Developing Critical Thinking in a First-Year University Chemistry Course

by

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ABSTRACT

Critical thinking is a key quality in learning first-year university chemistry. And therefore, teaching critical thinking enables students to take a stance on scientific issues, to logically rationalise the issue under discussion, to detect fallacies in arguments, or to suspend making of a decision when there is insufficient proof to trace and sustain a conclusion. The aim of this thesis is to examine the perceptions of university lecturers towards the integration of critical thinking into their teaching and how they develop critical thinking in their students. The literature has limited research on teaching strategies and activities that foster critical thinking in first-year university chemistry students in New Zealand, a shortcoming this thesis addresses. The thesis asks how critical thinking is planned, enacted and assessed. Using a case study of lecturers, their perceptions about critical thinking and perceived barriers to promoting critical thinking are described.

Universities have a responsibility, with the support of lecturers, to develop teaching models of best practice to enable students starting from their first year of university to develop critical thinking skills. As such, the descriptive method to case study was carefully chosen, as it permits data to be collected from several sources as are considered suitable to provide in-depth evidence. The research was conducted through an interpretivist approach with the use of the research questions. It utilised both qualitative methods, which included lecture observations, interviews, and document analysis to address research questions and, quantitative methods, which included the use of surveys. The research explored what students thought about the critical thinking experiences they received through a focus group with the students.

In West University, nine university lecturers and approximately 740 students from a New Zealand university in an urban centre, was the target population. Data were collected from voluntary student participants in first-year chemistry enrolled in 2015/2016 academic sessions, and there were nine lecturers involved in teaching at this level. Findings were derived from the data collection. Eight case studies were formed from data analysis of lecturers' interviews, surveys

and observations of their teaching, and feedback was generated from the students.

Not only can the findings of this study be transferred to other contexts where chemistry is taught in universities, but it can also be transferred to other subjects as well. The findings highlight that:

- Lecturers are moderately involved in supporting students to develop critical thinking in CEM1880 and CEM1881, but they do not plan to include critical thinking specifically.
- There was a misalignment between the planned curriculum and the assessed curriculum, and critical thinking was not explicitly assessed.
- The contribution of the first-year chemistry course to the achievement of the university's graduate attribute of critical thinking is minimal at best.

The discussion highlights:

- The assumption that critical thinking teaching strategies were practised in first-year chemistry classes at West University was false.
- Lecturers' lack of knowledge of how to teach critical thinking explicitly within the context of this study; and
- Critical thinking was not deliberately included in the planning, nor was it explicitly enacted and assessed in the first-year chemistry course that was the focus of this study.

The thesis shows the importance of infusing critical thinking into teaching and learning in chemistry education. The significance of this study is that it prompted a commitment to change assessment items and created an awareness and immediate impact of integrating critical thinking into teaching practices.

GLOSSARY

The lack of uniformity in the use of terms to discuss critical thinking and how lecturers describe their teaching practice in higher education is apparent in the review of the literature. Several authors refer to critical thinking as problem-solving or decision making, while some refer to 'lecturing' as 'traditional lecture method'. Some authors use the process involved in engaging students in critical thinking as active learning or learner-centred, and learner-focused. This study uses active learning as a means of integrating critical thinking into teaching practices. This terminology pandemonium increases the rigour in exploring this topic with many of these terms used synonymously. The following definitions and synonyms are provided to enable the reader to understand the meaning that the researcher has given to these words within the context of this thesis.

Active learning: meaningful learning, deep learning, learner-focused, learner-centred.

Active learning is a form of learning in which teaching strives to involve students in the learning process more directly than in other methods. Active learning can occur with the use of critical thinking. Active learning is an alternative to alternatives to rote learning. Any method that facilitates active engagement of students with the material to be learned.

Critical thinking: problem-solving, higher-order thinking.

Critical thinking is a progression of thinking that is intended to lead to a comprehensive, defensible choice, inference or result rather than a category of thinking while higher-order thinking requires learners to use their knowledge in a variety of domains, perform critical analysis, and solve problems.

Critical thinking is a purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based while problem-solving included higher-order thinking skills such as visualisation, association, abstraction, comprehension, manipulation, reasoning, analysis, synthesis, generalization each need to be managed and coordinated.

Critical thinking is the process of developing in thinking that results in better understanding capable of evidential argument.

Discipline: field, subject, topic, course, class.

A branch of knowledge, typically one studied in higher education.

Higher-order thinking: critical thinking.

Critical thinking is a higher-order thinking ability.

Interactive lecture: active teaching, flipped classroom, blended learning.

Interactive lectures are classes in which the instructor incorporates engagement triggers and breaks the lecture at least once per class to have students participate in an activity that lets them work directly with the material.

Interactive teaching approaches: student-focused.

Student-centred methodologies that actively engage students.

Learner-centred: learner-focused.

Student-centred learning, also known as learner-centred education, broadly encompasses methods of teaching that shift the focus of instruction from the teacher to the student. Active learning occurs when teaching is learner-focused.

Learning outcomes: learning intent.

The intention of learning outcomes is to make it clear to the students what they, as learners, are expected to achieve as a result of having successfully completed the course. It identifies what the learner will know and be able to do by the end of a course or program.

Learning objective: aim, focus.

An assessment tool that allows a teacher to quantify his/her impact on student achievement as measured within the parameters of a particular academic or elective standard.

Lecturer: educator, teacher, faculty member, academic staff.

A person who gives lectures, especially as an occupation at a university or college of higher education.

Lecture-based: chalk and talk, traditional teaching approach, traditional style.

Lectures delivered in traditional style. An oral presentation intended to present information or teach people about a particular subject, for example, by a university lecturer.

Lecture model: method of teaching, teaching practice.

An oral presentation intended to present information. Lecture model is used to convey critical information, history, background, theories, and equations.

Memorisation: rote learning.

The process of committing something to memory or learning something by heart.

Pedagogy: teaching practice, teaching strategy, teaching approach, teaching instruction, instructional, lecture method, teaching practice.

The method and practice of teaching, especially as an academic subject (such as chemistry).

Perception: insights, views.

The way in which a concept is understood or interpreted.

Rote-learning: surface learning, rote memorisation.

A memorisation technique based on repetition. The idea is that one will be able to quickly recall the meaning of the material the more one repeats it.

Skills: ability, aptitude, competence, prowess, mastery.

The ability to do something well or have expertise.

Teaching strategies: teaching activities, teaching practices, approaches to teaching.

Teaching strategies refer to different available learning methods used to help students learn the desired course contents and be able to develop achievable goals in the future.

Training: professional development, professional training.

The action of teaching a person a particular skill and the action of undertaking a course.

ACRONYMS

CAT	Critical-thinking Assessment Test
CCTST	California Critical Thinking Skills Test
CCTT	Cornell Critical Thinking Tests
CGPA	Cumulative Grade Point Average
CT	Critical Thinking
CTIPCS	Critical Thinking Interview Profile for College Students
ECTET	Ennis-Weir Critical Thinking Essay Test
LOG	Lecture Observation Guide
NZC	New Zealand Curriculum
ITI	Intellectual Trait Inventory
IUPAC	International Union of Pure and Applied Chemistry
STEM	Science, Technology, Engineering and Mathematics
UCSCTST	University Chemistry Student Critical Thinking Skill Test
ULCTS	University Lecturer Critical Thinking Strategy
WCTA	Watson-Glaser Critical Thinking Appraisal

DECLARATION

I certify that this thesis does not incorporate without acknowledgement 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.

Signed

Yetunde Kolajo

Date

May 2020

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PEER REVIEW

There is a peer-reviewed conference paper from this thesis accepted by the American Educational Research Association (AERA) with three reviewers' report. The details are as follows:

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There is a peer-reviewed book chapter publication in press from this thesis. The details are:

Kolajo, Y. A. & Conner, L. N. (*in press*). The chemistry of critical thinking: the pursuit to do it better. In P. Blessinger & E. Sengupta (Eds). *International Perspectives on Improving Classroom Engagement and International Development Programs: Humanizing Higher Education* is part of the series titled Innovations in Higher Education Teaching and Learning (IHETL) Emerald Group Publishing Bingley, United Kingdom. The target book release date is August 2020.

CHAPTER 1.
INTRODUCTION

"…critical thinking is a progression of thinking that is intended to lead to a comprehensive, defensible choice, inference or result rather than a category of thinking" (Vardi, 2013, p. 1)

1.1 Introduction

This study investigates the critical thinking teaching practices of lecturers in a New Zealand university first-year chemistry course. This chapter situates the study in a broad context by outlining the researcher's interest in the development of first-year chemistry students' critical thinking skills, the importance of critical thinking, the graduate attributes, the statement of the problem, study aim and research questions, the significance of the study and the New Zealand context of the study. This chapter will define critical thinking and outline the thesis structure.

1.2 Researcher's Perspective

This section outlines what prompted the researcher to investigate the development of critical thinking in a first-year chemistry course. Based on personal experience, it is the perspective of the researcher, that teaching chemistry at the university level should provide a holistic learning experience for students, rather than an emphasis on the memorisation of content knowledge to pass examinations throughout the degree. The researcher's undergraduate learning journey where there was limited opportunity and support available to enable her to process and develop an in-depth understanding of chemical concepts, and to recall and apply the knowledge after tests and examinations shaped her perception. That is, the emphasis on memorisation was perceived to have a negative effect on learning and further pursuit of the subject. This personal experience stimulated the researcher's curiosity in exploring the teaching practices of university lecturers. This thesis investigates the development of students' critical thinking skills in a first-year chemistry course in New Zealand. This study does not set out to compare the teaching practices between countries. Rather, it aims to investigate how lecturers in a New Zealand university are developing critical thinking in a first-year university chemistry course.

1.2.1 Critical Thinking Defined

The definition of critical thinking adopted for this study was from the work of Paul and Elder, Vardi and the published Delphi research project (P. A. Facione, 1990; Paul & Elder, 2008b; Vardi, 2013). The 1990 consensus definition by research experts stated that critical thinking is "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment" (P. A. Facione, 1990, p. 3). As the definition indicates, critical thinking is not seen as a stand-alone skill, but rather as a combination of a number of processes, higher-order cognitive skills, information, and perception, including, but not limited to analysis, inference, evaluation, explanation and interpretation. Additionally, critical thinking is described as a progression of thinking that is intended to lead to a large defensible choice, inference or result rather than a category of thinking (Vardi, 2013). It is also the mode of thinking about any subject, content, or problem in which the thinker improves the quality of his or her thinking by skilfully applying logical reasoning, the structures inherent in thinking, and intellectual standards (Paul & Elder, 2008b).

1.3 The Importance of Critical Thinking

Skill development has been identified as an important part of undergraduate education and a main goal of chemistry curricula (Klein & Carney, 2014). Furthermore, dealing with people often involves thinking (Paul & Elder, 2012c). Paul and Elder argue that we make sense of the world by thinking, and it would be difficult to understand anything without thinking. Thinking tells us what we know or believe. Paul and Elder (2012c) identified that quality of life depends on the quality of thought. Egege and Parker (2019) argue the importance of critical thinking is the application of knowledge in relevant contexts, given that students are future teachers, doctors, chemists, decision-makers, the voters and policy writers. They believe that students require critical thinking to be open-minded to alternative approaches and ideas and be willing to adapt and learn in line with new information (Egege & Parker, 2019, p. 1).

Acquiring the skill of critical thinking is a key feature that distinguishes higher education. Egege (2009) believes that critical thinking is prominent in many university graduate attributes, and a lack of it can affect academic achievement. In the same vein, critical thinking creates value, it takes effort but has clear, practical benefits that far exceed the effort, it produces better students' academic achievement (Nosich, 2012, p. 195).

Given that learning occurs through thinking and thinking is driven by questions (Paul & Elder, 1998, 2008a). DeWit (2006) suggests that first-year chemistry courses should be designed in a way that empowers students to understand, explain and predict rather than merely memorise the content. Panettieri (2015) supported the importance of critical thinking. Panettieri believes that deeper learning is associated with critical thinking. Similarly, Kanbay and Okanlı (2017) found that critical thinking improves academic success. Critical thinking is promoted in many disciplines to equip students with relevant 21st-century skills (Stone, Duffy, Pinckney, & Templeton-Bradley, 2017). Research studies in nursing, economics, psychology, business studies, geography and environmental management have demonstrated the importance of critical thinking to improve understanding, academic success and effective learning.

Critical thinking is beneficial to effective learning and problem-solving in chemistry. It focuses on the process of elaborating knowledge construction by way of accurate and valid conclusions (Stoica & Muraru, 2015). Evidence suggests a positive demonstration and correlation between critical thinking and problem solving (Larissa Bertacchini de, Leidy Johanna Rueda, Fábio Da Costa, Adriano Rogério Baldacin, & Vilanice Alves de Araújo, 2016). Critical thinking is for long-lasting learning, and it is the desired outcome of any university for its students (Abrami et al., 2008). According to Paul, "only a substantive concept of critical thinking affords the durability, flexibility, and richness of detail essential for planning long-term professional development to serve that end" (2005, p. 28). Hence, it can be understood that critical thinking is important to effective learning and problem-solving in chemistry.

Furthermore, critical thinking is important because employers demand individuals with critical thinking skills (Stowe & Cooper, 2017). Thus, developing critical thinking skills extends beyond the university classroom; it is an extension of daily life. Specifically, critical thinking is important for competent chemists to have the capacity to develop and apply chemistry knowledge and understanding when employed in industries external to the university.

Similarly, critical thinking is an essential skill recognised in the education system in different disciplines around the world (David & Brown, 2012; Kusumoto, 2018), no wonder it has become an important part of the university graduate attributes.

1.4 Graduate Attributes

Graduate attributes are the qualities, skills and understandings that a university community identifies that its students should develop during their time with the institution (Bowden, Hart, King, Trigwell, & Watts, 2000). These attributes include, but are not limited to, the disciplinary expertise or technical knowledge that has traditionally formed the core of most university courses. They are qualities that prepare graduates as agents of social good in an unknown future. According to Crosthwaite, Cameron, Lant, and Litster (2006), transferable graduate attributes are expected of graduates by employers.

Additionally, entrance to a postgraduate university program requires the applicant to employ critical thinking skills in the preparation and presentation of the application. This ability is considered a graduate attribute (Haigh, 2016). Therefore, critical thinking contributes to graduate attributes (Ahmed, 2018; Behar-Horenstein & Niu, 2011), whereby students must demonstrate the ability to connect ideas and question the importance and relevance of everything.

