learning activity [22,24,26,30-31,36,39-40,43,45,56,59-63]
	Course evaluations do not aggregate outcomes results from various types of assessments using appropriate weightage [24,26,39,45,48,56]
	Program evaluations do not aggregate multiple course and skill levels by applying appropriate weightage [22,26,37,39-40,45,48,53,56]

spanning the last 15 years. The results of the literature review were parsed using an OBE theory based qualitative analysis of CQI systems to yield the summary below:

IV. THEORETICAL, CONCEPTUAL AND PRACTICAL FRAMEWORKS

The philosophy, paradigm, premises and principles of Authentic OBE form the basis for theoretical frameworks that lead to the development of crucial models which act as the foundation of the IQMS implemented at the Faculty of Engineering. Several essential concepts are then induced from OBE theory, assessment best practices and ABET criterion 4, on continuous improvement. Several viable techniques and methods based on this conceptual framework are then constructed as a practical framework of automation tools, modules and digital features of a state of the art web-based software EvalTools® [47].

A. THEORETICAL FRAMEWORK

ABET and Washington Accord advocate the OBE model, that uses culminating learning outcomes, as their gold standard for evaluating the quality of engineering programs worldwide [11], [16]. Engineering programs seeking accreditation should ensure that all components of the education process such as learning activities, assessments, evaluations, feedback, and advising help students foster and attain the intended outcomes. The essential elements of OBE were developed at the High Success Network [2], [3] and expounded in more detail in a recent publication [4]. The paradigm, premises, philosophy and four power principles of the OBE model [4]–[6] are used as theoretical frameworks to implement and evaluate the IQMS at the Faculty of Engineering [26], [36], [40], [41], [56], [76]. In essence, culminating, enabling and discreet learning outcomes should be the basis of all components of an educational system for aiding all students to successfully attain the intended knowledge and skills as prescribed by international standards of engineering education and curriculum [11], [56], [76].

B. CONCEPTUAL FRAMEWORK – MODELS

1) LEARNING MODELS

Learning is a complex process that requires careful planning to achieve the desired outcomes. Models of teaching and learning inform educators and researchers regarding the education processes, their inputs, outputs, variables, the causal interconnections and interdependencies. Learning models are necessary to inform effective education practice. In this study, a hypothetical *Learning Domains Wheel* was used to analyze the popular learning domains, including Bloom's [26]. The objective was to categorise outcomes based on a precision framework that classified PIs into specific learning domains and their learning levels. The empirical findings indicated that it was relatively easier to classify specific PIs for realistic outcomes assessment by using Bloom's 3 learning domains [26], compared with other models that categorize learning domains as knowledge, cognitive, psychomotor, interpersonal, IT, numerical, and communication skills [13]. Classification of specific PIs, according to Bloom's domains and learning levels, resulted in the collection of useful outcomes information for aggregation of ABET program level SOs [26], [40]. This was possible since the majority of the PIs could be uniquely mapped to a specific learning level in each of the 3 domains consequently avoiding any overlap and redundancy [26], [40].

2) 'DESIGN DOWN' MAPPING MODEL FROM GOALS TO PERFORMANCE INDICATORS

Spady's "*design down*" [3]–[6] mapping model was used to develop an authentic OBE design flow linking goals, PEOs, SOs, course objectives, COs and PIs [26], [41], [76]. The mapping model defines an outcome-based framework that provides details regarding specificity of technical language and the breadth and depth of coverage for goals, objectives, outcomes, and PIs, in that hierarchical order [26], [41], [76]. The framework enables easy development and assessment of the various components of a typical OBE 'design down' process [3]–[6]. Goals and objectives consist of generic language for broad application that do not contain demonstrable verbs, field or topic-specific nominal content, or performance criteria. SOs and COs comprise operational action verbs, nominal subject content but do not contain performance scales. Performance criteria are applied with the dimension descriptors in rubrics [57]. As per Adelman (2015), language of PIs should be specific to accurately align with course content and student learning activity [20]. The PIs should be assessed in courses from all phases of a curriculum to achieve learning progression for achieving proficiency in engineering skills [20], [23], [26], [41], [52], [56]–[58], [76].

TABLE 2. **3-level skills grouping methodology of Bloom's revised taxonomy.**

Skills Level	Cognitive Domain (Bloom, 1856; Anderson & Krathwohl, 2001)	Affective Domain (Krathwohl, Bloom & Masia, 1973	Psychomotor Domain (Simpson, 1972)
Elementary	1.Knowledge 2.Comprehension	1.Receiving phenomena 2.Responding to phenomena	1.Perception 2.Set 3.Guided response
Intermediate	3.Application 4.Analysis	3.Valuing	4.Mechanism 5.Complex overt response
Advanced	5.Evaluation 6.Creation	4.Organizing values into problems 5.Internalizing	6.Adaptation 7.Origination

3) BLOOM'S TAXONOMIC MASTERY LEARNING MODEL AND 3-SKILLS GROUPING METHODOLOGY

Prior research has indicated learning models that group Bloom's learning levels in each domain using a classification of teaching and learning strategies [26], [40]. Since, teaching and learning strategies are dynamic and dependent on learners' potential deficiencies, it is more practical from an assessment stand point, to group learning levels based on degrees of complexity. Table 2 shows a new *3-Level Skills Grouping Methodology* proposed by Hussain and Addas (2015) [36] that groups learning activities for each learning domain that are closely associated to a similar degree of complexity of skills. Accurate grouping models enable a holistic and balanced distribution of learning in courses based on a broad but unique categorization of skills. The *3-Level Skills Grouping Methodology* helps implement an *Ideal Learning Distribution* in course delivery for a given program curriculum. As per this model, *Introductory* (100-200), *Reinforced* (300) and *Mastery* (400) levels courses should target holistic learning by assessing elementary, intermediate and advanced level skills in corresponding progressive proportions aligned with their course outcomes and specific PIs. Therefore, 100 and 200 level courses should offer *Introductory* learning with a majority of elementary level skills to cover fundamental engineering knowledge. *Mastery* learning would be achieved in 400 level courses with a higher proportion of advanced level skills in the cognitive, affective and psychomotor learning domains [26], [36], [40], [76].

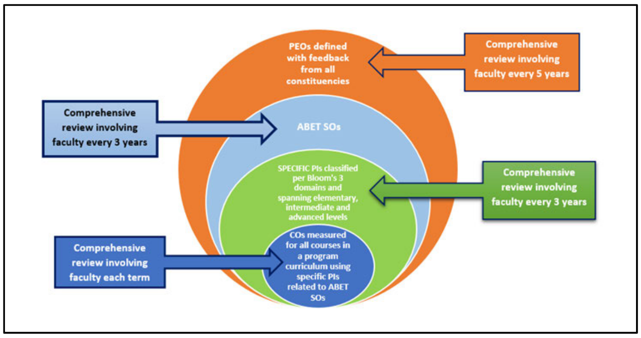


FIGURE 1. Outcomes assessment model implemented by faculty of engineering.

4) ABET ASSESSMENT MODEL

The Faculty of Engineering assessment model shown in Figure 1 was created from authentic OBE frameworks and incorporated regional and ABET accreditation standards and criteria. Notably, all activities in various phases of the quality assurance process involve faculty members who conduct mixed methods reviews of PEOs, SOs, PIs and course work [26], [36], [40], [41], [56], [76]. Specifically, the ABET (2020) self-study criteria: *Student Outcomes* (Criterion 2), *Program Educational Objectives* (Criterion 3) and *Continuous Improvement* (Criterion 4) [11] are incorporated in the assessment model, since they outline the entire assessment structure and provide clear guidelines for program CQI efforts. ABET's *Continuous Improvement* criteria ensure programs make informed quality improvement decisions using SOs assessment data and other stakeholders. Programs employ quantitative and qualitative analyses to evaluate fulfillment of COs, which are assessed using specific PIs, aligned assessments to attain the program SOs [11], [36], [37], [39]–[41], [45], [48], [56], [59].

C. CONCEPTUAL FRAMEWORK – TECHNIQUES, METHODS

1) EMBEDDED ASSESSMENTS METHODOLOGY USING FCAR

Majority of engineering programs pursue a macro level approach when implementing assessment plans for fulfillment of minimal accreditation standards [17]. Generally, programs employ standardized tests for direct assessments that are rescored by independent raters using vague and generic rubrics [65]. Indirect assessments use feedback from focus groups that are identified as course, alumni, and employer surveys [65]. However, these assessment plans do not adequately assess student outcomes aligned to actual course learning activities nor do they provide any formative information for real-time enhancement of any given cohort's learning. According to Cross (2005), if programs adopt comprehensive course assessment plans that can accurately align with and help attain program level SOs, then both qualities teaching as well as accreditation standards can be achieved [64]. These plans can be practically implemented using embedded assessments often called "*classroom-based*" assessments. Instructional materials and routine classwork activity is designed to align with course outcomes and specific PIs. Accurate alignment enables proper use of course embedded assessments to measure attainment of program level SOs by using routine classroom generated artifacts. Therefore, embedded assessments can save programs from significant expenditure of resources otherwise spent in creating additional assessments or in using independent raters for SOs assessment [26], [40], [41], [76].

The EAMU performance vector is the basis of the embedded assessment model in the FCAR [45], [68], [69]. The EAMU performance vector [69], [70] maintains a count of the number of students whose performance for a given outcome was rated with *Excellent* (E), *Adequate* (A), *Minimal* (M), or *Unsatisfactory* (U) levels. Where the EAMU levels are specifically defined by attainment of the following scores: E: scores $>= 90\%$; A: scores $>= 75\%$ and $< 90\%$; M: scores $>= 60\%$ and $< 75\%$; and U: scores $< 60\%$. Instructors report reflections in the FCAR for failing COs, SOs, PIs, and provide student feedback. New actions are generated based on this course reflections. Old action items from previous classes for the same course is ported into the FCAR if it is reoffered. Course delivery in a given term is modified based on recommendations incorporated from the carried over old actions. [45], [68], [69].

2) DESIGN RULES FOR COs AND PIs

A consistent standard for writing outcome statements was developed using: 1) Spady's (1992, 1994 a, b) basic guidelines related to the language of outcomes [4]–[6] 2) Adelman's (2015) construct of outcomes using verbs and nominal subject content [20] and 3) Mager's (1962) work on the hierarchical structure of outcomes [71]. Several essential principles for writing outcome statements were extracted from this standard providing detailed design rules for COs and PIs ensuring tight alignment with actual student learning activity [36], [41], [54], [56], [76]. The key principles are that the outcomes should be specific and measurable consisting of operational action verbs and nominal content. These could be compounded with multiple statements represented by PIs. The design rules for COs and PIs are based on these key principles that enable holistic coverage of course content while maintaining required learning progression of all relevant engineering topics to achieve an ideal learning distribution [36], [41], [54], [56], [76].

3) HYBRID RUBRIC

Jonson and Svingby (2007) reviewed 75 empirical studies on the application and benefits of rubrics [11]. Their finding concluded that analytic rubrics, with topic specific descriptors, exemplars and rater training, offer the most benefits to the practice of teaching and learning. Hussain and Spady (2017) elaborated on a hybrid rubric that was a combination of the holistic and analytic rubric to assess complex learning experiences for developing specific engineering activity that cannot rely on vague and generic performance

SO4: An ability to recognize ethical and professional responsibilities to engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

Health and Safety Constraints

[abet_PI_4_12] Affective: Internalizing values Evaluate the final prototype for (a) implementation of required safety factors in engineering design; (b) health and safety hazards in manufacturing/implementation/operation phases related to resources/ consumables utilization, reuse of byproduct of combustible fuels, carcinogenic materials, noise injury, toxic emissions, biological contagions, ergonomic conditions, seismic conditions, radioactive materials exposures etc.; (c) the maintenance and calibration details and implementations for safe operation of all electrical/ electronic equipment; implement safe supply of electricity ; ensure all electrical/ electronic equipment/components/systems are certified and electrically safe; check life safety implementation while dealing with RF and high voltage equipment; verify equipment handling and safety management instructions for product life time; to conform to the minimum acceptable limits set by the IEEE/national/international codes/standards and regulations

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
25%	Implement **all** required safety factors in engineering design	Implement **most** required safety factors in engineering design **AND/OR**	Implement **some** required safety factors in engineering design **AND/OR**	**Unable** to implement **some** required safety factors in engineering design **AND/OR**
25%	Provide **all** details of how health and safety hazards were minimized in manufacturing/implementation/operation phases related to resources/ consumables utilization, reuse of byproduct of combustible fuels, carcinogenic materials, noise injury, toxic emissions, biological contagions, ergonomic conditions, seismic conditions, handling RF and high voltage equipment, radioactive materials exposures etc.;	Provide **most** details of how health and safety hazards were minimized in manufacturing/implementation/operation phases related to resources/ consumables utilization, reuse of byproduct of combustible fuels, carcinogenic materials, noise injury, toxic emissions, biological contagions, ergonomic conditions, seismic conditions, radioactive materials exposures etc. **AND/OR**	Provide **some** details of how health and safety hazards were minimized in manufacturing/implementation/operation phases related to resources/ consumables utilization, reuse of byproduct of combustible fuels, carcinogenic materials, noise injury, toxic emissions, biological contagions, ergonomic conditions, seismic conditions, radioactive materials exposures etc. **AND/OR**	Multiple deficiencies to provide **some** details of how health and safety hazards were minimized in manufacturing/implementation/operation phases related to resources/ consumables utilization, reuse of byproduct of combustible fuels, carcinogenic materials, noise injury, toxic emissions, biological contagions, ergonomic conditions, seismic conditions, radioactive materials exposures etc. **AND/OR**
25%	Provide **all** maintenance and calibration details and implementations for safe operation of all engineering equipment;	Provide **most** maintenance and calibration details and implementations for safe operation of all engineering equipment **AND/OR**	Provide **some** maintenance and calibration details and implementations for safe operation of all engineering equipment; **AND/OR**	**Multiple deficiencies** to provide **some** maintenance and calibration details and implementations for safe operation of all engineering equipment; **AND/OR**
25%	Conform to all the minimum acceptable limits set by the IEEE/ national/international codes/standards and regulations	Conform to **most** minimum acceptable limits set by the IEEE/national/international codes/standards and regulations	Conform to **few** minimum acceptable limits set by the IEEE/national/international codes/standards and regulations	**Multiple deficiencies** to conform to **few** minimum acceptable limits set by the IEEE/national/international codes/standards and regulations

FIGURE 2. A specific PI 4_12 and its hybrid rubric for assessing health and safety factors aligned to abet SO '4'.

criteria [41]. The dimensions of the hybrid rubric are topic specific using detailed descriptors for the scored EAMU scales providing accurate details or steps of required student performances [41]. The hybrid rubrics address the two main criteria of a qualified assessment: (a) validity: achieve precision and accuracy by tight alignment with outcomes and PIs; and (b) inter/intra-rater reliability: by providing specific details of acceptable student performances [41]. The Hybrid Rubrics provide structured instruction that is aligned to outcomes assessments. Figure 2 shows a hybrid rubric for specific PI_4_12 to evaluate a final engineering prototype for fulfillment of health and safety constraints. The hybrid rubrics aligned to PI_4_12 help assess attainment of ABET SO '4', which targets skills for recognizing ethical and professional responsibilities for specific engineering situations and to make informed judgements about the impact of engineering solutions in global, economic, environmental, and societal contexts.

4) WEIGHTING FACTORS

Moon, 2007 [7] and Liu and Chen, 2012 [69] suggested applying weights when aggregating learning outcomes for varying proficiency. Hussain, Mak and Addas (2016) achieved this at the course level by specifying weights to different assessments according to a combination of their course grading policy and assessment type [26], [40]. The primary rationale given for applying weights to varying types of assessment considers their level of comprehension and holistic coverage. For example, higher weightage is allocated for assessments that measure laboratory or design work especially when they involve learning in all the three domains of Bloom's taxonomy [29], cognitive, psychomotor and affective versus purely theoretical work [52]; or final exams over quizzes since they are relatively more comprehensive, with students' skills reaching a higher level of maturity and proficiency by then [26], [40]. The secondary rationale considers the course grading scale which accounts for a given assessment's percentage contribution of assessments to the final grade [26], [40].

D. PRACTICAL FRAMEWORK – DIGITAL PLATFORM EVALTOOLS ®

Several engineering programs have utilized additional software applications such as True Outcomes® to compensate for comprehensive and accurate outcomes for assessment standards that are not features of Blackboard® [34]. The Faculty of Engineering chose EvalTools® 6 since it is the only current tool employing the embedded assessment model using the FCAR and EAMU performance vector methodology [36], [40], [45], [47], [68]. EvalTools® enables high levels of faculty involvement in CQI processes with full-scale automation achieved by integrating the Administrative Assistant (AAS), Learning Management (LMS), Outcomes Assessment (OAS) and Continuous Improvement Management (CIMS) Systems [36], [40], [45], [47], [68], [76]. The CIMS electronically integrates multiple results of term review outcomes from programs with CQI input from 20 standing administrative committees at the Faculty of Engineering.

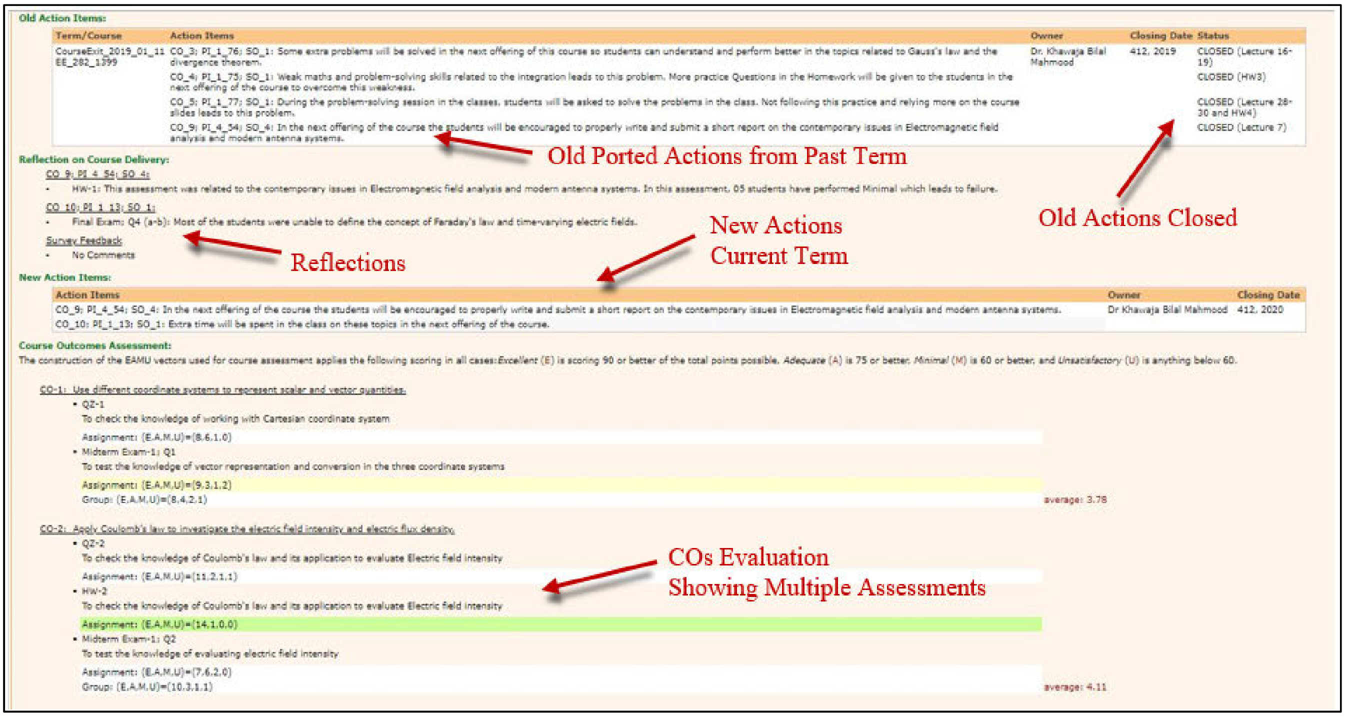


FIGURE 3. FCAR - actions, reflections and COs evaluation.

All corrective actions are generated with electronic ID, time stamp, priority and closure status to enable quality assurance processes. Therefore FCAR saves considerable amounts of precious teaching resources because outcomes assessments are automated and reported [35], [44], [45], [68]. When embedded assessments are aligned with learning outcomes, there is practical efficacy as indicated by Mead and Bennet (2009) [31]. Their findings highlighted the importance of creating specific performance criteria and corresponding rubrics to enable accurate alignment of assessments to actual student learning activities [31]. However, their work mainly concentrated on cognitive skills. Hussain, Mak and Addas proposed an enhanced FCAR + Specific PIs methodology using EvalTools® to implement holistic delivery of engineering curriculum by comprehensively covering all the 3 domains and associated learning levels of Bloom's Taxonomy. Table 3 presents the generic performance criteria for EAMU levels and heuristic rules for PVT applied to cohort or program level evaluations [26], [36], [40], [44], [45], [68], [76]. However, instructors can also opt to apply performance criteria of hybrid rubrics for assessing specific PIs of interest.

As shown in Figure 3, EvalTools® 6 employs a structured format for its FCAR module which consists of course descriptions, survey feedback results, grade distributions, COs evaluations, assignment lists, reflections, old and new action items, and SOs and PIs evaluations [36], [40], [45], [47], [68], [76]. Specifically, COs evaluation employs EAMU weighted averaging across various types of assessments aligned with specific PIs [36], [40], [45], [47], [68]. For example, CO1 is evaluated using assessments QZ1 and MidTerm Exam-I Q1 that measure skills related to their corresponding specific PIs.

TABLE 3. Heuristic rules for performance criteria.