As such, the New Zealand university where this study took place expects the following five graduate attributes from their students: critically competent in a core academic discipline of their degree, employable (critical thinking skills), innovative and enterprising, biculturally competent and confident, and engaged with the community and globally aware. Similarly, Whelan (2017) claimed that graduate attributes and course learning outcomes are an integral part of higher education in Australia. Lloyd and Bahr (2010) argue that any presumptuous perception by lecturers about teaching critical thinking may limit the achievement of graduate attributes. However, some lecturers may anticipate fully developed critical thinking skills of their student at the beginning of their first year, which is not necessarily the case. Lecturers want students to question more and be "less accepting of facts" (Grussendorf & Rogol, 2018). For this to occur, critical thinking must be taught and potentially be explicitly focussed upon.

1.5 Statement of the Problem

The problem of this study is best understood by firstly defining critical thinking and why it is important in the teaching of chemistry at the tertiary level. Critical thinking is defined as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as an explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based" (P. A. Facione, 1990, p. 3).

Also, critical thinking is a "progression of thinking that is intended to lead to a comprehensive, defensible choice, inference or result rather than a category of thinking" (Vardi, 2013, p. 6). Pedagogic progression is an educational response to, and engagement with, evidence-based developmental trajectories of learning (Siraj-Blatchford, 2009). The progression of thinking is known as the comprehensive knowledge of a whole new process of thinking which could be referred to as "lateral thinking" (McVey, 1995, p. 93). According to De Bono in Whitney (1992), lateral thinking is a logical, progressive and creative way of processing thoughts. McVey (1995, p. 96) argues that "one must progress in thought, from the known into the unknown". James, Hartzler, and Chen (2016, p. 772) found in their study that students progressed in their overall critical thinking skills throughout a three-year sequence of pre-pharmacy courses while some students failed to progress in their contextual skills of critical thinking and the implication for lecturers were to develop the students' critical thinking ability.

Secondly, critical thinking is important to chemistry education. Chemistry is the study of matter and chemists interpret the world from an atomic perspective. According to T. L. Brown (2009), chemistry is about understanding the properties of different substances and how these substances can change.

Chemistry allows the prediction of how substances may alter when the surrounding conditions change. As such, chemists are continually changing matter into new and more useful forms (Talanquer, 2013). Therefore, if chemistry allows the prediction of how substances may alter when the surrounding conditions change, it is then the educator's responsibility to apply critical thinking skills into these predictions to avoid possible future disaster and to educate tertiary students with the adequate process of being a competent chemist. In other words, in the education of tertiary students, educators have a responsibility to include critical thinking. This prompts investigation of the link between chemistry and critical thinking to understand better if, how and why lecturers are developing students' critical thinking skills.

Chemistry as a subject involves understanding chemical concepts, mechanisms, equations, reactions, elements, and making a sound judgment. Chemistry is the science that deals with the composition, structure and behaviour of atoms and molecules, which make up all forms of matter (Atkins, 2013). As in other science domains, chemistry knowledge is based on evidence. A relationship exists between the understanding and application of chemical concepts and higher-order thinking ability, such as analysis and evaluation (White et al., 2016).

Chemical ideas evolve. The field of chemistry is dynamic in that it changes, grows and evolves, which embody a distinctive way of looking at the world. A chemist should know how to use information and the concepts that structure the information. They know how to synthesise the information, how to think about chemistry and how to think within chemistry (Nosich, 2012, p. 94). The logic of the field of chemistry is the reasoning behind the field which Nosich describes as "Element of Reasoning" from the Paul-Elder critical thinking framework (Chapter 2 discusses in detail the elements of reasoning). Therefore, "chemistry requires higher-order thinking skills in addition to content knowledge" (Uzuntiryaki-Kondakci & Capa-Aydin, 2013, p. 666). Some scholars (e.g.Buckley, 2012; Xiang & Liu, 2017) have identified that higher-order thinking ability is a form of thinking that leads to critical thinking. Higher-order thinking should not be confused with critical thinking. According to Lewis and Smith, "higher-order thinking occurs when a person takes new information and information stored in memory and interrelates and/or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations" (1993, p. 136). Scientists need to develop curiosity and inquiry as to how this evidence was derived and what procedures and level of rigour were used to develop this knowledge. As such, this study argues that critical thinking is crucial to chemical education. To become graduates who can think critically, students need to appreciate the tentative nature of chemistry knowledge and question its reliability and validity.

Paul (2005) argues the disturbing state of critical thinking within higher education. He believes that lecturers lack a substantive concept of critical thinking; most lecturers not realising that they lack a substantive concept and instead of believing that they understand critical thinking sufficiently and are already successfully teaching it within their discipline. Also, he states that despite reform efforts, lecture, rote memorisation, and (largely ineffective) short-term study strategies are still the norm in university instruction and learning today (2005, p. 1). The researcher's stance for this study is that university chemistry lecturers play a critical role in developing students' critical thinking skills and this is important to produce reflective scientists able to engage in experimental work and decision making that may affect human life.

Another problem identified in the literature is the notion that memorisation hinders retention and content application (e.g. Tiruneh, Verburgh, & Elen, 2014). Paul and Elder (2008b) make the point that a fundamental aim of learning is to be able to think critically. A distinct trend in education is to develop students' ability to think critically as a means of understanding. However, DeWit (2006) attests to the exposure of first-year university chemistry students to a large number of principles and facts which encourages the memorising of facts and definitions.

Whether the university teaches students to think critically is a concern. Grussendorf and Rogol (2018) argue that universities do not teach critical thinking. A ramification of this is that students cannot question assumptions, let alone evaluate evidence, and are unable to engage in effective decision-making or challenge scientific stance. Bao emphasises that the development of scientific abilities is "critical to enable students of science, technology, engineering, and mathematics (STEM) to handle open-ended questions successfully, real-world tasks in future careers” (2009, p. 1). Thus, STEM teaching goals reflect cognitive abilities such as critical thinking and reasoning which are considered as transferable scientific abilities important for students to learn STEM content knowledge.

Organic chemists believe that chemistry is a lot like diagnosis, and without analytical thought processes, a valid conclusion is not attainable (Stowe & Cooper, 2017). Stowe, for example, claims that a chemist should be able to draw an analogy between problem-solving in organic chemistry and diagnosis of a disease. They believe that problem solving develops critical thinking skills.

1.5.1 Concerns about the Future of Chemistry

There is considerable concern about the decline in positive attitudes of secondary students towards science. The concern with a decline in secondary chemistry students may affect the number of enrolments of tertiary chemistry students. Research has found that positive attitudes to secondary school science decline significantly between the ages of 11 and 14 years, with female students displaying less positive attitudes (Bennett & Hogarth, 2009). Another study linked the uptake of physical science subjects to a predicted shortage of students choosing to pursue careers related to science, technology, engineering and mathematics (Bennett, Lubben, & Hampden-Thompson, 2013). Bennett et al. (2013), further highlighted a fall over the last 20 years in university entries in chemistry and physics. This study found that one reason for the decline of students in physical science, specifically chemistry, was the learning experiences of these students. The implications of this finding could be linked to the teaching approach in chemistry, such that a lack of engagement or interaction could lead to students’ inability to understand and apply knowledge, but, rather, simply to memorise it. The teaching and learning process itself could discourage interest in chemistry and the will to pursue any of the STEM subjects at the university level.

Similarly, Gillespie (1991) expresses concern over decreased enrolment, and he argues that though chemistry is the central science, there is a decrease in the number of first-year university students who opt to major in chemistry. Gillespie states that students find chemistry ‘uninspiring, uninteresting, irrelevant and one of the most difficult courses’ (1991, p. 192). Similar to Gabel, Gillespie also outlines that the major problems facing chemistry, such as too much material, that the course content is determined too much by the perceived needs of chemistry majors, and that there is not enough for the needs of the majority of the students in the course, as well as there being too much difficult and abstract theory. Gillespie advocates for fewer facts and content and more understanding so that students do not need to memorise facts. With regards to chemistry assessment, Gillespie further states that there is a need for a variety of qualitative questions to test students' understanding, rather than quantitative problems (i.e. multi-choice questions) which encourage the memorisation of facts (1991, p. 864).

The complex nature of chemistry is another barrier to the teaching of the subject. A study by Gabel (1999) revealed that she believed some concepts in chemistry are abstract. Gabel believed that in order for learning to occur, students need to connect their learning to their long-term memory to understand new concepts. Short-term memory has a limited capacity for a student to process new information and retain chemical concepts. As such, Gabel suggested stimulating students' learning by constructing knowledge in a social context. Gabel believed that "students are affected by the setting in which they learn" (1999, p. 551).

Another concern is the decrease in retention of chemical knowledge. This concern was argued by Habraken (1996), who noted that chemical content had been taught the same way for over 50 years. Habraken discussed that the decline in the numbers of students choosing chemistry as a major for the last three decades is a concern of chemistry as a discipline. This is a problem because a decline in enrolment might mean a decrease in the possibility of discoveries in chemistry. Habraken calls for a new approach to teaching chemistry.

Given the concerns in chemistry education today, this thesis emphasises a critical thinking approach to teaching and learning.

1.6 Aim and Research Questions

This study aims to investigate how lecturers are developing students' critical thinking in a first-year university chemistry course. The following research questions will guide the study:

1. What are university lecturers' perceptions of critical thinking?
2. How is critical thinking being planned, enacted and assessed in the first-year chemistry courses at this university?
3. What factors, if any, do lecturers perceive as obstacles to fostering critical thinking in their course?

This study contends that critical thinking is crucial to quality university teaching related to chemistry education. This study proposes that critical thinking is a process of thinking for learning purposes (Ahern, Connor, McRuairc, McNamara, & Donnell, 2012) and course-specific. The benefits of critical thinking are accumulated over time (Grussendorf & Rogol, 2018).

1.7 Significance of the Study

Numerous works have been published about the increasing interest of lecturers in improving students' critical thinking skills (Cheng, Ferris, & Perolio, 2018; Heijltjes, van Gog, Leppink, & Paas, 2014). However, limited literature has been published describing how lecturers are developing first-year students' critical thinking at the university level in chemistry in New Zealand. This study is in line with the findings of Abrami et al. (2008), which made clear that the improvement in students' critical thinking skills and disposition cannot be a matter of implicit expectation. This research calls on Kennedy et al.'s project that aimed at transforming tertiary science education by improving learning during a lecture (2013). The associated report established that lectures are still being used to teach in science education, and learner-centred teaching would promote active engagement. Therefore, this study is significant for the following reasons:

- It highlights the importance of critical thinking to tertiary chemical education.

- It contributes to the New Zealand context, and the literature on critical thinking.
- It contributes to the STEM curriculum priority to increase the proficiency of all students in STEM skills.
- It examines the teaching practices of university lecturers related to embedding critical thinking.
- Makes a series of recommendations about teaching critical thinking.
- It indicates gaps between current and future teaching and learning practices in the university.

Critical thinking has been suggested to be at the forefront of teaching approaches for chemistry courses in universities. Adopting critical thinking as a teaching method would benefit the world of scientific discovery and possibly lead to increasing the number of chemistry teachers, amongst other reasons. Given that research has shown that some students lack critical thinking, research findings encourage the integration of critical thinking into teaching practices. For example, in a recent study on critical thinking of nursing students in Australia, Abrami, Venkatesh, Meyer, and Wade (2013) found that a significant number of students lacked fundamental scientific reasoning skills. Scientific reasoning should not be confused with critical thinking, though scientific reasoning is a form of thinking that leads to the development of critical thinking within the sciences (Zimmerman, 2000).

The individual student will benefit more from a curriculum aimed at building thinking skills (Dewey, 1997). Furthermore, critical thinking transforms both the act of learning and the possibilities of both achieving the curriculum learning objectives and suitable assessment. With this in mind, the researcher noticed that developing critical thinking in a first-year university chemistry course through specific critical thinking teaching approaches lacks rich references in the literature and evidence in research within the New Zealand context.

This study was purposefully designed for the New Zealand context because research on developing critical thinking in a first-year university chemistry course in New Zealand was found in the literature to be in its infancy. Given that critical thinking teaching strategies will provide chemistry students at the university level more support in their learning journey, the researcher believes continuing the pedagogy early in the first year of the students' study would be more useful for developing a comprehensive and solid foundation, rather than in the third or fourth years. The researcher believes that introducing the pedagogy in the third or fourth years would be less effective as students might have omitted some fundamental knowledge and principles while memorising and, therefore, be left with a poor content knowledge base to build on.

The New Zealand curriculum framework (New Zealand Education Review Office, 2012) became of interest to the researcher because of its key competency that supports the development of students' critical thinking at the secondary level. With the national framework, secondary schools are expected to implement the curriculum to best suit the needs of the learners. As such, it becomes an assumption that both students and teachers from secondary level through to tertiary would be familiar with the practice of the concept of critical thinking and the processes involved in the teaching of critical thinking.

The New Zealand context contributes to the literature and the participants for two key reasons. The contribution to the literature is because New Zealand has a future-focused framework curriculum that fosters the development of capabilities for living and lifelong learning such as critical thinking (Gallagher, Hipkins, & Zohar, 2012). This curriculum encourages the combinations of the various curriculum elements resulting in a well-suited setting for critical thinking growth in students (*The New Zealand Curriculum*, 2007). The New Zealand Curriculum (NZC) contributes to the participants in that students are given the opportunity to develop their thinking skills in every aspect of learning. In other words, critical thinking is integrated into all the subjects taught to secondary students. This is evident because the five key competencies integrate knowledge and skills with attitudes and values (Gallagher et al., 2012, p. 137).

Some of the participants in this current study who have come through the New Zealand education system will have experienced the integration of critical thinking activities into their learning. The 1992 New Zealand national curriculum was revised in 2007. The curriculum is a clear statement (New Zealand Education Review Office, 2012) and is also referred to as "a future-focused framework curriculum" (Gallagher et al., 2012). The vision statement has a set of principles, values and key competencies which the New Zealand Government identified as important in education (Benade, 2009). The five key competencies of the curriculum claim to be critical to sustain learning and effective participation in society and underline the emphasis on lifelong learning. The first of the five competencies are "thinking". The curriculum defines thinking as "using creative, critical and metacognitive processes to make sense of information, experiences and ideas" (New Zealand Education Review Office, 2012, p. 12). Also, "the main criterion for entry to New Zealand universities is some form of evidence of academic performance at secondary school, which provides a level of confidence that the qualifying students will succeed at university study" (Shulruf, Hattie, & Tumen, 2008, p. 685). Keane and Blicblau (2012) state that students in the 21st century need what is called the 3Rs (reading, writing and arithmetic) and also need to embrace the 4Cs (collaboration, creativity, critical thinking and communication) as part of the fundamental building blocks that underpin learning (Keane & Blicblau, 2012).

Secondly, this study contributes to the science, technology, engineering and mathematics (STEM) curriculum priority. The goals of STEM are to increase the proficiency of all students in STEM and grow the number of students who pursue STEM careers and advanced studies (Thomasain, 2011). This is because "STEM occupations are among the highest paying, fastest-growing, and most influential in driving economic growth and innovation" (Thomasain, 2011, p. 5). Universities and other post-secondary institutions provide the required STEM graduates (Thomasain, 2011, p. 19). Therefore, the need arises for future chemists to be critical thinkers to contribute to STEM agendas for innovation and creating new knowledge. To understand the discipline deeply involves engagement with evaluating and synthesising information critically. Piaget puts it elegantly, saying, "The principal goal of education in schools should be creating men and women who are capable of doing new things, not simply repeating what other generations have done" (Piaget, Varma, & Williams, 1976, p. 44).

Due to the numerous tools designed to increase critical thinking and the claim that university graduates are not necessarily good at using critical thinking, the contribution to knowledge of this thesis is the examination of the teaching practices of the participating university lecturers, analysis of the data collected, synthesis of the findings, and reporting on how critical thinking teaching strategies were used or not by university chemistry lecturers to develop critical thinking in their students. This study analyses what instructional strategies were practised to develop students' critical thinking skills. It also examines lecturers' perceptions of critical thinking and approaches to teaching. The information was recorded through a face-to-face, semi-structured interview with the lecturers, lecture observations, questionnaires, document analysis and a focus group with the students. The research explored what students thought about the critical thinking experiences they received. Not only can the findings of this study be transferred to other contexts where chemistry is taught in universities, but it can also be transferred to other subjects as well.

In this study, an attempt is made to answer some fundamental questions surrounding critical thinking at the university level as it relates to teaching. Lecturers' critical thinking teaching strategies are discussed. This research is a significant addition to the literature and the body of knowledge in this area. The contribution that would be made would be a more in-depth insight into teaching practices of university lecturers teaching first-year chemistry in a New Zealand context by use of a case study. This is an important contribution to the discussion of integrating critical thinking in tertiary chemical education and creating awareness about critical thinking in the New Zealand context adding to the limited research findings.

Another feature of this study is the development of a series of recommendations for university administrators in New Zealand and educators globally about how they might further enhance teaching in their universities that promote critical thinking and what might be required for professional development for staff. The contribution of this study will ultimately inform and enhance quality university teaching (Sheffield Jr, 2016). Sheffield Jr (2016, p. 9) argues that thinking in a critical way, regardless of the subject or circumstance, can empower one for a lifetime. He believes critical thinking should be a top priority for all of our students and faculty.

Additionally, through the literature, this study emphasises the importance of the connection between critical thinking and quality university teaching and the role of lecturers in this. It indicates gaps between desirable teaching and learning in a first-year university chemistry course and some barriers for this to occur. Essentially, this study illuminates the critical thinking teaching practices of lecturers in a New Zealand university first-year chemistry course.

1.8 Thesis Structure

A brief explanation of the content of the chapters follows. This overview will enable the reader to understand the structure of the argument of this thesis. Chapter 1 outlines the research focus, and the purpose of the study and the research questions provide the link between critical thinking and the need for the research questions. In other words, the justification for the study is established, and insight to the study provided.

Chapter 2 presents a review of the literature that outlines history, definitions and descriptions of critical thinking. The link between critical thinking and teaching and learning is established. The chapter draws together the research literature as evidence to demonstrate the importance of the current study. Reviews of literature related to planned, enacted, and the assessed curriculum is identified. The chapter examines the theoretical framework for the study and describes the framework.

Chapter 3 discusses the study's formed assumptions based on a theoretical framework, as seen in the review of the literature. These formed assumptions generated the conceptual framework. This helped further justify the study. The elements involved in the theoretical framework, as discussed in Chapter 2 are then combined in Chapter 3 as the conceptual framework.

Chapter 4 outlines the methodology which provides an account of the methods and methodology adopted in this study. The rationale is presented and in addition, how the methods help to answer the research questions is highlighted. Data were collected using semi-structured interviews, lecture observations, document analyses, student focus group and survey from both lecturers and students. Thematic analysis was used for the interviews, lecture observation, student focus group and document analysis. Descriptive statistics were used for the lecturer and student surveys.

Chapter 5 presents the context of the study by providing data about the drivers and background factors that influenced what the lecturers did in their course. The chapter describes the findings from document analysis. The documents analysed are the graduate attribute, the course outlines and the examination paper. Another significant aspect of the chapter is the survey findings from individual lecturers, followed by the responses from the students. Student focus group feedback is also presented and is useful to triangulate the lecturers' interviews.

Chapter 6 describes the data findings collected and analysed from the interviews and observations. The data collected from the lecturers formed the case studies. Rich data that provide an understanding of the differences amongst the case studies are also presented.

Chapter 7 argues the findings, is linked to the literature and provides answers to the research questions. The discussion highlights that:

- any assumptions that critical thinking teaching strategies were practised in chemistry classes at the West University was false;
- there was a lack of knowledge of how to teach critical thinking explicitly within the context of this study; and
- that critical thinking was not deliberately included in the planning, nor was it explicitly enacted and assessed in the curriculum.

Chapter 8 discusses the synthesis of the study. It presents the impact, relevance and consequences of the findings from this thesis. Based on the results of the study, recommendations are made, and a pathway to future research is provided. The conclusion indicates impact and key points that are:

- Lecturers should not assume that students know how to use critical thinking without some role modelling.
- Vital competencies such as critical thinking is developed through effective application of active learning.

- The infusion of critical thinking into the planning, teaching and assessment of the chemistry curriculum in the first-year university requires a change of perception from lecturers.
- There is an opportunity for this group of lecturers to undertake professional learning about critical thinking, especially in the use of questioning techniques.

1.9 Chapter Summary

The global recognition of the need for students to develop a broader set of skills such as critical thinking during the years of formal education and the increasingly problematic inadequacy of knowledge of how these skills are developed gave rise to this study. This chapter provides a concise overview of the background to the critical thinking investigation and establishes a definition that will be used throughout this thesis.

This chapter provides a contextual frame (New Zealand) for the study. The statement of the problem and significance of the study are identified. This introductory chapter has outlined the vital relationship between critical thinking, university education and chemistry. The key message is that this study investigates teaching critical thinking in a subject domain, the perceptions of the lecturers and their application in practice. The significance of this thesis is important for identifying changes needed to teach if we are to produce better university graduates and as a starting point for reforming tertiary education (Low, Hui, & Cai, 2017).

The next chapter reviews the literature on critical thinking and higher education pedagogy.

CHAPTER 2.
LITERATURE REVIEW

"Too many facts, too little conceptualizing, too much memorizing, and too little thinking" (Hurd, 2004, p. 1).

2.1 Introduction

This chapter presents a review of the relevant scholarly literature focused on links between critical thinking and teaching and learning in tertiary education, chemistry education, curriculum design and assessment. The scope of the review includes the classic works by John Dewey, to more recent studies by Peter Facione and Noreen Facione and numerous scholars (Abrami et al., 2008; Brookfield, 2012; Dewey, 1933; Elder & Paul, 2010a; Ennis, 1989; N. C. Facione, Facione, & Sanchez, 1994; P. A. Facione, 1991; Halpern, 2001; Kahneman, 2011; Kuhn, 1999; McPeck, 1990).

While the use of the lecture model to teaching in universities will facilitate wider content coverage, the risk is that students memorise facts and do not develop skills in the application of knowledge. The literature on critical thinking in higher education is regarded as indispensable (Lloyd & Bahr, 2010). A large and growing body of literature has established that the use of interactive teaching approaches would develop students' critical thinking skills. The literature in science, technology, engineering and mathematics (STEM) education, particularly in chemistry education, focuses on the intentional development of students' cognitive abilities. The broader literature in teaching and learning has also underscored the importance of intentionally developing such thinking skills (Toledo & Dubas, 2016).

This chapter locates the importance of critical thinking to university chemistry teaching. This chapter reviews the literature related to the elements that can promote evidence-based teaching strategies; interactive teaching approaches and the importance of universities producing graduates who can think critically. Additionally, this chapter describes the important role of lecturers in being proactive in the students' learning process through quality teaching. The literature examines the types of teaching strategies that can foster critical thinking skills in a chemistry course and this chapter examines how assessment can facilitate critical thinking skills and be structured as a tool to promote critical thinking skills in chemistry students. The concluding section discusses how the literature presented here opens new avenues for research into how university chemistry lecturers are developing critical thinking skills in their students.

2.2 History of Critical Thinking

The literature emphasises the significant contribution of the development of the thinking system in education and the importance of embedding critical thinking into teaching. In seeking to examine the development of students' critical thinking skills and how it became the fundamental component of university education, it is helpful to briefly review its historical development. The history of critical thinking serves as an extension of the importance of critical thinking to education. The following history of critical thinking demonstrates the decades of dedication to the promotion of critical thinking skills. It will articulate the accountability of scholars on the construct of critical thinking, its aim and its importance to teaching and learning. This section explains the history of the cultivation, delivery and implementation of critical thinking as a didactic goal.

The literature on critical thinking has roots in two primary academic disciplines: philosophy and psychology. In contrast, some argue it originated from the work of early scientists and psychologists (Lai, 2011). Sternberg (1986) has also noted a third critical thinking component in the field of education, which he called "the educational tradition". Educational theories are closely tied to classroom observation and experience and the educational theorists respond to students' to think critically and to solve problems. Lai (2011) claimed that Socrates, Plato, Aristotle, and more recently, Richard Paul, exemplify the philosophical approach. In comparison, Vieira, Tenreiro-Vieira, and Martins (2011) concur with Lai (2011) that Plato and Aristotle are founders of the critical thinking movement and created the awareness that education is responsible for teaching people to think, a concept dating back to Socrates. This approach focuses on the assumed critical thinker, demonstrating the abilities of this person, rather than the actions a critical thinker can achieve.

The intellectual roots of critical thinking are as ancient as its etymology, traceable to Socrates, 2,400 years ago. Socrates found that one cannot depend upon those in authority to have sound knowledge and insight. Socrates established the importance of seeking evidence, closely examining reasoning and assumptions. This method of questioning is called Socratic questioning (Paul & Elder, 2012c). Snyder and Snyder (2008) equally established the place of questioning technique as a method of developing students' critical thinking. Nosich (2012) argues that

> "questions are a sign of growth, of opening to new ways of thinking. In the past, we have seen questions as an indication of not understanding. Critical thinking lives in questions" (2012, p. 29).

Socrates' practise was followed by the critical thinking of Plato, Aristotle and the Greek sceptics. In the Middle Ages, the tradition of systematic critical thinking was partially embodied in the writing and teachings of thinkers such as Thomas Aquinas and Felix Markham. In the 15th and 16th centuries, a flood of scholars from Europe began to think critically about religion, art, society, human nature, law and freedom. By the 16th and 17th centuries, Hobbes and Locke also displayed confidence in the critical mind and opened up new ideas about learning. In the 18th century, the concept of critical thinking extended further, developing a sense of the power of critical thought and its tools. In the 19th century, Comte and Spencer extended even further into critical thought of human social life. In the 20th century, increasing explicit formulations of critical thinking emerged. Additionally, in the 1980s, there was increased consideration and appreciation for promoting critical thinking. The 1990s were characterized by the responsiveness and significance ascribed to the use of critical thinking processes in varied situations and within school settings. In the 21st century, depth-psychology and research into critical thinking developed (Paul & Elder, 2012c).

Paul and Elder (2012c) elaborated on the concept of critical thinking and stated that it reflects an idea with roots in ancient Greek. The word 'critical' derives etymologically from two Greek roots: *kriticos* and *criterion*. Together, critical thinking can be defined as "thinking aimed at the sound judgement, using appropriate evaluative standards in an attempt to determine the true worth, merit or values of something", Or, alternatively ‘the Alternatively, put, as "the systematic monitoring of thought with the goal of improvement" (2012c, p. 22).

2.3 Challenges of Defining Critical Thinking

Despite the established importance of critical thinking to education, the concept lacks a unified singular definition. It is important to examine the definition of critical thinking so that it is not confused with other forms of thinking, such as emotive thinking or creative thinking. Creative thought developments draw from the mind and human awareness (Leggett, 2017), characterised by preparation, incubation, illumination and revision or verification (Patrick, 1955, p. 4). On the other hand, according to Z. Chan (2013, p. 1382), creative thinking complements critical thinking and using creative approaches may foster critical thinking. Similarly, Chirico, Glaveanu, Cipresso, Riva, and Gaggioli (2018, p. 124) believe that "creative thinking is the ability to recombine ideas and to find new relationships between them". On the contrary, emotive thinking is responding to the emotion of a message rather than the content (Huitt, 1998). According to J. Brown and Woodruffe-Burton (2015), emotive thinking is the influence of emotions on decision making, which results in irrationality.

To illustrate the diverse range of definitions of critical thinking, some specific examples are presented, highlighting the opinions of scholars in a variety of disciplines. For example, critical thinking involves asking questions, internalising the answers, drawing conclusions on the basis of those reasons, believing the results of your reasoning, and being responsible for the result (Nosich, 2012). In their review, Dwyer, Hogan, and Stewart investigated existing theoretical frameworks of thinking skills and educational objectives and defined critical thinking as a "metacognitive process that, through purposeful, reflective judgement, increases the chances of producing a logical conclusion to an argument or solution to a problem" (2014, p. 43). Similarly, Arsal (2015) considered the concept of critical thinking as rich and unrestricted. He supported the current observation that there were many ways to explain critical thinking. Stephenson, Miller, and Sadler-McKnight (2019) argue that the development of critical thinking is known as one of the key pointers of the quality of student learning.

Furthermore, a variety of scholars from diverse disciplines have sought to define critical thinking and describe its core characteristics. Definitions originate from two schools of thought and vary according to the scholar and their intended research questions. Ennis (1989); P. A. Facione (1998); McPeck (1983) proposed the following definitions based on their analysis of various works. Critical thinking is "the means of using reasoning to arrive at professionally informed decisions when the risks are high, time is not readily available, and problems are complex" (P. A. Facione, 1998, p. 27). This definition is close to that of Ennis (1989, p. 4), who stated 'reasonable reflective thinking focused on deciding what to believe or do', and of McPeck (1983, p. 19), who termed it as 'engaging in an activity with reflective scepticism'.

Another definition stated that critical thinking helps make an informed decision (Vardi, 2013), while Arsal (2015, p. 141) proposed that "critical thinking is self-guided and self-disciplined thinking that attempts to reason at the highest level of quality in a fair-minded way". Halpern described critical thinking as "the process of evaluation of some previously accepted standards" (2014, p. 8). The definition of critical thinking adopted for this study identified in Chapter 1 emphasises critical thinking as a progression, and in the progression of thinking rather than a category, students are able to critically evaluate chemical problems.