Specification of EAMU performance indicator levels:

Category –Scale%	Description
Excellent (E) (90 – 100)	Apply knowledge with virtually no conceptual or procedural errors
Adequate (A) (75 - 90)	Apply knowledge without significant conceptual errors and only minor procedural errors
Minimal (M) (60 – 75)	Apply knowledge with occasional conceptual errors and only minor procedural errors
Unsatisfactory (U) (0 - 60)	Significant conceptual and/or procedural errors when applying knowledge

Heuristic rules for Performance Vector Tables (PVT):

Category	General Description
Red Flag	Any performance vector with an average below 3.3 and a level of unsatisfactory performance (U) that exceeds 10%
Yellow Flag	Any performance vector with an average below 3.3 or a level of unsatisfactory performance (U) that exceeds 10%, but not both
Green Flag	Any performance vector with an average that is at least greater than 4.6 and no indication of unsatisfactory performance (U)
No Flag	Any performance vector that does not fall into one of the above categories

E. PRACTICAL FRAMEWORK – SUMMARY OF DIGITAL TECHNOLOGY AND ASSESSMENT METHODOLOGY

The Faculty of Engineering studied several manual and automated CQI systems for developing an authentic outcome-based IQMS that offers efficient functionality and seamless implementation to achieve desired quality improvement and not just minimal accreditation standards. [21], [22], [24], [30], [31], [34], [35], [37], [38], [42]–[44], [46], [68]. Sixteen essential elements were identified by the Faculty to attain cutting edge assessment methodology. This uses state-of-the-art digital technology for achieving a high level of automation and realistic CQI for engineering education [26], [40], [72], [76]:

1. OBE assessment model.
2. ABET, EAC outcomes assessment model employing PEOs, 11/7 ABET EAC SOs and PIs to measure COs.
3. Measurement of outcomes information in all course levels of a program curriculum: introductory, reinforced and mastery.
4. The FCAR utilizing the EAMU performance vector methodology.
5. Well-defined performance criteria for course and program levels.
6. A digital database of specific PIs and their hybrid rubrics classified as per Bloom's revised 3 domains of learning and their associated levels (according to the *3-Level Skills Grouping Methodology*).
7. Unique Assessment mapping to one specific PI.
8. Scientific Constructive Alignment for designing assessments to obtain realistic outcomes data representing information for one specific PI per assessment.
9. Integration of direct, indirect, formative, and summative outcomes assessments for course and program evaluations.
10. Calculation of program and course level ABET SOs, COs data based upon weights assigned to type of assessments, PIs and course levels.
11. Program as well as student performance evaluations considering their respective measured ABET SOs and associated PIs as a relevant indicator scheme.
12. The Program Term Review module of EvalTools® 6 consisting of 3 parts a) Learning Domains Evaluation b) PIs Evaluation and c) ABET SOs Evaluation.
13. A student academic advising module based on measured learning outcomes data.
14. Electronic integration of the Administrative Assistant System (AAS), the Learning Management System (LMS), the Outcomes Assessment System (OAS) and the Continuous Improvement Management System (CIMS), facilitating faculty involvement for realistic CQI.
15. Electronic integration of AIs generated from program outcomes term reviews with the Faculty of Engineering standing committees' meetings, tasks, lists and overall CQI processes (CIMS feature).
16. Customized web-based software EvalTools® 6 facilitating all of the above.

V. SOs AND PIS EVALUATIONS

The program term review evaluation process involves three distinct phases: *SOs, PIs* and *Learning Domains Evaluations* [26], [40], [56], [76]. The program term reviews determine SOs and PIs failures, course actions and whenever necessary report on program level improvement actions and their associated corrective actions. The term summary report consists of composite histogram plots showing SOs and PIs evaluation results, detailed information on contributing courses, and EAMU PVT values for all assessed PIs [26], [40], [56], [76]. The Final SO values for a given term are computed by applying a High Frequency Weighting Factor Scheme (HFWFS) to aggregate PIs results obtained by accessing student performances at the course level [26], [40], [41], [56], [76]. The HFWFS based PIs aggregation gives higher priority to advanced skill levels and mastery level courses. Figure 4 shows a sample EE program, term 391 (Fall, 2018), PIs evaluation for the revised ABET SO_5 related to team work skills. Failing PIs are easily identified and examined based on color coded results that correspond with the performance criteria listed in Table 3.

EvalTools® term summary reports consist of the following evaluation reports [40], [56], [76]:

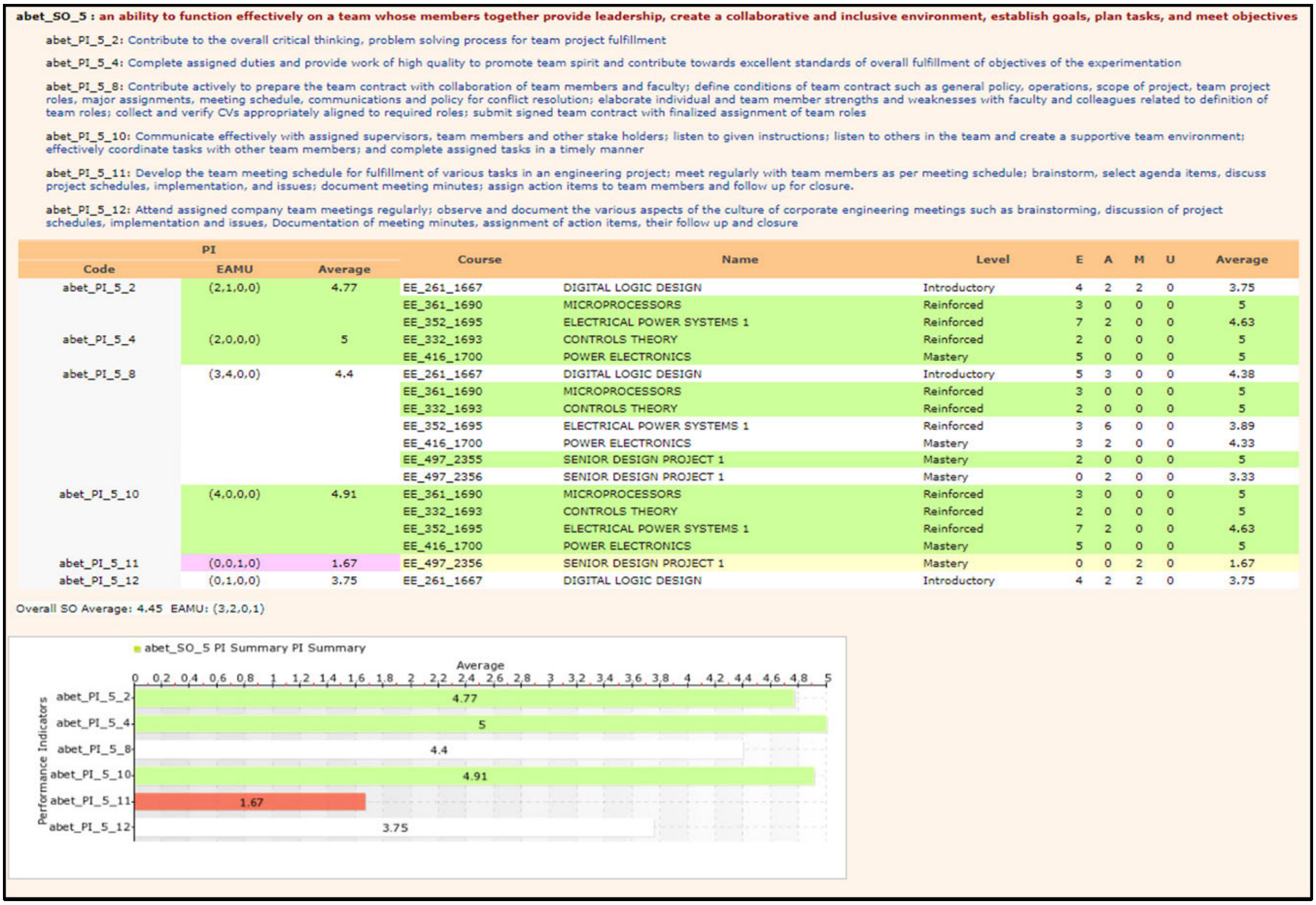
a) SO executive summary
b) Detailed SO/PI executive summary
c) SO/PI Performance Vector Table PVT summary and
d) Course reflections/action items

A. DIRECT ASSESSMENT OF SOS – A SAMPLE FROM A SINGLE TERM 382 ANALYSIS

In this section, we present the results of direct assessments for a single term as a sample. The section below presents a program evaluation conducted in term 382 (Spring 2018) and refers to outcomes assessment evaluations for ABET SOs (a-k). Table 4 shows a summary of EE program committee decisions *Exceeding, Meeting* or *Below Expectations* (*EE, ME or BE*) for an overall review of ABET SOs (a-k) score results in a program term review term 382 (Spring 2018). Figure 5 shows a composite plot for ABET SOs (a-k) obtained from an EE program term review term 382. The Red, Yellow, Green and White flags have already been explained in Table 3 listing performance criteria.

VI. PDCA QUALITY CYCLE Q5: SOS MULTI-TERM REVIEW RESULTS

The IQMS implemented at the Faculty of Engineering incorporates six Plan, Do, Check, ACT (PDCA) Quality Cycles Q_1 to Q_6. The six quality cycles ensure course and program level teaching, learning, assessment, evaluation, feedback and CQI processes adhere to specified quality and accreditation standards [56], [76]. As shown in Figure 6, the PDCA quality cycle Q_5 involves program level SO reviews over multiple terms and conducted by faculty every three years [55], [56], [76]. A comprehensive multi-term impact evaluation uses regression analyses for at least six terms of program level quantitative SOs data followed with



abet_SO_5 : an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

abet_PI_5_2: Contribute to the overall critical thinking, problem solving process for team project fulfillment

abet_PI_5_4: Complete assigned duties and provide work of high quality to promote team spirit and contribute towards excellent standards of overall fulfillment of objectives of the experimentation

abet_PI_5_8: Contribute actively to prepare the team contract with collaboration of team members and faculty; define conditions of team contract such as general policy, operations, scope of project, team project roles, major assignments, meeting schedule, communications and policy for conflict resolution; elaborate individual and team member strengths and weaknesses with faculty and colleagues related to definition of team roles; collect and verify CVs appropriately aligned to required roles; submit signed team contract with finalized assignment of team roles

abet_PI_5_10: Communicate effectively with assigned supervisors, team members and other stake holders; listen to given instructions; listen to others in the team and create a supportive team environment; effectively coordinate tasks with other team members; and complete assigned tasks in a timely manner

abet_PI_5_11: Develop the team meeting schedule for fulfillment of various tasks in an engineering project; meet regularly with team members as per meeting schedule; brainstorm, select agenda items, discuss project schedules, implementation, and issues; document meeting minutes; assign action items to team members and follow up for closure.

abet_PI_5_12: Attend assigned company team meetings regularly; observe and document the various aspects of the culture of corporate engineering meetings such as brainstorming, discussion of project schedules, implementation and issues, Documentation of meeting minutes, assignment of action items, their follow up and closure

PI			Course	Name	Level	E	A	M	U	Average
Code	EAMU	Average								
abet_PI_5_2	(2,1,0,0)	4.77	EE_261_1667	DIGITAL LOGIC DESIGN	Introductory	4	2	2	0	3.75
			EE_361_1690	MICROPROCESSORS	Reinforced	3	0	0	0	5
			EE_352_1695	ELECTRICAL POWER SYSTEMS 1	Reinforced	7	2	0	0	4.63
abet_PI_5_4	(2,0,0,0)	5	EE_332_1693	CONTROLS THEORY	Reinforced	2	0	0	0	5
			EE_416_1700	POWER ELECTRONICS	Mastery	5	0	0	0	5
abet_PI_5_8	(3,4,0,0)	4.4	EE_261_1667	DIGITAL LOGIC DESIGN	Introductory	5	3	0	0	4.38
			EE_361_1690	MICROPROCESSORS	Reinforced	3	0	0	0	5
			EE_332_1693	CONTROLS THEORY	Reinforced	2	0	0	0	5
			EE_352_1695	ELECTRICAL POWER SYSTEMS 1	Reinforced	3	6	0	0	3.89
			EE_416_1700	POWER ELECTRONICS	Mastery	3	2	0	0	4.33
			EE_497_2355	SENIOR DESIGN PROJECT 1	Mastery	2	0	0	0	5
			EE_497_2356	SENIOR DESIGN PROJECT 1	Mastery	0	2	0	0	3.33
abet_PI_5_10	(4,0,0,0)	4.91	EE_361_1690	MICROPROCESSORS	Reinforced	3	0	0	0	5
			EE_332_1693	CONTROLS THEORY	Reinforced	2	0	0	0	5
			EE_352_1695	ELECTRICAL POWER SYSTEMS 1	Reinforced	7	2	0	0	4.63
			EE_416_1700	POWER ELECTRONICS	Mastery	5	0	0	0	5
abet_PI_5_11	(0,0,1,0)	1.67	EE_497_2356	SENIOR DESIGN PROJECT 1	Mastery	0	0	2	0	1.67
abet_PI_5_12	(0,1,0,0)	3.75	EE_261_1667	DIGITAL LOGIC DESIGN	Introductory	4	2	2	0	3.75

Overall SO Average: 4.45 EAMU: (3,2,0,1)

FIGURE 4. ABET SOs (1-7) evaluation module for term 391 (fall 2018) showing PIs assessed for abet revised SO 5 (teamwork skills).