Furthermore, critical thinking and Bloom's Taxonomy are sometimes confused because both are necessary to metacognition. Metacognition is the monitoring and control of thought (Martinez, 2006, p. 1). R. Fisher (1998, p. 10) claims that metacognition is thinking about thinking rather than just remembering facts and recalling events. Scholars such as Duran and Dökme (2016) and Živkovil· (2016) argue that students' critical thinking skills can be developed when they are guided through the levels of Bloom's Taxonomy. These levels are: engage in questioning, interpreting, exemplifying, classifying, summarising, inferring, comparing, explaining, applying, analysing, synthesising and evaluating (Dowd, Thompson, Schif, & Reynolds, 2018).

Given the challenge of defining critical thinking, adopting varying philosophical lenses enables a deeper understanding of the description of critical thinking, as significant questions are raised and expanded. For example, Dewey proposes that “critical thinking involves the suspension of judgement and healthy scepticism” (1997, p. 19). From a philosophical perspective, Dewey claims that any school subject may foster critical thinking if teachers base their teaching on challenging the students and encouraging reflection.

One other thing, Sternberg (1986) differentiated between the cognitive psychological approach and the philosophical perspective definitions in two ways. Cognitive psychologists lean towards emphasising *how* individuals think as opposed to the philosophical approach of how they *could* or *should* think. For the purpose of this study, critical thinking is seen as how individuals *think* and *evaluate* information (Sommers, 2014).

Instead of describing critical thinking by highlighting the abilities of the ideal critical thinker, those researching in cognitive psychology tend to define critical thinking by the forms of necessary actions which thinkers can display. Descriptions of critical thinking that have emerged from the cognitive psychological approach include: “the mental processes, strategies, and representations people use to solve problems, make decisions, and learn new concepts” (Sternberg, 1986, p. 3). Halpern considered critical thinking as “the use of cognitive skills or strategies that increase the probability of a desirable outcome” (1998, p. 450). In addition to this, Willingham described it as ‘seeing both sides of an issue, being open to new evidence that disconfirms your ideas, reasoning dispassionately, demanding that claims be backed by evidence, deducing and inferring conclusions from available facts, and solving problems” (Willingham, 2008, p. 8).

Furthermore, Ennis (1962), in an attempt at a definition for critical thinking, established that “there are dimensions of critical thinking such as logical and pragmatic dimension, dimension’ and that ‘this implied knowing how judging how and the purpose of judging. Ennis further re-defined critical thinking in 1989, writing ‘I assumed critical thinking to be reasonable, reflective thinking focused on deciding what to believe or do” (Ennis, 1989, p. 4). Additionally, McPeck stated “the propensity and skill to engage in an activity with reflective scepticism” (McPeck, 1981, p. 8). McPeck’s definition was a reflection of his philosophical theory of critical thinking which is the “basic skills of reasoning and the avoidance of fallacies” (1983, p. 20).

While there are differences in the description of critical thinking across disciplines, lecturers seem to agree that it involves students questioning more and being less accepting of facts (Ahern et al., 2012). As such, it requires hard work at being a skilled thinker. Critical thinking could be incorporated as part of the approach to teaching rather than something added to everything else (Paul & Elder, 2012c). In other words, since critical thinking is a way of learning, then it should be a way of teaching rather than an addition or checklist in a curriculum. Following Alfaro-LeFevre (2017), critical thinking, therefore, is a complex development within a range of thinking skills; there is no one correct definition, but rather a range of descriptions.

Critical thinking has been described in different ways. First, as a process by Grussendorf and Rogol (2018) and Ahern et al. (2012); second, as a skill-set by Swanwick et al. (2014); and third, as an attitude (Bailin, 2002; Bailin, Case, Coombs, & Daniels, 1999a, 1999b). Halloran, Tan and Marissa established in their multimodal analysis that critical thinking is "to become informed, confident, responsible and active contributors to the consumption, creation and dissemination of knowledge and information in the present-day society" (2017, p. 148). Paul and Elder believe that critical thinking is "the art of analysing and evaluating thinking with a view to improving it" (2008b, p. 1). They argued that critical thinking is "a self-directed, self-disciplined, self-motivated, and self-corrective thinking that requires rigorous standards of excellence and mindful command of their use".

Critical thinking is the ability to question, check assumptions and view learning from a wider context, one that needs to be and can be challenged (Brookfield, 2012). Zielinski (2004) adopted another view of critical thinking by suggesting that critical thinking refers to those who can and do perform higher-order thought processes such as applying, analysing, synthesising, and evaluating information or methods in a variety of situations. Critical thinking is required to answer a question or the ability to assess chemical data for understanding (Alfaro-LeFevre, 2017).

While the descriptions above state that critical thinking may differ in the details, they all share the same element: reasoning. While there have been differences in disciplinary points of view related to the description of critical thinking, a significant aspect of this debate created by some scholars is in specificity. Some argued that critical thinking should be subject-specific, while others describe critical thinking in a more generic way (Abrami et al., 2015). For example, the idea that critical thinking skills are general across the domain of subjects was supported by scholars such as (Ennis, 1985, 1989);(Siegel, 1989) and (Vardi, 2013).

In summary, the definition of critical thinking has been a matter of ongoing discussion and debate, and there is yet to be an agreed-upon definition of the concept of critical thinking. Numerous scholars have provided descriptions and definition on the concept and experts of critical thinking like Paul and Elder, had several descriptions of critical thinking in terms of its elements and characteristics. This shows a need to be explicit about what is meant by the term 'critical thinking' in this study.

While a variety of descriptions of the term critical thinking have been suggested, this study has described critical thinking as follows: as a progression of thinking that is intended to lead to a comprehensive, defensible choice, inference or result rather than a category of thinking (Vardi, 2013). The descriptions by (Paul & Elder, 2008b) and (Vardi, 2013) when integrated, describe critical thinking as the process of developing thinking that results in better understandings capable of evidential argument.

2.4 Critical Thinking and Lecturers

Lecturers play an important role in supporting the development of students' critical thinking; specifically, lecturers who adopt a learner-centred approach to teaching (James et al., 2016). Given that developing students' critical thinking skills has been identified as a key goal of science education (Wang, Chen, Lin, Huang, & Hong, 2017), it becomes paramount for lecturers to promote the development of students' critical thinking from the moment they are enrolled in the university. Critical thinking includes evaluating evidence, problem-posing, problem-solving, developing sound arguments and simply making good decisions. How chemistry is taught can influence students' understanding of chemistry and what skills they gain; integrating critical thinking into teaching strategies has been shown to foster learning and retention. This perception is supported by Jacob (2004), who contends that chemists need to use critical thinking to decide between well-supported and theoretical conclusions.

Critical thinking and chemistry form a "dynamic connection" when the relevance of promoting students' critical thinking in science classrooms is recognised by lecturers (Vieira et al., 2011). Learning to be a chemist is more than learning chemical facts, and chemistry is not solely a "factual subject" (Garratt, Overton, & Threlfall, 1999; Osborne, Erduran, & Simon, 2004).

Additionally, critical thinking needs to be taught. Numerous scholars (e.g. Chang, 2011; Fung, 2014; Heijltjes et al., 2014; June, Yaacob, & Kheng, 2014; Morlino, 2012; Vieira et al., 2011) have found that critical thinking contributes towards a better and deeper understanding of science. In particular, the use of critical thinking prepares students to take a stance on scientific issues, logically rationalising issues under discussions, to detect fallacies in arguments, and to suspend taking of a decision when there is insufficient proof to trace and sustain a conclusion (Osborne, 2014; Vieira et al., 2011). Cheng et al. (2018) argue that in order to analyse, interpret and report data, critical thinking needs to be taught (further discussion in Section 2.5.2).

Again, research literature and reports across disciplines consistently conclude that the promotion of critical thinking skills amongst students is an essential goal of universities (De Bono, 1985; Dwyer et al., 2014; Paideya, 2011; Riggs & Hellyer-Riggs, 2014; Welch, Hieb, & Graham, 2015; Zhang, Parker, Koehler, & Eberhardt, 2015; Zhou, Huang, & Tian, 2013). The debate around the need for integrating critical thinking into teaching has led universities to adopt this view and to establish policies on the importance of helping students to develop critical thinking skills (Davies & Barnett, 2015).

The importance of infusing critical thinking into tertiary education can be defined in the following four points: some studies have identified a low level of critical thinking skills in university students (Berube, 2012; Espey, 2018). As such, the heart of education is to support students to think more widely about things (Wade, 2008).

Brookfield (2012) and Payette and Barnes (2017) argue that active learning is the ultimate achievement any teacher wants in their classroom. However, the same scholars note sadly that not all students are experiencing active learning. The learning environment provided for students is crucial to the develoment of students' critical thinking. Walker established that the university is the "safe environment where critical thinking can be developed" (2017, p. 497).

Critical thinking is integral to thinking, and, following this, chemistry students need to develop critical thinking skills to make sound judgments and systematically monitor their thoughts with the goal of becoming critical thinker (Paul & Elder, 2012a, 2012b, 2012c).

Lastly, Paul and Elder argue that "without critical thinking guiding the process of learning, rote memorisation is likely to become the primary resource, with students forgetting at about the same rate they are learning and rarely if ever, internalising powerful ideas" (Elder & Paul, 2010a, p. 39). This time requirement has implications for the adoption of critical thinking into universities, as shall be seen.

2.4.1 Lecturer Perceptions

Perception is a multifaceted development by which people accept or summarize information (Amin & Adiansyah, 2018). Lecturers seem to perceive that they are teaching critical thinking skills (Rhoades, Ricketts, & Friedel, 2009) and that they may believe they are promoting or teaching critical thinking when they are not (Nicole & Adams, 2012). Egege and Parker (2019) argue that lecturers are, in fact, not developing students' critical thinking. This study aims to investigate the current perceptions of the lecturers pertaining to critical thinking which would help to answer research question three ("What factors, if any, do lecturers perceive as obstacles to fostering critical thinking in their course?").

Lecturers' perceptions about the development of students' critical thinking skills could be improved. In their descriptive quantitative study, Amin and Adiansyah (2018) reported that only 32% of the lecturers evaluated their students' critical thinking skills, and the study suggested that promoting lecturers' awareness of developing students' critical thinking skills is necessary. Also, in their study, Dwee, Anthony, Salleh, Kamarulzaman, and Kadir (2016) provided insights for lecturers to reflect on their own teaching practices and integrate critical thinking into their teaching. In another study, Aliakbari and Sadeghdaghighi (2013) reported that one of the major barriers to teaching critical thinking is the lack of critical thinking knowledge in how lecturers develop students' critical thinking. It could also be that lecturers' teaching and assessment strategies emphasise rote learning rather than the requirement to engage critically with ideas and information. This suggests that lecturers need to focus more on the process of learning and less on content.

Lecturers need to be critical thinkers and open-minded (Riggs & Hellyer-Riggs, 2014), as being open-minded has been linked to being an effective teacher (Biggs, 2003b; Brookfield, 1995). This is why, Brookfield (1995) and Riggs and Hellyer-Riggs (2014) believe that to be an effective teacher, one has to be a reflective teacher and able to educate students to think critically. Consequently, expanding on lecturers' perceptions, Facione in his experiment of the nature of the human disposition, concluded with this comical statement: "not every compassionate person is a Mother Teresa" (2000, p. 63), implying that skill and disposition are two distinct things in people because being skilled does not mean that one is disposed to use critical thinking. Moreover, being disposed toward critical thinking does not ensure that one is skilled. Therefore, willingness and the ability to teach critical thinking work together and are required for effective teaching of critical thinking skills (McBride, Xiang, Wittenburg, & Shen, 2002). Additionally, A. Fisher (2011) supported this proposition in that disposition and skills are both indispensable to boost critical thinking in students. Admittedly, Tsui (2001) identified three types of faculty attitudes: confidence in student capability for higher-order thinking (in this case critical thinking); enthusiasm for teaching; and teaching as a process of mutual learning. She argues that whilst lecturers' value critical thinking, many do not feel they can successfully teach the skill.

Another concern argued in the literature is the resistance from lecturers towards teaching critical thinking. Consequently, some scholars Keeley, Shemberg, Cowell, and Zinnbauer (1995); Haas and Keeley (1998); and (Shell, 2001) believe that lecturer resistance to teaching critical thinking was inhibiting their full understanding of critical thinking. Correspondingly, Haas and Keeley (1998, p. 145) supported Keeley et al. (1995), stating

> … many faculty members seem to resist employing more student-centred approaches to instruction. As shown by their unwillingness to give up the lecture-discussion format, we believe that a continuing dialogue about the resistance process is necessary for educators to implement active learning in the classroom. (Haas & Keeley, 1998)

Similarly, Raikou, Karalis, and Ravanis (2017) argue that teachers thinking might be an obstacle to effective professional training. Contrary to this view, not all lecturers are resistant to the practice of teaching critical thinking. Kraft (2000) encouraged lecturers to see themselves as architects of learning, orchestrating significant learning experiences for students by encouraging students to question and search for truth. In the same vein, Welch et al. (2015) reported that lecturers unanimously agreed that critical thinking was a requirement to be successful in the electrical engineering profession.

Whether resistant or non-resistant, it is essential that lecturers be trained in teaching critical thinking for effective practice to occur. This suggests that lecturers need professional development in the context of educational reforms and curricular changes (Zhang et al., 2015). Their study found that the issue of professional development in teachers has predominantly focused on the effectiveness of program design, rather than teacher needs. Further, Zhang et al. (2015) created a list of common science topics in which teachers professed they needed to improve. In addition, from analysis of data from 118 science teachers over a period of three years, Zhang et al. (2015) reported the necessity for teachers to develop in numerous areas of pedagogical content knowledge to teach effectively using different teaching strategies. One of these areas was critical thinking teaching strategy. Alhamad (2016) supported this argument and stated that engaging in critical thinking strategies requires lecturers to demonstrate critical thinking themselves.

True to Kuhn's claim that "enthusiasm for critical thinking as a goal of education shows no signs of waning" (1999, p. 16), the research literature has shown that most lecturers and educators embrace the importance of critical thinking. However, this alone is not enough to assume that lecturers are actually developing critical thinking in students. Critical thinking must be treated as a developmental phenomenon. For this reason, some scholars believe that critical thinking is central to metacognitive development; Kuhn called it "meta-knowing" (1999, p. 23). Therefore, to know about thinking (metacognition) and being aware of one's thinking process; this then enables us to explore how we come to learn. In other words, metacognitive development examining how people learn (neuroscience) and how lecturers might support this developmental process. It has been established that the hippocampus and the amygdala in the human brain stem play a major role in how we learn since all of our senses are directly attached to these parts of the brain, and therefore, we take in information (Goleman, 2013). Further, Goleman explained that the hippocampus is like a recording device: it takes the information in and holds it before pushing it out to the rest of the brain to become a memory.

Further analysis of the brain revealed that focus is needed for the hippocampus to become active: without focus, there is less activity in the hippocampus, hence less input to the brain and therefore less learning (Goleman, 2013). Goleman stated that, in a learning environment, when someone is distracted, this ultimately distracts the person seated next to that person, eventually distracting the whole class. As the hippocampus cannot hold focus for more than twenty minutes Goleman (2013), Goleman suggested that learning be divided into blocks in which there are different strategies for learning. Goleman argued that it is possible for students to learn for an hour, but not focus on one thing for an hour. In other words, teachers should vary learning activities to limit and spread out the intensity or length of time needed to focus.

From the above, it is clear that for thinking and learning to take place, there has to be classroom interaction between the lecturers and students. Case (2015) argues that teaching-learning interactions are forgotten in educational theory, although they contribute to active learning. Undeniably "the key strategy for changing the student's role from passive to active is cooperative learning. In cooperative learning situations, students work in small groups to achieve a shared set of goals relating to academic assignments" R. T. Johnson and Johnson (2008, p. 29).

Foundationally, classroom interactions can either foster learning or deter learning, depending on their existence or non-existence (Biggs, 1988). This further demonstrates the crucial role of lecturers in students' learning. In like manner, Fassinger (1995) believes that most classes contain students who have not articulated a view since the first-day introduction of their course. He argued that lecturers need to understand classroom interaction and their contribution to student silences, potentially through the lecturer's inactivity. He stated that lecturers are guilty of seeing classrooms predominantly from the viewpoint of providing information. On this account, student perceptions of critical thinking might subtly be subject to classroom interactions based on the relationship's students have with lecturers (Mathews & Lowe, 2011). It is likely that the expectations lecturers convey through their teaching approaches contribute to whether students engage cognitively with the content or not. Active learning is discussed further in the following section.

2.5 University Teaching

There are some educational practices that discourage critical thinking with assumptions that a students' role is to memorise and regurgitate information, and the lecturers' role is to dispense knowledge (Nosich, 2012). As such, universities must work to enlighten such practices. Scholars (e.g. P. A. Facione, 1998; Paul & Elder, 2008a; Snyder & Snyder, 2008) have suggested various teaching methods that they believe would develop student critical thinking, such as heuristic teaching methods, the active learning approach to teaching, critical thinking embedded curriculum, and modelling critical thinking and questioning techniques.

It follows that teaching critical thinking is more effective when it is explicit. Abrami et al. (2008) make clear the positive effects of explicit instruction on critical thinking. As such, this present study seeks to investigate and describe how lecturers in a particular university are developing students' critical thinking. The previous section was a review of the relevant literature related to responding to the research question concerning the perception of university lecturers towards critical thinking. This section will discuss the teaching approaches that are effective in developing critical thinking.

2.5.1 Active Learning in Universities

In higher education, effective teaching is key to student learning. Effective teaching occurs when teaching is learner-focused (Oyelana, Martin, Scanlan, & Temple, 2018; Tudor, 1993). Consequently, a learner-focused approach to teaching results in active learning for students (Roehl, Reddy, & Shannon, 2013). Therefore, university lecturers are encouraged to facilitate student cognitive engagement by adopting an active learning approach to teaching (Almeida & Franco, 2011). Kusumoto (2018) stated that active learning is ''any instructional methods that engage students in the learning process''(2018, p. 47). The strength of such an approach such as active learning techniques and modelling is that students shed the traditional role of passive receptors and are then able to learn and practice how to apprehend knowledge and skills and use them meaningfully Xhafa and Kristo (2014, p. 457). Similarly, active learning methods may include classroom activities such as case studies, discussions or debates, experiments, field trips, role play, and Socratic questioning (Popil, 2011).

Active pedagogies are supported by the findings of Abrami et al. (2015). Remarkably, Abrami et al. (2008) provided extensive meta-analysis evidence on the effect of instructional interventions in the development of student critical thinking skills and dispositions at all educational levels. Their study established that enhancing student critical thinking skills and dispositions should never be implied, in that there has to be a blueprint in the curriculum, which should include pre-service and in-service training and faculty training. As such, lecturers are encouraged to guide students to question new information and concepts, thereby becoming active and deep learners (Nelson, 2017).

Ultimately, previous two sections have established that though dispositions and skill to teach are two distinct elements, they are both necessary for teaching critical thinking effectively, as effective teaching leads to active learning particularly when critical thinking is embedded.

2.5.2 Need for Critical Thinking in Universities

The current debate about developing critical thinking in higher education identifies an interesting viewpoint on the need to teach for the retention of knowledge. There is a growing body of evidence that demonstrates the need to integrate critical thinking into teaching in universities, given that active learning promotes critical thinking (David & Brown, 2012; Ijaiya, Alabi, & Fasasi, 2011; Malam & Grundy - Warr, 2011; Popil, 2011). On the contrary, traditionally, lecture has been the means by which university lecturers disseminate information and ideas. This involves one-way transmission of knowledge, not giving students enough time to process information (Xhafa & Kristo, 2014). Additionally, Biggs believes that the primary teaching approach at universities over the past decades has been predominantly lecturing (Biggs, 2003b), thus effectively eliminating the possibility of integrating critical thinking into such a teaching approach or curriculum.

Equally, Sharples et al. (2017) argue that critical thinking is not being promoted in science education, resulting in rote learning by students. Rote-memorisation is characterised by the repetition of facts with no or little understanding of the content learnt (C. Tan, 2015; P. L. Tan, 2011). Lecture is a method of transmission of information, it could be considered to be what Case and Marshall (2004, p. 609) termed as a "surface approach" or "information-based approach" to learning; a strategy that promotes memorisation of formulae. In the same way, "surface learning approach" negatively predicts achievement (Burton & Nelson, 2006). As such, there is a need to move beyond the familiar traditional way of teaching (lecture-based) in university teaching. Several studies have established that the lecture-based pedagogy still predominant with lecturers as a way of teaching (Eagan et al., 2014). As a result, teaching strategies that engage students with course material are encouraged as an effective way to challenge their thinking (Espey, 2018). In the same vein, Krusemark (2017) concurs with P. Williams, Murray, Green, and Chan (2014) that “safe” and traditional approaches to teaching by lecturers need to change.

The review of the literature around lectures is relative to what university lecturers think the purpose of lectures is. In the argument about what the literature suggests is an effective teaching approach for developing students’ critical thinking, some lecturers can use much questioning and indicate critical aspects of evaluating data, which can all be done through a lecture. Therefore, it is not lecturing per se that is the issue; it is that lecturers think they have to transmit facts. The only advantage of lectures is that they expose students to the lecturers’ ongoing thinking (Biggs, 2003b). Similar to Goleman (2013), Biggs described lectures as comprising low-activity and being more about listening, with concentration decreasing quickly after 15 minutes. This resonates with the researcher’s personal undergraduate experience, which was the sequence of memorising content knowledge in order to pass tests and examinations as earlier discussed in Chapter 1.

Accordingly, most university students strive to store a large amount of information in short-term memory to pass tests for academic success (Paul & Elder, 2012c). This is an indication that lectures are not just monotonous; they are also ineffectual (Brookfield, 1995, 2012; Watts & Becker, 2008). Therefore, integrating critical thinking into the teaching of chemistry at the university will nurture and promote high-quality chemistry graduates and may foster discoveries in chemistry (Walker, 2017) (Section 2.4). Critical thinking is a skill that is obtained through an explicit process. The process includes, but is not limited to, the ability to validate recall information and being able to develop further findings when required. This process can be taught. Likewise, Danczak, Thompson, and Overton (2017) support the understanding that critical thinking is a method, not a goal, and that it can be taught. In like manner, Almeida and Franco (2011) state critical thinking will not “spontaneously sprout” (2011, p. 187). It is, therefore, a process that is deliberately acquired over time (P. A. Facione, 1998; Gelder, 2005). In a similar fashion, Panettieri (2015) and T. Thomas (2011) suggested that different critical thinking teaching strategies could be used by chemistry lecturers. Therefore, this study aims to explore the effective critical thinking teaching strategies for teaching chemistry.

Given that pedagogy is the method or approach used by a teacher, that is, the practice of teaching in an academic subject, lecturers are encouraged to make classroom learning more meaningful by incorporating critical thinking skills into their instruction (Forawi, 2016). Students are unable to transfer the skills of reasoning when given content knowledge. Therefore, teaching to think critically can only be achieved when students are taught critical thinking explicitly (T. W. Johnson, 1984), as this sort of teaching empowers students to evaluate problems critically (Abrami et al., 2008; Bennett, Hogarth, Lubben, Campbell, & Robinson, 2010). Similarly, a study by Saavedra and Saavedra (2011) revealed that universities with lower student-teacher ratios have higher critical thinking outcomes.

However, Cargas, Williams, and Rosenberg (2017) criticise the lack of clarity on how to precisely prepare students to become critical thinkers. One of the reasons is that there is no one path toward critical thinking; there is an excess of tools designed to increase critical thinking (Howard, Tang, & Jill Austin, 2015). As such, lecturers should be concerned with finding out which of these tools will foster critical thinking in their students and how their students, conceptualise the course materials (Gow & Kember, 1990).

It is clear that traditional, lecture-based teaching only produces passive learners. A deep approach to learning was related to academic performance when a problem-based teaching approach was integrated (Chen & Hu, 2013). To achieve change, lecturers need professional training in teaching critical thinking (Mgijima, 2014). Based on theoretical perceptions, student learning progress could be hindered from an unwillingness or lack of capacity on the part of lecturers to push beyond the lecture model (Whiley, Witt, Colvin, Sapiains Arrue, & Kotir, 2017).

2.5.3 Lecturers and Critical Thinking

Lecturers agreed that critical thinking is an essential tool for students to solve problems (Behar-Horenstein & Niu, 2011). For lecturers to apply a pedagogy that promotes an increased level of critical thinking (Paul & Elder, 2012c), lecturers need to relate the subject to students' prior knowledge in order for students to make sense of that subject. Evidence from Shell (2001) showed that lecturing as a teaching style is regarded negatively by many educational leaders and this should encourage lecturers in universities to accept that lecturing alone is “pedagogically incorrect” as it is inadequate for preparing students for an uncertain and changing world.

There is developing discussion among some scholars that might be concerning. Some research literature states that the reality that university lecturers are expected to develop students’ critical thinking may be hindered by the demand that the university expects more research productivity than teaching evaluations from the lecturers (Beachboard & Beachboard, 2010). By the same token, Schimanski and Alperin (2018) argued that there is a shift from excellence in teaching to tenure and promotion, which is research-focused. Mamiseishvili, Miller, and Lee (2016) also expressed concern about how faculty members view their service roles within the university. Mamiseishvili et al. (2016) concluded that faculty members were dissatisfied with the time spent on teaching and research expectations. In other words: lecturer workload is a concern, and as such, this might affect the time for explicit teaching of critical thinking in university courses. Universities need to prioritise quality teaching and create a better balance between research and student-centred teaching and learning.

Further, into the review of the literature, some key points were identified in the university policies and the role of lecturers in the implementation. First, there was a high frequency of critical thinking in educational policy documents, but lecturers had individualised understandings about what critical thinking meant (Atabaki, Keshtiaray, & Yarmohammadian, 2015). This affected how lecturers integrated or did not integrate the concept into their teaching. In addition, lecturers agreed that a teacher’s role is to nurture and polish critical thinking skills in students (Halx & Reybold, 2006). In the same vein, N. C. Facione et al. (1994); N. C. Facione and Facione (1996); Eslamdoost and Fahim (2014) concurred that the responsibility of teaching critical thinking had been laid on lecturers whereas lecturers hoped that students were able to apply facts by the end of the course (DeWit, 2006). Sometimes some lecturers assumed that they were teaching critical thinking, although not explicitly. For example, evidence from Cooney, Alfrey, and Owens (2008) showed a disconnect between the amount of critical thinking skill experience that lecturers of engineering and technology believed they were providing to students and the amount of critical thinking skill experience that their students perceived they were receiving. Evidently, universities do not teach critical thinking (Grussendorf & Rogol, 2018).

The evidence highlights that developing student critical thinking requires teaching strategies that deepen student capacity for sound reasoning across the curriculum. As has been shown, to be successful in teaching and developing student critical thinking, "it goes beyond embedding critical thinking into a curriculum" (Walker, 2017, p. 496). This realisation requires that critical thinking be explicitly taught, and this current study argues that incorporating critical thinking into teaching through a range of strategies would develop student's critical thinking skills. Some of the best practices across disciplines reported in the literature have been the use of tools such as interactive learning with numerous writing-based assignments, project-based learning, or inquiry-based learning accompanied by feedback and support (Heinrich, Habron, Johnson, & Goralnik, 2015). These tools are discussed further as critical thinking indicators in Section 2.8.3. To understand the use of the critical thinking indicators related to the role of lecturers in developing students' critical thinking skills, learner-centred teaching is crucial, as seen in the next section.

2.5.4 Learner-Centred Teaching

Building on from the idea that lecturing, an approach for teaching in higher education, often promotes passive learning. The fundamental limitation of lectures is that they are based on the transmission of information. Lectures alone do not foster critical thinking. This section presents the proponents for the use of learner-centred teaching approaches.

Another line of thought on developing students' critical thinking demonstrates that learner-centred teaching puts learners' thinking as the focus for planning for learning, rather than focusing on what is taught. How science is taught might be more important than what is taught (Keinonen & De Jager, 2017, p. 485). Many recent studies (e.g. Henk, Stephanie, Guus, Lianne, & Henk, 2015; White et al., 2016) have shown that lectures are focused on content; the practice being that students learn by being told and hardly require the use of critical thinking. It has been conclusively shown that lecture is the standard format of transmitting information to a large group of students. It was an established didactic approach many decades before the availability of books (Ko, Rana, & Burgin, 2018). Data from several studies suggest that the lecture has shortcomings, such as lack of student engagement, failure in developing critical thinking, lack of lecturer-student interaction, and diminished knowledge retention (Case, 2015; Gehlen-Baum & Weinberger, 2014; Henk et al., 2015; Ko et al., 2018; White et al., 2016).

On account of the above evidence, the use of active learning with the inclusion of critical thinking teaching activities is proposed in this current study as an alternative. Roberts (2018) emphasised the importance of active learning in replacing the concept of passive learning. Thus, there is a need to promote student-centred approaches to teaching, where there is room for lecturer-student interactions (Doyle & Zakrajsek, 2012). Similarly, Case (2015) proposed a rethinking of the relationship between lecturer approaches to teaching and student learning: lecturing is useful for developing thinking skills provided the appropriate teaching strategies are included.