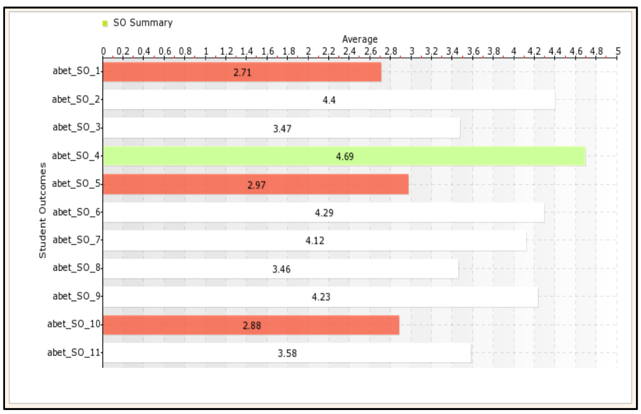


FIGURE 5. ABET SOs (a-k) composite plot EE program term review term 382 (spring 2018).

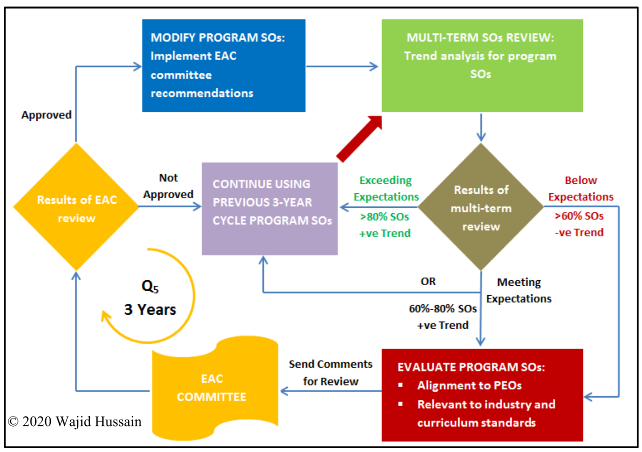


FIGURE 6. PDCA quality cycle Q5: SOs multi-term review process flow.

application of precision rubrics to estimate the improvement in overall SOs trend performance [55], [56], [76].

As per the process flow indicated in Figure 6, based on the quantitative results of the multi-term SOs trend analyses, the program reviews would result in either of the three decisions: a) *Exceeding Expectations*, if more than 80% of the total number of SOs exhibit a positive trend b) *Meeting Expectations*, if 60% to 80% of the total number of program SOs display an improving trend and c) *Below Expectations*, when more than 60% of the total number of program SOs exhibit a negative trend in overall performance. A *Below Expectations* decision mandates an examination of language, content and

TABLE 4. Executive summary report for term 382 (spring 2018).

SO	Student Outcomes	Avg.	Result
1	an ability to apply knowledge of mathematics, science, and engineering	2.71	BE
2	an ability to design and conduct experiments, as well as to analyze and interpret data	4.40	ME
3	an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	3.47	ME
4	an ability to function on multidisciplinary teams	4.69	ME
5	an ability to identify, formulate, and solve engineering problems	2.97	BE
6	an understanding of professional and ethical responsibility	4.29	ME
7	an ability to communicate effectively	4.12	ME
8	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	3.46	ME
9	a recognition of the need for, and an ability to engage in life-long learning	4.23	ME
10	a knowledge of contemporary issues	2.88	BE
11	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	3.58	ME

scope of the failing SOs besides any other corrective actions. A detailed multi-term SOs impact evaluation report including recommendations for improvement and any modifications to SOs is sent to the *External Advisory Committee* (EAC) for review and approval.

For gaining a better understanding of the impact evaluation process, the following sections provide detailed information regarding various SOs, PIs evaluation reports and rubrics that form the basis for program committees' review discussion and decision process:

1. *Multi-term Executive Summary Report - SOs Attainment* results for multi-year [2014-18] ABET SOs (a-k) data.
2. *Multi-term Executive Summary Report —— PIs Evaluation.*
3. *Multi-term Executive Summary Report —— SOs Trend Plots.*
4. Rubrics establishing performance criteria for SOs trend analyses.
5. ME program sample showing trend analysis using regression methods for SO 'a' (SO_1), "*an ability to apply knowledge of mathematics, science, and engineering*".
6. *Multi-term Executive Summary Report —— Program Committee Review* of trend analysis for ME SO 'a' (SO_1).
7. Impact evaluation for the EE, ME and CE programs based on summary of results of trend analyses for ABET SOs (a-k).

A. MULTI-TERM EXECUTIVE SUMMARY REPORT – SOs ATTAINMENT ABET SOs (a-k) FALL 2014 – SPRING 2018 (TERMS 382, 381, 372, 371, 362, 361, 352 AND 351)

In this section, we present summarized data for the attainment of SOs and also samples of EE, ME and CE program level multi-term ABET SOs (a-k) executive summary reports. A summary of 8 terms of ABET SOs (a-k) and CQI data from term 351 (Fall 2014) up to term 382 (Spring 2018) is presented in this section. The multi-term detailed executive summary report presented does not include any data related to the revised ABET SOs (1-7) since the ABET EAC Commission approved changes to the 2019-20 accreditation cycle for implementation in mid-2018. As per the Q_5 PDCA Quality Cycle's assessment plan, the multi-term SOs evaluation is conducted every three years necessitating collection of at least 6 terms of outcomes and CQI data related to revised ABET SOs (1-7). Therefore, a detailed multi-term review related to the revised ABET SOs (1-7) will be conducted in Spring 2022. Tables 5, 6 and 7 below show a summary of EE, ME and CE program committee decisions *Exceeding, Meeting* or *Below Expectations* for overall review of ABET SOs (a-k) score results spanning 8 terms from term 351 (Fall 2014) up to term 382 (Spring 2018). The Red, Yellow, Green and White flags and criteria for *Exceeding, Meeting* and *Below Expectations* (*EE, ME, BE*) have already been explained in Table 3

B. ME PROGRAM SAMPLE - MULTI-TERM EXECUTIVE SUMMARY REPORT PIs EVALUATION FOR ABET SOs (a-k)

Since the multi-term executive summary reports are detailed and lengthy, running into tens of pages for each program, we present a small portion of the ME program's multi-term report as a sample in Table 8 for just SO 'g' (SO_7) on "*an ability to communicate effectively*". The executive summary report shows a list of PIs, courses assessed, terms covered followed by summarized notes and actions by attending program faculty members for deficiencies reviewed during program term reviews spanning Fall 2014 to Spring 2018 time period. The overall summary includes a program level decision of whether the ABET SO is *Exceeding, Meeting* or *Below Expectations*. The actions of the multi-term SOs executive summary report mainly involve either review and approval of faculty actions in the FCAR or their elevation to the program level for assignment to administrative committees for closure.

TABLE 5. EE program multi-term executive summary report fall 2014 to spring 2018 (terms 382, 381, 372, 371, 362, 361, 352 and 351).

SO	382 2018		381 2017		372 2017		371 2016		362 2016		361 2015		352 2015		351 2014	
	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result
SO_1	2.71	BE	2.80	BE	2.81	BE	2.35	BE	1.98	BE	2.50	BE	1.80	BE	2.69	BE
SO_2	4.40	ME	4.10	ME	3.83	ME	3.47	ME	3.42	ME	2.97	BE	3.67	ME	4.32	ME
SO_3	3.47	ME	3.78	ME	4.04	ME	3.33	ME	2.64	BE	1.67	BE	2.96	ME	1.76	BE
SO_4	4.69	ME	4.59	ME	4.40	ME	4.35	ME	2.43	BE	0.00	BE		N/A	4.49	ME
SO_5	2.97	BE	2.89	BE	2.96	BE	2.08	BE	2.05	BE	2.48	BE	2.61	BE	3.14	BE
SO_6	4.29	ME	3.16	BE	3.66	ME	2.98	BE	2.88	BE	1.96	BE		N/A		N/A
SO_7	4.12	ME	3.56	ME	3.94	ME	4.32	ME	3.52	ME	3.06	BE		N/A	0.49	BE
SO_8	3.46	ME	3.73	ME	4.02	ME	4.43	ME	2.76	BE	0.71	BE		N/A		N/A
SO_9	4.23	ME	3.85	ME	3.64	ME	4.27	ME	4.58	ME		N/A		N/A		N/A
SO_10	2.88	BE	3.39	ME	1.43	BE	2.54	BE	4.72	ME	2.14	BE		N/A		N/A
SO_11	3.58	ME	3.22	BE	3.27	BE	2.61	BE	2.13	BE	1.81	BE	1.63	BE	2.82	BE

C. ME SAMPLE MULTI-TERM EXECUTIVE SUMMARY REPORT - SOs TREND PLOTS

Multi-term Trend plots for ME program sample for ABET SOs (a-k) terms 351 to 382 (Fall 2014 to Spring 2018) are shown in Figure 7. Most of the ABET SOs (a-k) display a stable average with variance under 30% and notable improvement in performance with an increasing trend in average values reported in ME program term reviews data for the Fall 2014 to Spring 2018 time period.

D. RUBRICS ESTABLISHING PERFORMANCE CRITERIA FOR MULTI-TERM SOs TREND ANALYSES

Table 9 shows rubrics the Faculty of Engineering EE, ME and CE programs employ to establish performance criteria for multi-term SOs trend analyses. The non-experimental impact evaluation approach applied in this study involves regression methods and rubrics instead of an explicit comparison group. A linear regression based trend analysis is employed to evaluate the multi-term trend performance of SOs (a-k). The next year's forecast for the SO performance is extrapolated from the linear trend. This forecast is then compared with the average of SO values collected from the 351-382 terms to obtain the percentage increase. The SO's next year forecast value and percentage increase are compared to ranges as described in Table 9 to define seven case types and obtain the *Below, Meeting* and *Exceeding Expectations* review decisions for each SO.

E. OVERALL AVERAGE AND NEXT YEAR'S FORECAST FOR MULTI-TERM SOs TREND ANALYSES

As shown in Table 10, SO 'a' (SO_1) average values obtained for ME program terms 351-382 are input as excel data and averaged to obtain the *Overall Average*. A linear regression trend curve is then used to estimate the following year's forecasted SO 'a' (SO_1) value. Figure 8 shows the linear regression based trend curve obtained using excel for multi-term SO 'a' values. The percentage increase '% INCREASE' is computed by dividing the multi-term overall SO 'a' average value with the next year's forecasted SO 'a' value.

F. MULTI-TERM EXECUTIVE SUMMARY REPORT – PROGRAM COMMITTEE REVIEW SOs (a-k) TREND ANALYSES

For brevity, a portion of the ME program's multi-term SOs (a-k) Trend Analysis Executive Summary Report for SO 'a' (SO_1) is shown in Table 11. The report indicates multi-term (351-382) SO 'a' (SO_1) data, trend curve, list of ME program reviewers, comments, corrective action, date of review

TABLE 6. ME program multi-term executive summary report fall 2014 to spring 2018 (terms 382, 381, 372, 371, 362, 361, 352 and 351).