As a result, Abrami, Bernard, Bures, Borokhovski, and Tamim (2011) supported the importance of lecturer-student interaction for students learning, as did Bennett et al. (2010, p. 70), who stated: "active learning strategies will stimulate students' interest in what they are studying when they are provided with a significant degree of autonomy over the learning activity". Haigh argued that "applying critical thinking and achieving critical depth are mantras of Higher Education but, other than promoting mimicry, little attention is paid to how to help learners search for deeper understanding" (2016, p. 165).

Undeniably, in recent years, there has been an increasing amount of literature on the role and importance of argument and explanation. Scholars believe argumentation is missing in many classrooms. Some scholars believe arguments enable well thought-out analytical reasoning, while explanations do not serve a persuasive function (Osborne, 2014; Stowe & Cooper, 2017). How teaching occurs and what approaches are used seems important for what kind of learning can occur. Some research suggests that lectures as a mode of teaching only communicate direct information and are found to be less effective in developing student critical thinking (Whiley et al., 2017). It is possible for a lecturer to adopt a lecture-mode approach combined with a range of other teaching strategies (Pritchard, 2010).

Consequently, numerous scholars (e.g. Fullan & Langworthy, 2014; Gelder, 2005; Mulnix, 2012; Whiley et al., 2017) believed lectures promote content memorisation in students rather than the development of critical thinking through the application of knowledge. Recent studies have been concerned with rote-learning as a result of the lecture approach. For example, in nursing, most students were found to engage in the use of techniques such as rote learning (memorisation). Memorisation is considered as passive or shallow learning, matching words for the purpose of an examination with no understanding of the information or future ability to recall and apply knowledge (Nelson, 2017). Similarly, Adams and Wieman (2011) advocated for critical thinking teaching strategies rather than memorisation.

The current debate about developing students' critical thinking also identifies an interesting viewpoint on barriers that might prevent this development. There is a large volume of studies attributing the predominant lecture approach in higher education to barriers and obstacles such as time, and lack of professional training and incentives (White et al., 2016). White et al.'s (2016) empirical study found that institutional leadership is significant to transformation in teaching for quality learning. The critical role of leadership was emphasised in the change process as well as a community of practice and the use of resources, especially PhD students.

2.6 Developing Critical Thinking in Students

Critical thinking enables students' ability to analyse and interpret data and to provide sound reasoning to buttress claims (Stowe & Cooper, 2017). The importance of critical thinking has been extensively discussed among scholars, lecturers, universities, policymakers, stakeholders and employers (Section 2.5). The next question is how lecturers are contributing to the learning journey of students and to the aspirations of universities to develop critical thinking in their students while they study.

Indeed, the success of students developing their critical thinking skills may depend on the lecturers' understanding of the concept of critical thinking. Some research (e.g Elder & Paul, 2010a, 2010b) stressed that the role played by lecturers in fostering critical thinking was dependant on the degree to which lecturers themselves think critically. Thus, teaching for critical thinking necessitates a clear conception and awareness of the concept. Understanding the process of critical thinking helps in effectively developing student critical thinking (Alhamad, 2016).

In a way, the critical thinking process mimics the scientific method (Snyder & Snyder, 2008). The scientific method is illustrated in Figure 1, where the research question generates a purpose, point of view, concept or assumption, just like the element of reasoning. The relevant data gathered ("information" in the critical thinking theory) based on the element of reasoning is then tested. The testing stage in the thinking process can be referred to as the intellectual standard, that involves accuracy, clarity, relevance, logic, sufficiency, precision, depth and significance. The last stage of the scientific method is drawing conclusion, and in the critical thinking framework, it results in intellectual traits such as humility, autonomy, courage, fair-mindedness, perseverance, empathy and confidence in reasoning. Figure 1 was created and presented in a figure form by the researcher in this thesis research study based on the interpretation of Paul and Elder critical thinking framework (Paul & Elder, 2008b) and understanding from (Snyder & Snyder, 2008).

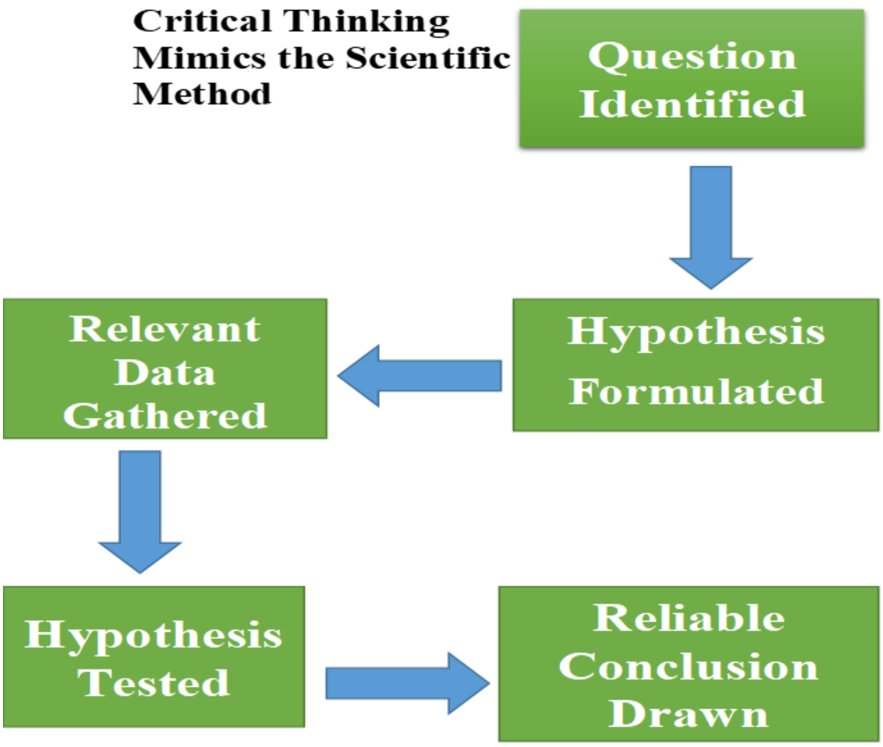

Figure 1. Critical thinking process mimics the scientific method

Furthermore, when lecturers did not understand the critical thinking process, it is almost impossible for them to teach their students to think critically (Nicole & Adams, 2012). The development of student critical thinking requires explicit teaching, and this explains the need for learner-centred teaching as stated earlier in Section 2.5.4. For example, Grussendorf and Rogol (2018) encouraged an explicit critical thinking curriculum, and they found in their study that students had significant improvement in their critical thinking scores after a semester of focused, critical-thinking activities.

Undoubtedly, explicit teaching of critical thinking requires pedagogical expertise in knowing and implementing specific activities and teaching behaviours. Studies consistently show that although lecturers say that critical thinking is important to their teaching, they have difficulty articulating a clear conception of it and demonstrating how they foster it through their teaching (Gardiner, 1994; Low et al., 2017; Paul, Elder, & Bartell, 1997).

On the other hand, lecturers might not know how to incorporate critical thinking into their lessons (Lauer, 2005). Nicole and Adams (2012) concurred with Choy and Cheah (2009) and stated that teachers may have positive attitudes and aspirations to teach critical thinking, but may not be doing so or know what teaching strategies to use. Additionally, there is a notion that lecturers lean heavily on traditional lectures and PowerPoint presentations and this could be the reason teachers have difficulty integrating critical thinking into teaching (Nicole & Adams, 2012). Perhaps because it is easier to stick with the status quo!

It is often assumed that university lecturers possess all it takes to develop critical thinking in their students (disciplinary-specific assumption). According to Alhamad (2016), lecturers are always assumed to possess a reasonable level of critical thinking skills themselves, since they have postgraduate education and experience. Thus, they are expected to develop critical thinking equally in their students. On the contrary, several studies have established that lecturers can lack the knowledge to foster student critical thinking (Lauer, 2005; Nicole & Adams, 2012; Rhoades et al., 2009). The reasons for this could be that lecturers may not be clear about the concept of critical thinking (Vieira et al., 2011). Further, it is occasionally easy to attribute shortfalls in student performance to laziness, which Buskist and Irons (2008) call a misguided attribution. They argued that some students, like teachers, are lazy, though they concluded that student resistance to investing the time necessary to develop critical thinking skills was likely not exclusively due to slothfulness. They noted that just as students may avoid critical thinking because it requires more intellectual effort, lecturers may enable this avoidance by failing to integrate critical thinking teaching approach to the course material. In addition, if critical thinking is not included as an integral part of assessment, neither lecturers nor students are likely to value it enough.

2.6.1 Teaching for Critical Thinking

Students should be given the experience of learning to think things through as a process of thoughts (Nosich, 2012). Critical thinking needs to be learned by students (W. M. Williams & Sternberg, 2002) and it can be taught (Brookfield, 2012; De Bertacchini, Díaz, Carbogim, Rodrigues, & Püschel, 2016; Payette & Barnes, 2017). Failure to teach critical thinking would mean "deficiencies emerge in the abilities of students to make sound judgments" (Sharples et al., 2017, p.

2). Brookfield (2012) suggested that lecturers should model critical thinking to students by giving students explicit teaching of critical thinking. For example, sharing personal experience of how lecturers have been able to navigate critical thinking, in this case, when presented with a chemical problem.

Critical thinking has some essential characteristics that can guide and serve as a framework for teaching. A particular interest of these characteristics is what P. A. Facione (2000) and Uzuntiryaki-Kondakci and Capa-Aydin (2013) described as “effective guidance” that is needed to develop critical thinking. As illustrated in Figure 2, this study argues for an active learning approach to teaching by integrating critical thinking. Figure 2 was developed by the researcher in this thesis research study. The Paul-Elder’s framework of critical thinking is suggested, and its details are discussed in the next section (2.7). In section 2.7, the relationship between Figure 3 and Figure 2 such that the infusion of Paul-Elder critical thinking framework is proposed into teaching and learning. Figure 3 demonstrate the process involved in the Paul-Elder critical thinking framework.

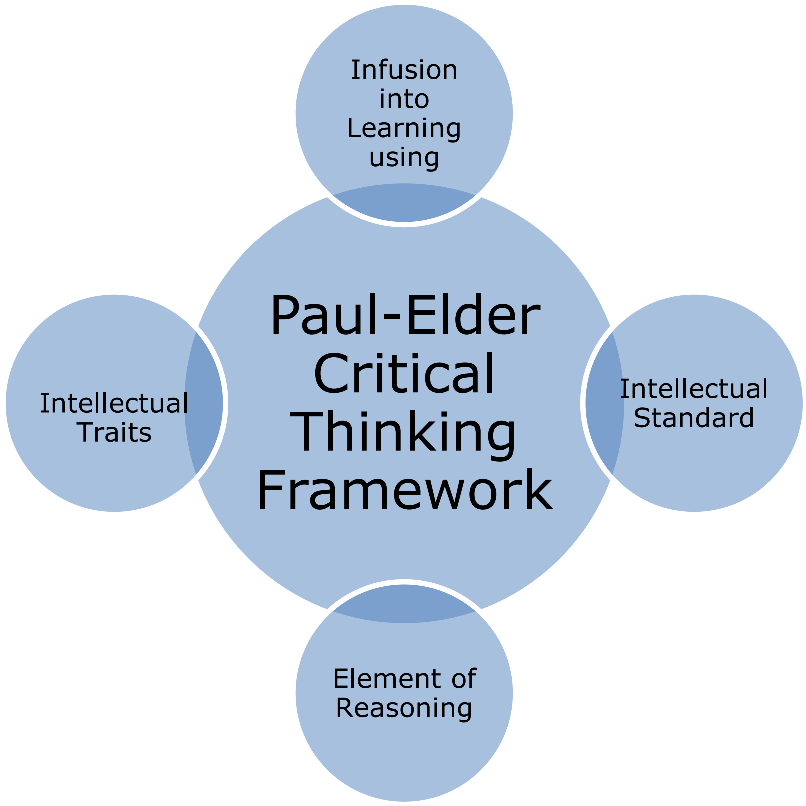

Figure 2. Teaching for critical thinking

If a goal of the university is to develop critical thinking skills among students, then the proficiency required of lecturers to teach the skill is paramount. As mentioned earlier Section 2.5.3, without a well-informed lecturer who knows specific teaching approaches that support its development, the mission of developing critical thinking skills is problematic, if not impossible to accomplish (Brookfield, 1995; Dewey, 1997; Ennis, 1962; Halpern, 2003; McPeck, 1981; Paul, 1995; Van Der Werff, 2016; Willingham, 2008). A systematic review of the literature by Bennett et al., revealed that "students often struggle to formulate and express coherent arguments and demonstrate a low level of engagement with tasks" (Bennett et al., 2010, p. 69). This concern is also linked to the need for teaching critical thinking as identified by educators, employers, and policymakers (Abrami et al., 2008).

There are many different approaches to teaching subject content, with most techniques being either transmissive or transformative. Transmissive-based techniques are usually teacher-centred and are also known as transmissive pedagogy, while the transformative mode of teaching is student-centred (Pratt, 2002). Tay, Lim, Lim, and Koh (2012) describe the transmissive approach as learning based on the information delivery method with no collaboration from students, which is what the lecture approach sometimes tends to be if not used effectively.

Research has shown that cognitive loading of content knowledge does not have a significant impact on aiding the development of student critical thinking skills (Bao et al., 2009). The impact of cognitive loading can be evident when there is lack of student engagement. Sometimes in a classroom, when this occurs, it is an indication of a lack of an active learning approach to teaching (Bao et al., 2009).

Lecturers need a plan that would enrich their teaching so that students will learn how to use critical thinking skills. Dawson, Macfadyen, Evan, Foulsham, and Kingstone (2012), attempt to promote student engagement with peers and learning materials (which they believe offers learners greater ownership of their learning. They suggest that lecturers must create enriched opportunities by designing learning activities that build upon the "artefacts of traditional didactic modes of teaching". (Section 2.9 further discusses curriculum design.) Similarly, Hew and Cheung (2013) suggest evidence-based pedagogical approaches for educators interested in fostering student learning. This suggestion can be linked to the discussion on critical thinking indicators and some critical thinking teaching strategies that is discussed later (see Section 2.8). For example, Hew and Cheung (2013) established that the use of a podcast in their study appeared to support learning. Tsui (1999) also suggested that the use of writing that involves analysis facilitates critical thinking.

Lastly, the objective of a curriculum should not be limited to lecturers just covering the required content, but should also include developing the art of critical thinking (Živkovil·, 2016). Therefore, this current study argues that critical thinking should be embedded in the teaching of chemistry at university as it is in a variety of other academic disciplines (Živkovil·, 2016). Lecturers should help students develop critical thinking by involving them in active learning and using critical thinking teaching activities (referred to as critical thinking indicators in this study in Section 2.8).