SO	382 2018		381 2017		372 2017		371 2016		362 2016		361 2015		352 2015		351 2014	
	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result
SO_1	3.35	ME	3.28	BE	3.41	ME	3.71	ME	2.60	BE	2.63	BE	1.79	BE	3.53	ME
SO_2	4.49	ME	3.65	ME	3.62	ME	3.57	ME	3.97	ME	3.56	ME	3.78	ME	4.52	ME
SO_3	4.06	ME	3.86	ME	4.24	ME	3.08	BE	3.34	ME		N/A		N/A		N/A
SO_4	4.61	ME	4.11	ME	4.93	ME	4.15	ME		N/A		N/A		N/A		N/A
SO_5	3.58	ME	3.30	ME	3.13	BE	3.21	BE	3.17	BE	2.22	BE	2.29	BE	2.89	BE
SO_6	3.53	ME	3.41	ME	4.40	ME	2.88	ME		N/A	3.33	ME		N/A		N/A
SO_7	4.42	ME	3.81	ME	4.67	ME	3.60	ME	3.88	ME		N/A	2.25	BE	3.41	BE
SO_8	3.79	ME	3.36	ME	4.02	ME	3.66	ME		N/A		N/A		N/A		N/A
SO_9	4.17	ME	3.33	ME	4.51	ME	3.87	ME		N/A		N/A		N/A		N/A
SO_10	3.60	ME	1.68	BE		N/A		N/A		N/A		N/A		N/A		N/A
SO_11	3.14	BE	3.18	BE	3.14	BE	3.52	ME	3.13	BE	3.59	ME	2.81	BE	3.08	BE

and review decision of Exceeding Expectations for SO 'a' multi-term trend analysis.

abet_SO_1: an ability to apply knowledge of mathematics, science, and engineering

Classification: **Exceeding Expectations**
Discussion:

AVERAGE = 3.0375;

FORECAST = 3.668690476;

% INCREASE = 20.7799334;

STANDARD DEVIATION = 0.68;

STANDARD ERROR = 0.24;

According to multi-term SOs trend analysis performance criteria this is ***Case 3***: Forecast after 1 year ≥ 3.0 AND < 4.0 with ≥ 10% increase compared to AVERAGE

The Review Decision for this SO is ***EXCEEDING EXPECTATIONS***

Action: No action

Reviewers:

Dr. KHT, Dr. MO, Dr. MA, Dr. AS, Dr. SZ, Dr. ERIM, Dr. MB, Mr. MF, Mr. YA, Mr. ANS, Mr. WH

Review Date:2018-09-03

G. IMPACT EVALUATIONS ME, CE AND EE PROGRAMS BASED ON SUMMARY OF RESULTS OF TREND ANALYSES FOR ABET SOs (a-k)

Impact evaluations of the ME, CE and EE programs involve a mixed methods review of the multi-term executive summary and trend analyses reports by the Program and External Advisory Committees (EAC) every 3-5 years to establish final review decisions and initiate any necessary corrective actions to:

1. Benchmark and adjust the existing performance criteria
2. Review coverage of SOs data coupled with faculty feedback of the validity/reliability of current assessment and evaluation data/process of individual SOs
3. Abrogate, modify or delete any SOs (refer to recommended actions for cases 4,6 and 7 mentioned in Table 9).

Based on the rubrics establishing the performance criteria shown in Table 9 and the PDCA Quality Cycle Q5: *SOs Multi-Term Review Process Flow* shown in Figure 6 the ME, CE and EE program committees arrived at the following final review decisions for the impact evaluations of ABET SOs (a-k) 5-year [2014-18] trend analyses:

1) ME PROGRAM FINAL REVIEW DECISION

Table 12 summarizes the ABET SOs (a-k) overall average, % increase, next year forecast, case type, review date and review decision data for the ME program.

Since 8 out of 11 SOs, 60-80% of SOs results were either *Exceeding* or *Meeting Expectations*, an overall review

TABLE 7. CE program multi-term executive summary report fall 2014 to spring 2018 (terms 382, 381, 372, 371, 362, 361, 352 and 351).

SO	382 2018		381 2017		372 2017		371 2016		362 2016		361 2015		352 2015		351 2014	
	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result
SO_1	3.89	ME	3.82	ME	3.67	ME	3.95	ME	2.57	BE	3.49	ME	2.23	BE	3.10	BE
SO_2	4.73	ME	4.32	ME	4.28	ME	3.80	ME	3.15	BE	3.12	BE	3.64	ME	3.14	BE
SO_3	3.08	BE	3.99	ME	3.66	ME	3.62	ME	2.41	BE	3.68	ME		N/A		N/A
SO_4	4.47	ME	4.50	ME	4.74	ME	4.76	ME		N/A		N/A		N/A		N/A
SO_5	3.34	ME	3.05	BE	3.26	BE	2.80	BE	3.20	BE	2.90	BE	2.35	BE	3.35	ME
SO_6	3.42	ME	2.92	BE	3.50	ME	3.89	ME		N/A		N/A		N/A		N/A
SO_7	4.34	ME	3.49	ME	3.39	ME	3.99	ME	2.64	BE	3.66	ME		N/A		N/A
SO_8	4.22	ME	3.76	ME	4.00	ME	2.14	BE	2.41	BE	1.25	BE		N/A		N/A
SO_9	4.30	ME	4.63	ME	3.13	ME	4.49	ME		N/A		N/A		N/A		N/A
SO_10	3.47	ME	2.82	BE	4.07	ME	3.33	ME		N/A		N/A		N/A		N/A
SO_11	3.64	ME	3.43	ME	3.45	ME	3.58	ME	3.31	BE	3.20	BE	2.13	BE	3.09	BE

decision of *Meeting Expectations* was obtained for the ME program. Figure 9 shows the meeting minutes for *Meeting ID ME:MTG:2018-09-03:V57* which indicate the ME program's overall review decision for 11 SOs (a-k) multi-term (351-382) trend analysis as *Meeting Expectations*.

2) CE PROGRAM FINAL REVIEW DECISION

Table 13 summarizes the ABET SOs (a-k) overall average, % increase, next year forecast, case type, review date and review decision data for the CE program. Since 10 out of 11 SOs, >80% of SOs results were either *Exceeding* or *Meeting Expectations*, an overall review decision of *Exceeding Expectations* was obtained for the CE program.

3) EE PROGRAM FINAL REVIEW DECISION:

Table 14 summarizes the ABET SOs (a-k) overall average, % increase, next year forecast, case type, review date and review decision data for the EE program. Since 8 out of 11 SOs, 60-80% of SOs results were either *Exceeding* or *Meeting Expectations*, an overall review decision of *Meeting Expectations* was obtained for the EE program.

Table 15 summarizes results of all the three engineering programs by showing overall comments and actions for SOs aggregated values and trend analyses results. As mentioned in Table 9, based on trend forecast, achieved % increase, coverage of SOs data in several terms, and faculty feedback, the following general observations were recorded and corresponding actions taken:

1. The majority of SOs (a-k) performances just stabilized to aggregate SOs values with a *Meeting Expectations* result in the last few terms towards 382 and therefore did not require any modifications to performance criteria. If *Meeting* or *Exceeding Expectations* results were observed in multiple terms for any of the SOs, then the minimum performance criteria would have been raised to increase the performance standards.
2. The majority of SOs trends were positive with reasonable multi-term coverage and faculty feedback also indicated acceptable assessment and evaluation data/processes and did not necessitate any modifications to the 11 SOs.

The impact evaluation based on the overall multi-term ABET SOs (a-k) results were therefore acceptable and the CE, ME and EE programs' position to transition to revised 7 ABET SOs was reinforced in the summer of 2018.

VII. DISCUSSION

The driving force behind this research was to examine the benefits and limitations of applying an authentic OBE model to engineering programs to evaluate a holistic and comprehensive educational process that maximizes opportunities for the attainment of successful student learning. The objective was to conduct impact evaluations of the Faculty of Engineering's EE, CE and ME programs by employing a non-experimental approach using regression methods for

TABLE 8. ME program multi-term executive summary report for abet SOs (a-k).

abet_SO_7 : an ability to communicate effectively

abet_PI_7_2: Present technical information with proper Format and Organization

abet_PI_7_3: Communicate Graphical Information

abet_PI_7_4: Write complete technical reports with title, front matter, list of tables and contents, details of overall organization of the report, English(grammar/spelling/sentence structure), abstract/introduction, description of training program, case studies/measurements/supervision and design, theory and field applications, research activities, conclusions & recommendations etc. with proper formatting and style

abet_PI_7_5: Make effective oral presentations in a given time frame to defend course projects with required professionalism, style, slide quality, delivery, response to questions and adequate technical content of problem definition, literature review, design specifications, design estimation and target determination, deliverables, methodology, design decision identification, design concepts, concepts evaluation, concepts selection, detailed design presentation, necessary planning, budget, conclusion, references, appendices etc.

abet_PI_7_12: Communicate on time and effectively with the concerned stake holders using oral and written means in the form of presentations, technical reports, diagrammatic representations using electronic or other media

abet_PI_7_13: Write complete technical reports with title, front matter, list of tables and contents, details of problem definition, literature review, design specifications, design estimation and target determination, deliverables, methodology, design decision identification, design concepts, concepts evaluation, concepts selection, detailed design presentation, necessary planning, budget, conclusion, references, appendices etc. with proper formatting and style.

abet_PI_7_14: Make effective clear oral presentations in given time frame providing details of title, front matter, list of tables and contents, details of overall organization of the report, English(grammar/spelling/sentence structure), abstract/introduction, description of training program, case studies/measurments/supervision and design, theory and field applications, research activities, conclusions & recommendations etc. with proper formatting and style

abet_PI_7_15: Develop an elaborate project proposal for the design of a mechanism related to theory of machines such as gears, cams etc.: provide a summarized project abstract; reference literature survey detailing the construction (components, dimensions), manufacturability (material, facility, costs) and operation (schematic and text detailing inter-related motions) of the mechanism; provide design specifications (customer requirements and constraints); discuss manufacturability of the design (facilities, materials required and costs); provide a detailed project implementation schedule in the form of a Gantt chart.

abet_PI_7_16: Prepare interim Senior Design Report incorporating modifications in literature review, any other suggestion for improvements based on advisor feedback; Write a detail technical report following a specific/standard format to present: Abstract; Problem Definition; Problem Statement; Problem Formulation (Goals of Project, Scope of Project); Literature Review; Design Concepts Development (List all existing design methods, Propose new design methods); Design Evaluation & Selection (Concept Evaluation & Selection, Design Specifications, Constraints, Customer requirements (modifiable with customer agreement)

abet_PI_7_17: Make a professional poster presentation of Capstone design Project; display Abstract, Methodology, Summarized simulation/mathematical Results, conclusions, references; Provide necessary technical diagrams

abet_PI_7_18: Make a professional poster presentation of Capstone design Project; interact with audience, visitors, reviewers; respond/answer questions proactively in an appropriate technical and professional manner.

Student Outcomes	382 2018		381 2017		372 2017		371 2016		362 2016		361 2015		352 2015		351 2014	
	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result	Avg	Result
abet_SO_7	4.42	Meeting Expectations	3.81	Meeting Expectations	4.67	Meeting Expectations	3.60	Meeting Expectations	3.88	Meeting Expectations		N/A	2.25	Below Expectations	3.41	Below Expectations

PI	Assessment Resources	Evaluation							
		382 2018	381 2017	372 2017	371 2016	362 2016	361 2015	352 2015	351 2014
abet_PI_7_2	ME_317_1531 ME_312_1536					EAMU: (0,2,0,0) Avg:3.64			
abet_PI_7_3	ME_262_962 ME_211_1593							EAMU: (0,0,0,1) Avg:2.25 Below Expectations	EAMU: (0,0,1,0) Avg:3.41 Below Expectations
abet_PI_7_4	ME_498_928			EAMU: (1,0,0,0) Avg:4.91					

TABLE 8. ***(Continued.)*** **ME program multi-term executive summary report for abet SOs (a-k).**

abet_PI_7_5	ME_323_2181 ME_413_2200 ME_323_1091 ME_497_1104 ME_323_791 ME_498_928 ME_497_3008	EAMU: (2,0,0,0) Avg:5	EAMU: (1,0,1,0) Avg:3.36	EAMU: (0,2,0,0) Avg:4.09	EAMU: (0,1,0,0) Avg:4.26				
abet_PI_7_12	ME_431_3022				EAMU: (0,1,0,0) Avg:3.61				
abet_PI_7_13	ME_323_2181 ME_413_2200 ME_498_2461 ME_323_1091 ME_497_1104 ME_323_791 ME_498_928 ME_323_2994 ME_497_3008	EAMU: (1,2,0,0) Avg:4.71	EAMU: (0,2,0,0) Avg:4.17	EAMU: (0,1,1,0) Avg:4.25	EAMU: (0,1,1,0) Avg:2.92 Below Expectations	EAMU: (1,2,0,0) Avg:4.05			
	ME_317_1531 ME_334_1532 ME_312_1536								
abet_PI_7_14	ME_498_2461 ME_323_2994	EAMU: (0,1,0,0) Avg:4.5			EAMU: (1,0,0,0) Avg:5				
abet_PI_7_15	ME_323_2181 ME_323_1091 ME_323_791	EAMU: (1,0,0,0) Avg:5	EAMU: (0,1,0,0) Avg:4.17	EAMU: (0,1,0,0) Avg:3.79					
abet_PI_7_16	ME_497_2460 ME_498_2461 ME_498_928	EAMU: (0,2,0,0) Avg:3.75		EAMU: (1,0,0,0) Avg:5					
abet_PI_7_17	ME_498_2461 ME_498_928	EAMU: (0,1,0,0) Avg:4.33		EAMU: (1,0,0,0) Avg:5					
abet_PI_7_18	ME_498_2461 ME_498_928	EAMU: (0,1,0,0) Avg:4.5		EAMU: (1,0,0,0) Avg:5					

trend analyses of ABET SOs (a-k). The Faculty of Engineering programs' multi-term outcomes data was aggregated across thousands of assessment data points collected over 5 years. The data comprise reflections, actions, discussions, decisions based on a detailed review of information from FCARs, COs, PIs, SOs program evaluations. The comprehensive outcomes data, meta-analyses reports and subsequent CQI efforts had a multi-dimensional impact on the opinions of all the constituencies of the engineering programs. Relevant details of CQI results motivated students, alumni and employers to provide valuable feedback, participate in the EAC meetings, surveys or discussions and eventually contribute to several types of program level improvement actions [56], [76]. These actions impacted multiple aspects of the Faculty's quality assurance process resulting in improvements to teaching/learning strategies, direct/indirect assessments, advising, curriculum development, facilities, CQI processes, and an approach for drawing institutional support. The SOs (a-k) multi-term data published in this study is not outdated despite ABET's revised SOs (1-7), since the SOs (a-k) align with the revised ABET SOs [11] and the IEA's Washington Accord 12 current *Graduate Attributes* [16] thereby providing the latest skills-based impact evaluation information to thousands of engineering programs worldwide.

For impact evaluations, we applied the main aspects mentioned by Onwuegbuzie and Hitchcock (2017) to examine the validity and credibility of qualitative and quantitative statistical data as well as type and level of generalizability and transferability [49]. To better understand the statistical power of quantitative data used in the study, we explained how the sampling methodology and accuracy of outcomes evaluation was employed for the Faculty of Engineering programs. Firstly, quantitative outcomes data was collected from direct assessments, following a rigorous quality assurance procedure at both the course and program level. Importantly, embedded assesments using FCAR and PVT technology helped to fulfill OBE's "all students can succeed" paradigm by enabling the collection of specific outcomes data for all enrolled students. Secondly, two types of sampling methods were applied to aggregate course level assessment data. In the first type, any aspect of a given CO was measured using specific PIs and their tightly aligned assessments with higher course grade contributions [36]. The other sampling method involved collecting data from a cohort of students for specific PIs and corresponding COs. In contrast, manual CQI systems

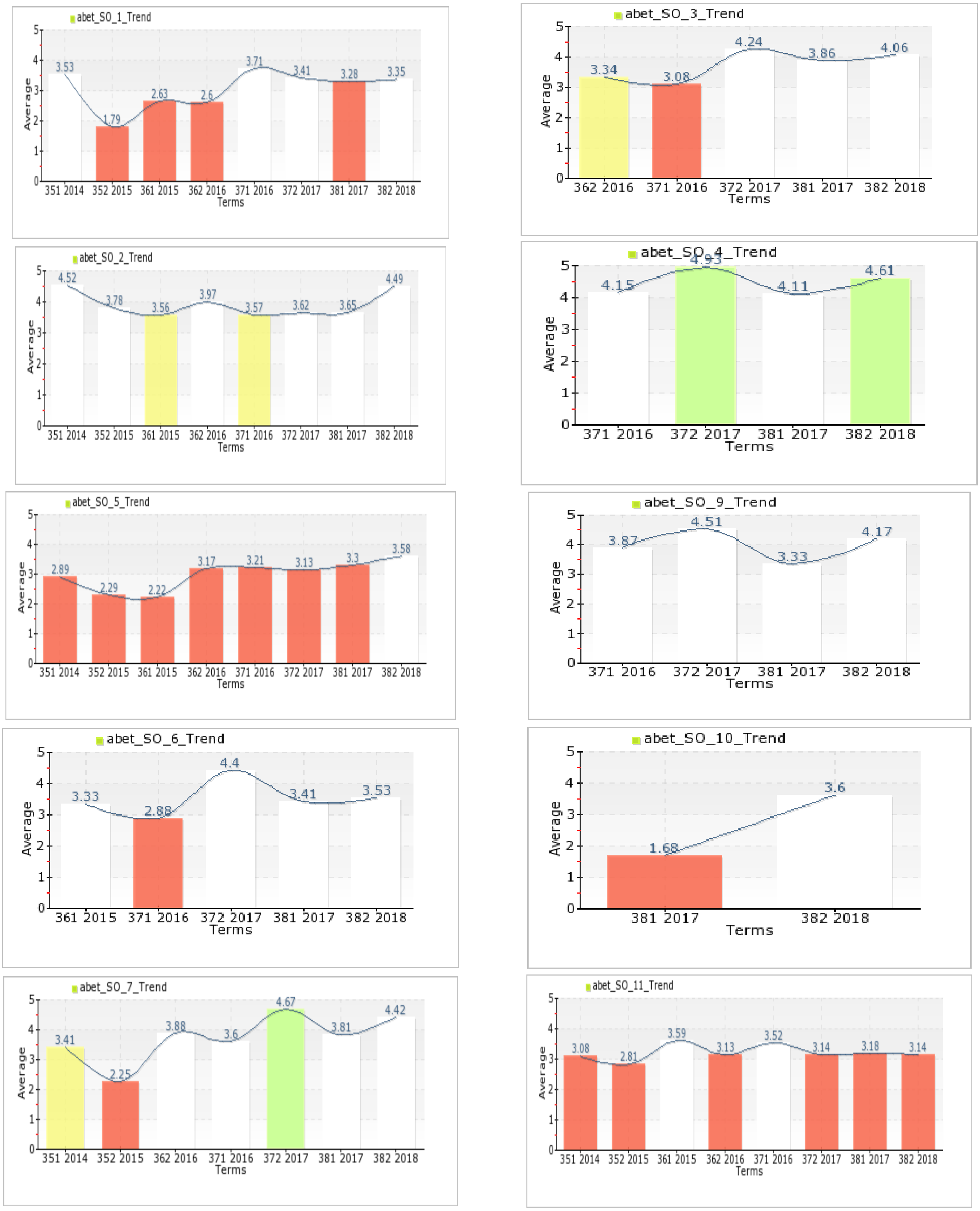


FIGURE 7. Consolidated Plot for ME program abet SOs (a-k) multi-term trend analysis.

TABLE 9. Rubrics to establich performance criteria for multi-term SOs (a-k) trend analyses.

Case#	Multi-term SO Trend Analysis Results	Review Decision	Recommended Action
1	Forecast after 1 year ≥ **4.0**	*Exceeding Expectations*	No action
2	Forecast after 1 year ≥ **3.0 AND < 4.0** with **> 0 AND < 10%** increase compared to AVERAGE	*Meeting Expectations*	Need comments for SO based on term evaluations and create necessary action items
3	Forecast after 1 year ≥ **3.0 AND < 4.0** with ≥ **10%** increase compared to AVERAGE	*Exceeding Expectations*	No action
4	Forecast after 1 year ≥ **3.0 AND < 4.0** with **< 0%** increase compared to AVERAGE	*Below Expectations*	Need comments for SO based on term evaluations and create action items, review SO change
5	Forecast after 1 year ≥ **2.5 AND < 3.0** with ≥ **10%** increase compared to AVERAGE	*Meeting Expectations*	Need comments for SO based on term evaluations and create necessary action items
6	Forecast after 1 year ≥ **2.5 AND < 3.0** with ≤ **10%** increase compared to AVERAGE	*Below Expectations*	Need comments for SO based on term evaluations and create necessary action items
7	Forecast after 1 year < **2.5**	*Below Expectations*	Review SO change, aggressive actions

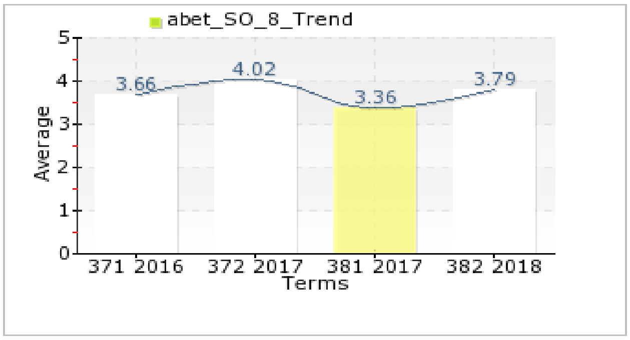


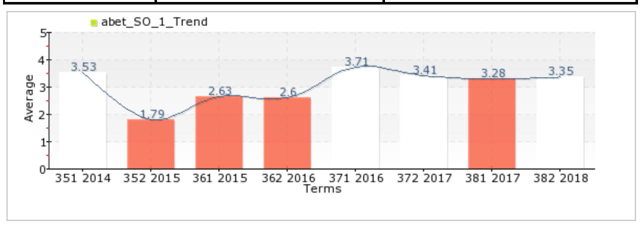
FIGURE 7. ***(Continued.)*** **Consolidated Plot for ME program abet SOs (a-k) multi-term trend analysis.**

TABLE 10. Average calculation and next year forecast estimation for SO 'a' (SO_1).

TERM	SNO.	SO_1 Results
351	1	3.53
352	2	1.79
361	3	2.63
362	4	2.6
371	5	3.71
372	6	3.41
381	7	3.28
382	8	3.35
	AVERAGE	**3.04**
	FORECAST (NEXT YEAR)	**3.67**
	% INCREASE	**20.78**

TABLE 11. ME program trend analysis report for SO 'a' SO_1.