2.6.2 Critical Thinking Teaching Practice in Chemistry

A variety of teaching practices and activities have been used to demonstrate whether critical thinking skills are promoted in chemistry education. For instance, an inquiry-based instruction is believed to promote the critical thinking skills of first-year general chemistry students as well as encourage an understanding of scientific concepts and principles (Gupta, Burke, Mehta, & Greenbowe, 2015). Similarly, in an undergraduate general science course the effects of active learning on enhancing student critical thinking showed that a significant level of change occurred in students' critical thinking when the curriculum was designed and implemented by incorporating small group-based learning with authentic tasks, scaffolding, and individual writing. (Kim, Sharma, Land, & Furlong, 2013). Likewise, in introduction to organic chemistry, students were exposed to partial retrosynthetic analyses of real and complex synthetic targets (Flynn, 2011). Furthermore, the study revealed different methods that the students had formulated by submitting their answers with a clicker. Following this, the author believed that the multiple reasoning of these students provided a foundation for the development of critical-thinking skills. Again, Noblitt, Vance, and Smith (2010) found that the use of case study method significantly enhanced students' critical-thinking skills.

Additionally, in a qualitative study, university teaching associates and academics were asked 'can you provide an example of when you have provided students with the opportunity to develop their critical thinking while studying chemistry?'. The findings from this study revealed that the teaching staff identified themes such as 'practical environments', 'application of knowledge', 'critique', 'project work' and 'research'. The students also identified activities they believe was effective for their learning in developing transferable skills such as critical thinking. Forty-five per cent of students identified an activity relating to a practical environment. The inquiry-based learning was at 17%, 36% of second-year students and 14% of third-year students specifically reported guided inquiry activities performed as part of their first-year laboratory program helped develop their critical thinking (Danczak et al., 2017).

2.7 Theoretical Framework

The terms 'theoretical framework' and 'conceptual framework' are often used interchangeably in the literature. This research has adopted a combination of theories reviewed in the literature to create a conceptual framework (there is further discussion on the conceptual framework in Chapter 3). The conceptual framework for this study is derived from the integration of both empirical and theoretical findings in the review of the literature.

Evidently, one of the reasons why the Paul-Elder critical thinking framework was chosen was because the framework has progress included as part of its process. In the same vein, the critical thinking definition adopted in this current study states that critical thinking is a progression of thinking that is intended to lead to a defensible choice, inference or result rather than a category of thinking (Vardi, 2013).

Likewise, in the definition by Paul and Elder (2008b), critical thinking is positioned as the mode of thinking about any subject, content, or problem in which the thinker improves the quality of his or her thinking by skilfully applying logical reasoning, the structures inherent in thinking, and intellectual standards. Each stage of the framework requires being purposeful, explaining evidence, clarity, accuracy, depth, significance, precision and relevance. As well P. A. Facione (1990, p. 3) defined critical thinking as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment".

The literature on critical thinking in higher education (university) is constructed around some fundamental assumptions. The theoretical framework is the stance a researcher brings to a study, which is the underlying structure or frame of the study. A theory enables us to see what would otherwise be missed: it determines what we do and do not ask, it reveals meaning and understanding of which the researchers should be aware (Merriam, 2016). Given that in the field of critical thinking there is no consensus on a single principle framework, this section discusses some theoretical frameworks and later narrows to the theoretical frame guiding this current study, which is based on the work of Paul and Elder.

As noted earlier, (see Section 2.3), critical thinking is contextualised by two main theoretical perspectives: the philosophical perspective and the cognitive psychology. The philosophical perspective has been mainly concerned with teaching, while the cognitive psychology perspective frequently relates to the broader, more general concept of teaching thinking (Atabaki et al., 2015; Vieira et al., 2011).

A review of existing theoretical frameworks of thinking skills and educational objectives by Dwyer et al. (2014) claims that it is imperative for people to possess the capacity and disposition to engage critically with different information so that they can practically solve problems, acquire reasonable inferences and make informed judgements. They believe that promoting critical thinking may eventually support people to become more flexible, able to manage the fast development of perpetually growing information.

Scholars have developed numerous critical thinking frameworks and theories of critical thinking (Davies & Barnett, 2015; Wilson & Varma-Nelson, 2016). Davies and Barnett (2015) believe that a critical thinking framework is much needed in higher education as employers demand critical thinking from graduates.

This study is based on the principles of Paul and Elder's critical thinking framework (Paul & Elder, 2008b), in which certain steps must be followed to develop critical thinking skills. There is further discussion on theoretical framework in Chapter 3 (Section 3.3).

2.7.1 Choosing a Critical Thinking Framework

The Paul and Elder critical thinking framework was chosen because it provides well-structured, underpinning theories for understanding what critical thinking components are and what they aim to achieve. Another advantage of this framework is that it has been more widely implemented by higher education institutions globally than other frameworks (Han & Brown, 2013). The framework has comprehensive approach (Payette & Ross, 2016) and extensiveness with explicit process and examples. The work of Paul and Elder describes critical thinking as a strategic and deliberate process of learning. They believe critical thinking is the primary process of thinking about any specific subject, in which the thinker controls the reasoning process (Paul & Elder, 2008b, 2009, 2012a, 2012c).

Paul and Elder stated that there should be less emphasis on coverage of content knowledge in the teaching of chemistry at the university level. Elder and Paul (2010a) argued that lecturers have not yet realised the potential results of fostering critical thinking through learning for their students. They believe that lecturers assume answers can be taught independently from questions. Thinking, they propose, must be experienced as a journey and is not static. Chemistry students need to learn some principles, theories and laws; however, lecturers should not teach what seems an almost never-ending amount of content solely for recall. Paul and Elder (1998) and Paul and Elder (2008a) believe that when students are engaged in thinking while content is integrated, they are stimulated to ask questions.

2.7.2 Detail of the Paul and Elder critical thinking framework

In the Paul-Elder framework, there are three components (Foundation for Critical Thinking - Learn the Elements and Standards, 2015; Foundation for critical thinking, 2014; Paul & Elder, 2008b, 2012c; University of Louisville, 2015):

1. Elements of thought (known as element of reasoning).

2. Intellectual standards that should be applied to the elements of reasoning.

3. Intellectual traits associated with a cultivated critical thinker that result from the consistent and disciplined application of the intellectual standards to the elements of thought.

Figure 3. Critical thinking framework

Figure 3 was developed by the researcher in this thesis research study. Figure 3 provides an overview of the Paul-Elder critical thinking framework. Paul and Elder termed the relationship among these components as a three-tiered process such that, in order to achieve the intellectual traits of critical thinking, one needs to apply the intellectual standards to each element of one's thoughts (Paul, 1995; Paul & Elder, 2008b). Therefore, the element of thought is vital in the model as it requires intellectual standards to function, which would result in the intellectual traits. Browne and Freeman (2000) noted earlier that intellectual perceptions are broadened by critical thinking if approached with a "spirit of openness". Figure 3 shows the process involved in the element of thought that sets critical thinking into motion through the thinking process or for solving a problem.

Regarding the elements of thought in the Paul-Elder critical thinking framework, which states that all reasoning must have a purpose – there must be a question which requires an answer and therefore an attempt to answer the question. One should gather information to form an assumption and have a different viewpoint, which helps to develop concepts. Theories formed are then interpreted to arrive at implications and consequences.

The intellectual standards are clarified as universal. Thus, the Paul-Elder framework sets out the process of elements of thought; that reasoning must seek clarity, accuracy, precision, relevance, depth, breadth, logic, significance and fairness. Therefore, thoughts that lack the application of these intellectual standards are classified as void of critical thinking.

The Paul-Elder framework states that the consistent application of the intellectual standard to the elements of thought would develop the eight intellectual traits of intellectual humility, intellectual courage, intellectual empathy, intellectual autonomy, intellectual integrity, intellectual perseverance, confidence in reason, and fair-mindedness.

The Paul-Elder framework states that once the standards are validated during reasoning, the traits are developed. Paul and Elder explain that ‘intellectual humility’, develops one’s ability to perceive the known limitation and the circumstances that may cause biases and self-deception. Intellectual courage represents developing a consciousness to address ideas fairly, regardless of point of view or negative emotions. Intellectual empathy develops the ability to put ourselves in another's shoes in order to understand them. Intellectual integrity develops the ability to integrate with others’ intellectual reasoning and avoid the confusion that comes from our reasoning. Intellectual perseverance develops the need to seek truth about insight, regardless of barriers, such as difficulties, frustration, and obstacles. Confidence in reason encourages people to build confidence in their reason and think rationally. And finally, fair-mindedness develops the ability to start with a fair look at all the reasoning and traits of all viewpoints equally, putting aside one’s feelings and interests (Foundation for critical thinking, 2014; Paul & Elder, 2008b, 2012a).

There are specific teaching activities that can be integrated into the Paul-Elder critical thinking framework some of which are highlighted in the next section.

2.8 Indicators of Critical Thinking

Critical thinking offers a way to improve chemistry instruction in universities by promoting a holistic approach. The approach promotes active, student-centred learning and the infusion of both drives enables students to develop critical thinking skills. This section establishes the active learning instructional approaches and activities (critical thinking indicators) that will guide the analysis of the data later in the study and will provide understanding of what could be expected in the classroom.

Given that the main method of teaching in the university is the use of lectures, lectures that promote active learning are therefore encouraged. There is robust literature stating that active learning can contribute to the learning of university students (Section 2.5.4). Similarly, active learning instructional approaches are believed to develop student critical thinking (Oyelana et al., 2018). Roehl et al. (2013) argue that active learning compared with lecture provides opportunities for greater teacher-to-student mentoring, peer-to-peer collaboration and cross-disciplinary engagement (2013, p. 44). Morton (2008) suggested tools for integrating active learning into lectures, with some of activities being echoed in Bonwell and Eison (1991). These authors discussed student engagement with the use of class discussion, reading and writing. In another study by Jesson, McNaughton, Rosedale, Zhu, and Cockle (2018), they found that effective use of specific teaching practices such as digital tools, class discussion and critical thinking increased students' writing progress.

Also, critical thinking skills develop through the use of diverse teaching approaches that promote the ability to critique and verify information and knowledge (Allamnakhrah, 2013; Alwehaibi, 2012; Jaladanki & Bhattacharya, 2014; Stanley, 2017). Some of these teaching practices include the use of class discussion, problem-based learning, role-play, peer discussion, case study and explicit instruction (Abrami et al., 2008; Kogut, 1996; Laird, Seifert, Pascarella, Mayhew, & Blaich, 2014; Wan & Cheng, 2018). Numerous researchers have shown that the use of these approaches increases students’ critical thinking skills (Heijltjes, van Gog, Leppink, & Paas, 2015; Holmes, Wieman, & Bonn, 2015; Zhou et al., 2013).

Stephenson, Miller and Sadler-McKnight (2019) developed strategies that combine writing, inquiry, collaboration, and reflection, which can also be found in other active learning instructional approaches, such as questioning and formative assessment. As many scholars and educators advocate embedding critical thinking into teaching, the question arises as to how the concept is being integrated into teaching in chemistry classes. If ideas are presented in research, then it is worth investigating what strategies are effectively developing students' critical thinking. Also, there might be a risk that lecturers are unable to develop and present the ideas that might be suitable for their students.

Paul and Elder (2008b) promote their architecture of critical thinking framework by referring to elements of thoughts, intellectual traits, and intellectual standards. Their critical thinking framework promotes critical evaluation. There are certain indicators to demonstrate whether critical thinking has occurred or that can facilitate students' thinking at a high level. Alfaro-LeFevre (2017) described critical thinking indicators as personal behaviours and characteristics of a critical thinker.

2.8.1 Use of Humour and Imagination

Humour was another strategy discussed in the literature as a form of stimulating students' engagement, and ultimately promoting their critical thinking when embedded in classroom teaching. Some lecturers use cartoons, comics, videos or other animated technology and simulations as humour to stimulate interest, engagement and reflection on content. According to Rule and Auge (2005), cartoons are a type of humour. They believe that humour has positive effects on attention, attitude, and engagement in higher order thinking skills. Rule and Auge (2005) argues that to boost middle school students' excitement, humour was an effective pedagogy. In addition, they believed that humour could create a learning environment in which students viewed and analysed visual images that enhanced memory, made numerous connections between the new material and prior knowledge. They compared this to Vygotsky's social learning theory and constructivism.

Similarly, Cai, Wang, and Chiang (2014) argue that junior high school students' imaginative abilities were not yet mature; therefore, they suggested using augmented reality simulation system applications in a chemistry course, which is an extension of virtual reality. Sallis, Rule, and Jennings (2009) believe that the use of cartoons as a technique was successful in motivating underachieving students. Cheesman (2006) also argues that comics were attention getters for students in a science classroom and could be used as a pedagogical tool.

2.8.2 Approaches to Teaching

In this study, critical thinking indicators are regarded as teaching practices, attributes, characteristics or tools observed in the lecture as characteristics and behaviours and not by focusing on individual students. According to Paul and Elder (2008b) in their critical thinking framework, the level of competency for the cultivation of the three stages in the framework, namely intellectual standard, element of reasoning and intellectual traits, is an indicator for identifying the extent to which students are using critical thinking as a primary tool for learning. The implications of this framework suggest that the approach that lecturers apply to make the three stages effective for students are also indicators that critical thinking skills are being developed and evident. This study aims to report on the teaching approaches as indicators of critical thinking.

There is a need for teachers to be aware of the processes that are involved in the critical thinking framework, and of teaching strategies that will aid these processes (Behar-Horenstein & Niu, 2011). Studies have shown that there was an improvement in students' critical thinking when these processes were made explicit rather than being only implicit. Payette and Ross (2016) argue that critical thinking is being implicitly modelled by lecturers to students rather than explicit and systematic discussion. This study uses evidence-based research findings from the literature to construct lists of activities and practices that are suggested as indicators and that critical thinking has occurred within a classroom teaching. The identified strategies used for the promotion of critical thinking in the classroom was adopted in previous study (Gojkov, Stojanović, & Rajić, 2015).The next section highlights more of these indicators in addition to the ones discussed in Section 2.8 and 2.8.1.

It is assumed from the theory of student approaches to learning that a deep learning approach will lead to better academic performance (Chen & Hu, 2013);

therefore, teaching strategies that promote deep learning should be encouraged within the classroom. For example, Bennett et al. (2010) established the effectiveness of classroom small group discussions as a solution to the lack of students' ability to formulate and express arguments. Also, strategies such as group work or practice questions because they have no or minimal teacher participation, seem to improve the attainment of critical thinking skills. Written assignments were found to foster student engagement and active involvement in the class (Kolluru, 2012). Additionally, Parks (2017) suggested that simple strategies (such as casual class discussion forum) would help develop relationships with students and build an encouraging classroom environment.