382 2018	Avg	3.35
	Classification	Meeting Expectations
381 2017	Avg	3.28
	Classification	Below Expectations
372 2017	Avg	3.41
	Classification	Meeting Expectations
371 2016	Avg	3.71
	Classification	Meeting Expectations
362 2016	Avg	2.60
	Classification	Below Expectations
361 2015	Avg	2.63
	Classification	Below Expectations
352 2015	Avg	1.79
	Classification	Below Expectations
351 2014	Avg	3.53
	Classification	Meeting Expectations



employ either adhoc and/or limited sampling of assessments and students due to the lack of time and resource constraints for analysis [56], [59]–[63], [76]. EvalTools® embedded assessment technology using FCAR and PVT technology enabled collection of quantitative outcomes data from a large number of direct assessments and all students of associated cohorts [26], [40]–[45], [56]. The findings of Hussain *et al.* (2020) stated that course level outcomes data achieved high statistical power when it was comprehensive, heterogeneous and accurate. Findings of this study indicate that the quantitative outcomes information is valid and reliable since the data is collected using precision learning models, best assessment practice, and assured by having dedicated staff for the quality assurance processes within an automated digital IQMS environment. The aggregated course assessment data is also heterogeneous since it comprehensively represents

TABLE 12. ME program summary of abet SOs (a-k) trend analysis data with review decisions (n = 8).

ABET SOs	Overall Average	Forecast	% Increase	SD	SE	Case Type	Action	Review Date	Review Decision
SO_1 (SO 'a')	3.0375	3.67	120.78	0.64	0.23	3	None	2018-09-03	Exceeding Expectations
SO_2 (SO 'b')	3.90	3.82	98.18	0.40	0.14	4	Very marginal failure the program will continue with existing performance criteria and EAMU scales	2018-09-03	Below Expectations
SO_3 (SO 'c')	3.72	4.60	123.90	0.49	0.22	1	None	2018-09-03	Exceeding Expectations
SO_4 (SO 'd')	4.45	4.65	104.40	0.39	0.20	1	None	2018-09-03	Exceeding Expectations
SO_5 (SO 'e')	2.97	3.80	127.85	0.48	0.17	3	None	2018-09-03	Exceeding Expectations
SO_6 (SO 'f')	3.51	3.88	110.60	0.55	0.25	3	None	2018-09-03	Exceeding Expectations
SO_7 (SO 'g')	3.72	4.96	133.31	0.79	0.35	1	None	2018-09-03	Exceeding Expectations
SO_8 (SO 'h')	3.71	3.56	95.99	0.28	0.14	4	The program needs additional assessments to cover this SO in multiple courses; The performance criteria and EAMU scales will not be modified in the next cycle; This SO is merged with revised ABET SOs	2018-09-03	Below Expectations
SO_9 (SO 'i')	3.97	3.87	97.53	0.50	0.25	4	Very marginal failure. Concentrated focus on research skills and additional assessments are required in multiple courses; performance criteria and EAMU scales shall remain the same for the next cycle	2018-09-03	Below Expectations
SO_10 (SO 'j')	2.64	7.44	281.81	1.36	0.96	1	Need comprehensive assessments; this SO shall be merged with revised ABET SOs;	2018-09-03	Exceeding Expectations
SO_11 (SO 'k')	3.20	3.28	102.68	0.25	0.09	2	Need to concentrate on course level actions; performance criteria and EAMU scales shall remain the same in the next cycle; This SO is merged with revised ABET SOs	2018-09-03	Meeting Expectations
ME Program ABET SOs (a-k) Review Decision				0.56	0.27	Standard Error = 0.27 8 out of 11 SOs Meeting or Exceeding Expectations [60-80%] Final Review Decision: **Meeting Expectations**			

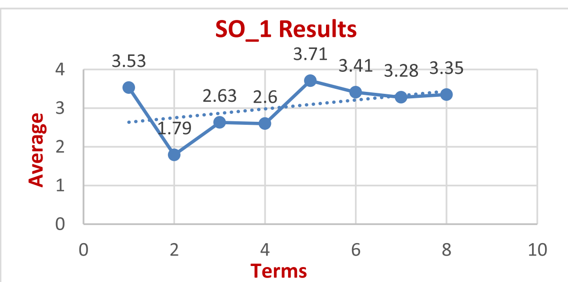


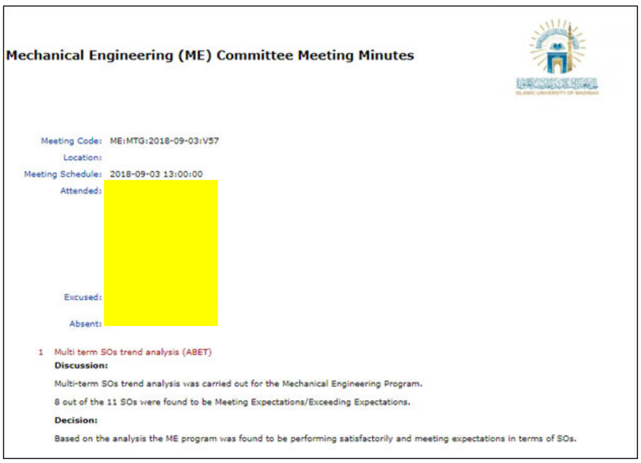
FIGURE 8. Trend analysis based on linear regression for multi-term 351-382 SO 'a' values.

the complete set of cohorts in all assessed courses. The key aspects used by the Faculty of engineering programs to ensure quality standards for accurate assessment and evaluation data include:

a. Implementation of *Bloom's Mastery Learning Model* [75] to develop and administer a curriculum.
b. Adopt the gold standards of Mager's [71] and Adelman's [20] outcomes design principles.
c. Classify COs and specific PIs as per Bloom's three domains and their learning levels and assign electronic indices for tracking and automated EAMU average computations [26].
d. Develop and implement hybrid rubrics for major course learning activities [41,76].
e. Implement unique assessments (where multiple PIs cannot map to a single assessment) [24], [26], [36], [39], [47]–[49], [52], [53], 56], 58], 76].
f. Implement tight scientific constructive alignment of outcomes to assessments using rigorous quality assurance processes [26], [36], [56], [76].

TABLE 13. CE program summary of abet SOs (a-k) trend analysis data with review decisions (n = 8).

ABET SOs	Overall Average	Forecast	% Increase	SD	SE	Case Type	Action	Review Date	Review Decision
SO_1 (SO 'a')	3.34	4.35	130.19	0.65	0.23	1	None	2018-09-04	Exceeding Expectations
SO_2 (SO 'b')	3.77	4.99	132.39	0.62	0.22	1	None	2018-09-04	Exceeding Expectations
SO_3 (SO 'c')	3.41	3.64	106.72	0.57	0.23	2	Need to concentrate on course level actions; performance criteria and EAMU scales shall remain the same in the next cycle;	2018-09-04	Meeting Expectations
SO_4 (SO 'd')	4.6175	4.23	91.59	0.15	0.08	1	None	2018-09-04	Exceeding Expectations
SO_5 (SO 'e')	3.03	3.30	108.88	0.34	0.12	2	None	2018-09-04	Meeting Expectations
SO_6 (SO 'f')	3.43	2.74	79.71	0.40	0.20	6	Need to identify additional course topics and assessments; performance criteria and EAMU scales shall remain the same in the next cycle; This SO is merged with revised ABET SOs	2018-09-04	Below Expectations
SO_7 (SO 'g')	3.59	4.27	119.19	0.58	0.24	1	None	2018-09-04	Exceeding Expectations
SO_8 (SO 'h')	2.96	5.63	190.07	1.2	0.49	1	None	2018-09-04	Exceeding Expectations
SO_9 (SO 'i')	4.02	5.78	143.66	0.79	0.46	1	None	2018-09-04	Exceeding Expectations
SO_10 (SO 'j')	3.62	3.83	105.80	0.39	0.23	2	None	2018-09-04	Meeting Expectations
SO_11 (SO 'k')	3.23	3.97	123.06	0.48	0.17	3	None	2018-09-04	Exceeding Expectations
CE Program ABET SOs (a-k) Review Decision				0.56	0.24	Standard Error (SE) = 0.24 10 out of 11 SOs Meeting or Exceeding Expectation >80% Final Review Decision: **Exceeding Expectations**			



Mechanical Engineering (ME) Committee Meeting Minutes

Meeting Code: ME:MTG:2018-09-03:V57
Location:
Meeting Schedule: 2018-09-03 13:00:00
Attended:
Excused:
Absent:

1 Multi term SOs trend analysis (ABET)
Discussion:
Multi-term SOs trend analysis was carried out for the Mechanical Engineering Program.
8 out of the 11 SOs were found to be Meeting Expectations/Exceeding Expectations.
Decision:
Based on the analysis the ME program was found to be performing satisfactorily and meeting expectations in terms of SOs.

FIGURE 9. ME program meeting ID ME:MTG:2018-09-03:V57 review decision for SOs (a-k) multi-term trend analysis.

g. Implement course level weighting factors for aggregating outcomes data from a range of types of assessments [26], [36], [40], [56], [76].

In summary, the evaluations of program level SOs, PIs and learning domains conducted at the Faculty of Engineering collected data from all courses, in all levels of the curriculum [26], [40], [41], [56], [76]. Additionally, the High Frequency Weighting Factor Scheme (HFWFS) achieved accurate aggregation of program level skills by assigning scientific weighting based on skill, course levels and frequency of assesments [40]. *Section IV.E* also presents a detailed list of 16 essential elements adopted by the IQMS to ensure high standards of valid and reliable quantitative outcomes assessment data [56], [76]. Therefore, both validity and reliability, and statistical power of quantitative data used for multi-term ABET SOs data were qualified for conducting credible, retrospective impact evaluations of the EE, CE and ME programs.

A. RESEARCH QUESTION 1: WHAT ARE SOME COMMON ISSUES THAT AFFECT THE STATISTICAL POWER OF QUANTITATIVE OUTCOMES DATA COLLECTED BY MANY ENGINEERING PROGRAMS?

Several issues both generic and specific have been listed in various sections of this paper regarding the outcomes data collected by engineering programs for quality and accreditation purposes. Section *I. Introduction* lists generic issues such as sample size, sampling methodology and timeframe, heterogeneity, attrition etc. affecting statistical power of collected data. Section *III.C SOs Data For Manual CQI Systems– A Qualitative Analysis* lists specific issues related to assessment methodology and supporting technology employed thereby affecting the validity and reliability, and statistical power of SOs data collected.

TABLE 14. EE program summary of abet SOs (a-k) trend analysis data with review decisions (n = 8).

ABET SOs	Overall Average	Forecast	% Increase	SD	SE	Case Type	Action	Review Date	Review Decision
SO_1 (SO 'a')	2.46	2.88	117.18	0.38	0.14	5	In general, SO 'a' is improving in overall trend performance so the performance criteria and EAMU levels are satisfactory and the program can continue employing the same performance criteria for this SO.	2018-09-02	Meeting Expectations
SO_2 (SO 'b')	3.77	4.12	109.27	0.49	0.17	1	None	2018-09-02	Exceeding Expectations
SO_3 (SO 'c')	2.96	4.52	152.87	0.88	0.31	1	None	2018-09-02	Exceeding Expectations
SO_4 (SO 'd')	3.56	5.66	158.87	1.76	0.66	1	None	2018-09-02	Exceeding Expectations
SO_5 (SO 'e')	2.65	2.76	104.15	0.42	0.15	6	This SO is modified as per the revised ABET SOs (1-7); Course actions have to be followed; performance criteria and EAMU values are to remain the same.	2018-09-02	Below Expectations
SO_6 (SO 'f')	3.05	4.35	142.61	0.63	0.26	1	None	2018-09-02	Exceeding Expectations
SO_7 (SO 'g')	3.28	5.49	166.87	1.3	0.49	1	None	2018-09-02	Exceeding Expectations
SO_8 (SO 'h')	3.19	5.27	165.60	1.34	0.55	1	None	2018-09-02	Exceeding Expectations
SO_9 (SO 'i')	4.11	3.55	86.39	0.37	0.17	3	The overall average is greater than 4.0 comprehensive assessments to be planned in courses and continued monitoring of this SO in the next cycle. The performance criteria and EAMU values to remain the same.	2018-09-02	Below Expectations
SO_10 (SO 'j')	2.85	2.67	93.68	1.13	0.46	6	Need comprehensive assessments in multiple courses and performance criteria, EAMU values to remain the same.	2018-09-02	Below Expectations
SO_11 (SO 'k')	2.63	3.82	145.07	0.72	0.25	3	None	2018-09-02	Exceeding Expectations
EE Program ABET SOs (a-k) Review Decision				0.86	0.33	Standard Error (SE) 0.33 10 out of 11 SOs Meeting or Exceeding Expectation >80% Final Review Decision: **Exceeding Expectations**			

B. RESEARCH QUESTION 2: WHAT ARE SOME ESSENTIAL ELEMENTS OF BEST ASSESSMENT PRACTICE AND AVAILABLE AUTOMATED DIGITAL TECHNOLOGY THAT HELP ATTAIN VALID AND RELIABLE OUTCOMES DATA?

Section *IV. Theoretical, Conceptual and Practical Frameworks* provides an elaborate discussion on authentic OBE theoretical frameworks followed by induced conceptual frameworks from which models and methods of best assessment practice can be derived. The OAS of EvalTools ® implements the ABET assessment model by aligning COs, with PIs and eventually with the program SOs. Additionally, the PIs are also classified as per affective, cognitive and psychomotor domains of Bloom's learning model which is adopted by both Washington Accord and ABET. Finally, Section *IV.E. Practical Framework —— Summary of Digital Technology and Assessment Methodology* summarized all the essential elements for assessment and described the digital technology that helped to attain valid and reliable outcomes data.

C. RESEARCH QUESTION 3: CAN MULTI-YEAR SOS DATA BE USED TO CONDUCT CREDIBLE IMPACT EVALUATIONS? IF SO, WHAT ARE SOME ESSENTIAL REQUIREMENTS TO ENSURE CREDIBILITY OF EVALUATIONS?

Yes. Multi-term SOs data was used for conducting credible impact evaluations. But, several aspects of authentic OBE assessment methodology have to be incorporated into the

TABLE 15. ME, CE and EE programs' summary of abet SOs (a-k) aggregate values and trend analysis data.

Program	SOs Aggregate Values	SOs Trend Analyses	Comments	Actions
ME	8 out of 11 SOs (a-k) performances just stabilized to aggregate values with *Meeting Expectations* results in the last few terms towards 382 excepting for SO 'k'	8 out of the 11 SOs trends were positive with reasonable multi-term coverage excepting for SOs 'b', 'h' and 'i'	1. If *Meeting* or *Exceeding Expectations* results were observed in multiple terms for any of the SOs, then the minimum performance criteria would have been raised to increase the performance standards. 2. Faculty feedback also indicated acceptable assessment and evaluation data/processes for all SOs except SOs 'b', 'h' and 'i'	**Based on SOs Aggregate Values Results and Comments #1:** No modifications required to performance criteria **Based on SOs Trend Analyses Results and Comments #2:** No modifications required to language of SOs **Transition to revised 7 ABET SOs was reinforced in the summer of 2018**
CE	10 out of 11 SOs (a-k) performances just stabilized to aggregate values with *Meeting Expectations* results in the last few terms towards 382 excepting for SO 'c'	10 out of the 11 SOs trends were positive with reasonable multi-term coverage excepting for SO 'f'	1. If *Meeting* or *Exceeding Expectations* results were observed in multiple terms for any of the SOs, then the minimum performance criteria would have been raised to increase the performance standards. 2. Faculty feedback also indicated acceptable assessment and evaluation data/processes for all SOs except SOs 'c', and 'f'	**Based on SOs Aggregate Values Results and Comments #1:** No modifications required to performance criteria **Based on SOs Trend Analyses Results and Comments #2:** No modifications required to language of SOs **Transition to revised 7 ABET SOs was reinforced in the summer of 2018**
EE	8 out of 11 SOs (a-k) performances just stabilized to aggregate values with *Meeting Expectations* results in the last few terms towards 382 excepting for SOs 'a', 'e' and 'j'	8 out of the 11 SOs trends were positive with reasonable multi-term coverage excepting for SOs 'e', 'i' and 'j'	1. If *Meeting* or *Exceeding Expectations* results were observed in multiple terms for any of the SOs, then the minimum performance criteria would have been raised to increase the performance standards. 2. Faculty feedback also indicated acceptable assessment and evaluation data/processes for all SOs except SOs 'a', 'e', 'i' and 'j'	**Based on SOs Aggregate Values Results and Comments #1:** No modifications required to performance criteria **Based on SOs Trend Analyses Results and Comments #2:** No modifications required to language of SOs **Transition to revised 7 ABET SOs was reinforced in the summer of 2018**

data collection and reporting processes. Sections *IV.A, IV.B* and *IV.C* provide required information to engineering programs for practical implementation of such practice. However, as clearly highlighted in the literature review of this study, manual CQI systems are severely limited for implementing authentic assessment practices since the data collection processes are time consuming, making them unsustainable. Therefore, as suggested in section *IV.D,* web-based software and embedded assessment technology such as that of *EvalTools* ® and *FCAR + specific/generic PIs methodology* offered automated data collection features for sustainable reporting of accurate outcomes data for both quality and accreditation, and impact evaluation purposes [56], [76]. This method was shown to be sustainable since faculty members spend just 5-8 hours additional time per course and have implemented these processes systematically and seamlessly since Fall 2014 [56], [76]. Several essential elements, such as those mentioned in section *IV.E,*were implemented to ensure the multi-term SOs data attained a high level of statistical power. A couple of million documents of evidentiary data in the form of course materials, student work and CQI information was made available on a cloud based environment. ABET evaluators were provided access to this display material using *EvalTools* ® *Remote Evaluator Module* resulting in a very successful 6 years full accreditation in 2020 listing just strengths without any deficiency, concern or weakness. The application of rubrics for linking performance criteria (using regression analysis) to the trend analyses for Sos, counteracted any need for control or comparison groups thereby providing an effective and practically feasible alternative for conducting credible impact evaluations.

VIII. LIMITATIONS

In this study, we focused on a non-experimental approach for impact evaluations using regression methods and rubrics without explicit comparison groups. The scope of this research just covered one PDCA quality cycle Q5 with multi-term SOs review. But, as stated by Onwuegbuzie and Hitchcock (2017), and White and Raitzer (2017), impact evaluations should also incorporate mixed methods approaches for each phase to thoroughly address the required rigor of credible evaluations [49], [73]. The context, construct, causal links of the process, their underlying assumptions and meta-analyses of both product and process should be tested thoroughly. Future research will entail a comprehensive and detailed study of each of the 6 PDCA quality cycles that include all the processes and aspects of the IQMS implemented in these Engineering programs by applying a comprehensive meta-framework proposed by Onwuegbuzie and Hitchcock (2017) [49].

IX. CONCLUSION

Student outcomes are the internationally accepted quality standards for evaluating accountability and student achievement for engineering programs [1], [11]–[16]. Any evaluation of impact of program interventions in engineering education, especially for quality and accreditation purposes, should focus on attainment and progressive improvement in performance of the SOs. By far, the most challenging aspect of accreditation was implementing traceable CQI with tangible improvements from outcomes assessment results [19], [21]–[24], [26], [30], [31], [34]–[41], [44], [45], [54]. Fergus (2012), who was the chair of the ABET Engineering Accreditation Commission, emphasized the need for limiting the sampling for outcomes assessment to make it manageable for manual CQI processes [19]. However, the tradeoff between quality and the amount and type of outcomes data is impractical to achieve manually, since sampling models, frequency and methods of collection are critical requirements that have to be designed carefully to achieve heterogeneous and accurate data. According to authentic OBE theory and the opinions of assessment and quality experts referred to in the introduction to this paper, the two aspects related to data are interchangeable. Sufficient amounts of accurate data have to be sampled appropriately, collected using precision methods and evaluated accurately [76]. When outcomes data is not collected in all courses, using multiple assessments, at various phases of the curriculum, and for all students, then engineering programs cannot attain real-time improvement since they do not have sufficient information to accurately identify failures for any given student, course or assessment. Any CQI model which does not solve problems on a real-time basis but relies on a deferment plan, does not satisfy the requirements of CQI at all. Therefore, manual CQI systems adopt program-centered models to fulfill minimal accreditation standards and do not address the urgent learning needs of current students. Unfortunately, as mentioned in the literature review of this study, manual CQI systems present several issues related to validity and reliability, and statistical power of the SOs data collected. Therefore, engineering programs that employ obsolete assessment methodology and manual CQI systems are forced to employ other means for collecting the necessary data for evaluations [56], [76]. Consequently, programs end up spending additional time and resources to develop and execute plans for credible impact evaluations that may include independent activities and not related to the time consuming activities already completed to ensure quality. The authentic OBE frameworks and digital solutions presented in this study provide a guide for programs on practical measures that can be adopted to avoid reinventing the wheel when it comes to quality and accreditation efforts or conducting credible impact evaluations. The quality of SOs data collected for accreditation achieved significantly higher statistical power and accuracy that enabled credible impact evaluations.

Onwuegbuzie and Hitchcock (2017) stated that programs should conduct a rigorous evaluation of impact, either prospectively or retrospectively by using a credible counterfactual to compare outcomes to those without application of the intervention under observation [49]. They suggested identifying such control or comparison groups to avoid confounding factors, selection issues, and misinformation leading to a spurious relationship between the intervention and its outcome [49]. The EE, CE and ME programs were assigned stipulated amounts from institutional budgetary allocations to cover costs for implementing CQI processes, preparation of self-study, procurement of required infrastructure and other resources to manage the ABET accreditation visit in 2019. Institutional budgetary allocations did not officially recognize the requirement for any additional spending on control or comparison groups functioning as counterfactuals due to difficulty in maintaining an anamolous observatory cohort in a mainstream educational setting and the lack of any mandate from international engineering accreditation agencies like ABET or the IEA's Washington Accord [1], [11], [16]. Therefore, instead of using counterfactuals, multi-term SOs were evaluated using regression trend analyses to confirm the impact of implementation of the IQMS at the CE, ME and EE programs of the Faculty of Engineering. The multi-term SOs data served as a better option to study impact of interventions since this data was quantitative, heterogeneous, valid and reliable. This was due to being collected from all students using direct assessments and state of the art digital technology, under the strict monitoring and supervision of dedicated staff, and following world class assessment practices. Multiple issues regarding management of control and/or comparison groups and strict regulation of interference conditions, or spurious relationships with interventions were totally avoided. Multi-term executive summary reports showed detailed reflections, corrective actions; and the CIMS system recorded improvements with thousands of actions and evidentiary CQI documentation [56], [76]. Multi-term SOs trend analyses with forecasted results showing improved SOs performances reinforced the decision of program committee reviewers, EAC members and other stakeholders to qualify the ME, CE and EE programs as *Meeting* or *Exceeding Expectations* in regards to attainment of SOs. In conclusion, the findings of this study provided evidence of a viable digital solution based on authentic OBE assessment methodology to collect accurate multi-term SOs data for conducting credible impact evaluations, without incurring additional resources other than those needed for quality and accreditation efforts.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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