Mentoring such as one-on-one student-teacher interaction should be encouraged (Abrami et al., 2015). Similarly, Whiley et al. (2017) argued that engagement would be part of an effective learning environment. Also, strategies that involved student collaboration, such as problem-based learning or projects, were found in a study by Abrami et al. (2008) to be more beneficial to students' learning. These are effective strategies for developing students' critical thinking.

Figure 4 was developed by the researcher in this thesis research study. Figure 4 highlights some of the teaching activities discussed in this section that can be integrated into teaching to promote active learning and participation of students. This approach to teaching is encouraged to foster the development of critical thinking in students, which can be obtained with frequent engagement and classroom interaction with lecturers. These practices would provide students with a one-on-one opportunity with the instructors.

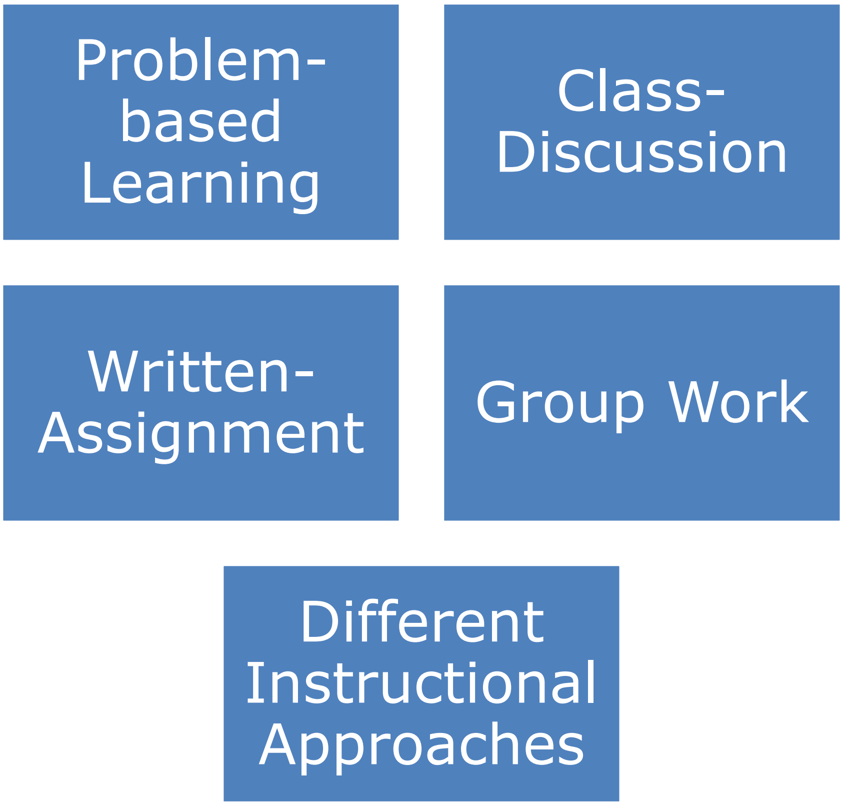

Figure 4. Examples of critical thinking indicators

2.8.3 Detail of Critical Thinking Indicators

The characteristics, attributes and strategies discussed in previous sections were adopted as critical thinking indicators in this study. These critical thinking indicators are teaching activities sought in the lecture observations in this study as teaching practices. Based on the research evidence that used certain activities as discussed from Section 2.8 to 2.8.2, the following are some of the critical thinking indicators identified for this current study:

- Questioning technique (Ebiendele Ebosele, 2012; Paul & Elder, 2012c; Rashid & Qaisar, 2016; Snyder & Snyder, 2008).
- Number of questions asked by lecturers (Osborne, 2014; Rashid & Qaisar, 2016).
- Number of questions asked by students (Elder & Paul, 1998).
- Level of lecturer-student interactions (Han & Brown, 2013).

- Group work (Ryder & Graves, 1997).
- Peer discussion (Cheng et al., 2018).
- Problem-Based Learning (PBL) (Abrami et al., 2008; De Bertacchini et al., 2016; Zhou et al., 2013).
- Class discussion (Kogut, 1996).
- Video segment (June et al., 2014; Kogut, 1996).
- Practice questions (Kogut, 1996).
- Written assignment (Kogut, 1996).
- Case study (Cotugno, 2018; Laird et al., 2014).
- Role-play (Laird et al., 2014).
- Explicit instruction (Bensley & Spero, 2014; Dwyer et al., 2014; Heijltjes et al., 2015; Holmes et al., 2015).
- Task-based learning in chemistry experiment (Zhou et al., 2013).
- Inquiry-based teaching (Arsal, 2015; Wartono, Hudha, & Batlolona, 2017).
- Verbs used during lectures versus verbs used in the assessment (from researcher’s document analysis section).
- Banishing put-downs and encouraging a free atmosphere for students to ask questions and make mistakes (Whiley et al., 2017).
- Small groups (Aktaş & Ünlü, 2013).
- Active learning (Roehl et al., 2013; Xhafa & Kristo, 2014).

As shown in Figure 4 and in the list above, when of some of these activities and strategies occurred in a lecture, this is an indicator that lecturers were developing critical thinking in their students using the content of subject. Critical thinking enables students to solve problems, be adaptable and learn new things (Walker, 2017). Teaching strategies that support critical thinking are demonstrated by an inquiry mindset and explicit teaching of critical thinking, promoted by strategies such as group discussion, case study evaluation and purposeful questioning, to mention a few. Therefore, this study posits that critical thinking will enable students to analyse and evaluate chemical concepts.

2.9 Planned, Enacted and Assessed Curriculum

The last section discusses some teaching practices that have integrated critical thinking into the model of teaching. These teaching practices could be signpost or indicators that critical thinking has taken place within a teaching session. Also, this section reviews literature on curriculum design.

Curriculum and instruction should place emphasis on evidence-based research (Lysenko, Abrami, Bernard, & Dagenais, 2015). It is also good practice to align learning outcomes of the curriculum with the assessment. Similarly, Abrami et al. (2008) found that it is important in course design that the course content is related to learning objectives for the critical thinking strategies to be explicit. Nelson (2017) recommended that during curriculum planning, focus should be on learning outcomes rather than course content. He believes that learning outcome is learner-centred, with specific high-level cognitive domains of application, analysis, and evaluation. Nelson (2017) suggested "flipped classroom" or "blended learning" as approaches to course delivery. He believes that interactive activities such as class discussions, case study, simulations and examination reviews can develop student critical thinking.

It is important that the intended, enacted, and assessed curricula align to achieve the learning outcomes (Seitz, 2017). This is because, for learners, their progression of knowledge can be easily documented. In addition, aligned curriculum could be used to determine if assessment restructuring is needed and to identify areas where learning expectations of students need to be identified.

What the university envisages as important to learn constitutes "planned" curriculum. What is delivered in the classroom constitutes "enacted" curriculum. What students learn constitutes "assessed" curriculum, and what is learned can be assessed through the end of semester examinations (Seitz, 2017).

2.10 Critical Thinking and Assessment

Assessment is key to learning (Delany et al., 2018). Assessment constitutes one of the pillars of education and the teaching-learning process, that always involves an evaluation of information (Siles-González & Solano-Ruiz, 2016). Delany et al. (2018) argued that assessment in the university should be designed to ‵′promote critical thinking necessary for sustained learning beyond university′′(2018, p. 255). However, there is gap between teaching and learning, which affects assessment methods, prevents lecturers from establishing the value of active learning strategies, and eventually hinders students from becoming independent learners (Carroll, 2017). As such, Stowe and Cooper (2017) proposed designing assessment tools that would provide students with learning opportunity and develop students' critical thinking.

Similarly, Carroll (2017) believes in assessment as a form of learning, when assessing is done for engagement which ultimately helps students develop critical thinking. Evidence from research has shown that critical thinking skills can help students' performance in examinations (Abeysekera, 2011; Winkle et al., 2014). Carroll suggests reintegrating assessment back into teaching by reflecting on teaching practices against the students' learning outcomes for a meaningful impact on students. Systematic reviews of research studies have clearly shown that critical thinking is essential for learning, and as such, critical thinking must be planned and followed through in teaching and assessment. Assessment can provide information about whether a student has learnt, and it exposes how they have defined or interpreted the content knowledge and how they can demonstrate the application of this knowledge. Assessment is essential to promoting critical thinking skills when structured appropriately. For this reason, assessing critical thinking should be intentional. Any assessment that focuses mainly on recall of content knowledge as the primary aim of testing-acquired learning encourages memorisation (Stowe & Cooper, 2017).

Thus, when sufficient questions are built upon throughout the curriculum, student learning can be promoted (Zielinski, 2004). Assessment that is thought-provoking and allows students to 'critically evaluate' and promote a more profound understanding of chemical concepts thus students' critical thinking is developed rather than an assessment that will encourage students to memorise content to pass the course at a given time.

Paul and Elder (1998) argue that an assessment that asks students to list, for example, is thought-stopping, and this approach will not generate further questions in the students. Wan and Cheng (2018) and Cheng et al. (2018) echoed this argument, stating that critical thinking-type assessment requires a multidimensional approach in which the questions asked should be open-ended. When students are asked to explain rather than answer multiple-choice questions, it fosters the habit of critical thinking (Grussendorf & Rogol, 2018).

Equally, open-answer questions are defined as being inclined to a more effective assessment when compared to the multiple-choice ones (Ennis, 1993). Toledo and Dubas (2016) found in their study that developing students' critical thinking and constructing their learning outcomes was possible with class activities and scaffolded assessment. They believe that assessment should align with the expected learning outcomes. Also, choice of language could impact the learning outcomes. As such, a curriculum should be aligned with the assessment tasks or choice of language in asking the assessment questions (Armstrong, 2010; Meyers & Nulty, 2009).

Naturally, the theory of student approaches to learning proposes that students will approach their studies differently depending on the perceived objectives of the course (Chen & Hu, 2013). Therefore, how a course is designed could affect academic performance.

Subsequently, interconnectedness should exist between critical thinking and the instructional method, along with the form of assessment. Students should not be left wondering about the link between what they understood from the taught content and how they are being assessed (Cargas et al., 2017; Heinrich et al., 2015). A good path towards effective and critical thinking assessment would be for lecturers to adopt the questioning technique that would develop students' critical thinking.

2.11 Objectives, Assessment, Graduate Attributes

There is a connectedness that exists among course learning objectives, assessment and university graduate attributes. Crosthwaite et al. (2006) adopted Josh and Lesley's pedagogical model to illustrate this connectedness (Josh & Lesley, 2004). They believed that specific learning objectives can be achieved through learning activities, which can prepare learners for assessment tasks (measured against standards) and can be used to demonstrate the attainment of the graduate attribute.

While much research in education is conducted along the graduate attributes' lines in the promotion of learning outcomes, lecturers should draw upon teaching strategies that are critical thinking focused. Significantly, the planned, enacted, and assessed curriculum is key to developing students' critical thinking skills (Kurz, Elliott, Wehby, & Smithson, 2010). In essence, action and learner focused teaching pedagogy is essential in order to meet the graduate attributes of a university and the learning outcomes of a curriculum (Duruk, Akgün, Dogan, & Gülsuyu, 2017; Treleaven & Voola, 2008).

There is an interconnectedness between developing critical thinking in a chemistry course and curriculum design (Gul et al., 2010) that carefully strategises the use of a critical thinking framework (see Section 1.4 for graduate attributes).

2.12 Chapter Summary

In spite of the popularity of critical thinking, it remains a problematic concept to define, although it is defined in multiple ways in the research literature. Arguably, commonality can be found among the different descriptions and definitions of critical thinking as discussed in this chapter. For example, scholars believe that the process of critical thinking will produce a positive result in student learning.

Other key points from the literature review are as follows. First, chemistry lecturers can gain ideas from the teaching strategies discussed in another field that resulted in the enhancement of critical thinking skills of students either at the primary, secondary or university levels. Second, there are numerous studies that have demonstrated the importance of teaching strategies and how they can develop students' critical thinking skills. Valuable information is gained from some studies that reported the importance of critical thinking in learning science at the primary, secondary and tertiary levels. Some studies used critical thinking strategies to teach at the university in another discipline other than chemistry. Third, critical thinking development is a long-term process embedded in daily teaching, not just a one-off intervention strategy, short course or workshop (Vardi, 2013).

In chemistry at the university level, everything builds upon previous concepts, so critical thinking could be considered as a puzzle, connecting the different parts. Fourth, a lecturer's role in developing students' critical thinking cannot be overemphasised in that great pedagogy cannot be accomplished without a committed lecturer willing to infuse critical thinking in their daily teaching (Vardi, 2013). Therefore, the focus of this study is on lecturers and their understanding of critical thinking and the implementation in their teaching. Fifth, active learning methods are highly recommended to engage students in critical thinking (Burbach, Matkin, & Fritz, 2004).

Additionally, based on research, there is a need for lecturers to change the course design and instructional approach (Kennedy et al., 2013). Last, teaching must be explicitly taught. Grussendorf and Rogol (2018) established that critical thinking in the classroom must be explicit for it to be developed in students and that this instruction should be combined with interactive learning. For this research work, the theoretical framework is based on the Paul-Elder critical thinking framework (Paul & Elder, 2008b). Critical thinking pedagogy entails injecting intellectual traits into the thinking process. When intellectual virtues are actively and explicitly taught across the academic institution, students develop critical thinking (Paul & Elder, 2012b, 2012c).

This chapter reviewed relevant literature towards better university teaching and located the importance of critical thinking to university chemistry teaching by discussing the need for education reforms related to quality teaching in universities as identified in the literature. The next chapter explores the study proposition and presents a conceptual framework.

CHAPTER 3.
PROPOSITIONS AND CONCEPTUAL FRAMEWORK

"The function of education is to teach one to think intensively and to think critically" (Popil, 2011, p. 207).

3.1 Introduction

The development of critical thinking in students should not be based on assumptions. Evidently, some lecturers assume they are developing critical thinking in their students (Welch et al., 2015). To this end, a framework is necessary to explicitly incorporate and measure the development and progress of students' critical thinking.

Thus, this chapter discusses the propositions that emerged from the review of the literature and the conceptual framework posed in this study. To answer the research questions, a qualitative case study design was employed. Details of this design are fully described in Chapter 4. To understand the role of Paul-Elder critical thinking framework in this study, this chapter provides a discussion of how the framework has been successfully integrated.

While several methods have been suggested for the investigation of problems using a case study design. The suggestions made by Merriam (1998); (Yin, 1994, 2014); Miles and Huberman (1994), and Creswell (2013) have been followed in an attempt to guarantee that the research questions are addressed descriptively, thus ensuring the study's reliability.

As a result of several authors suggesting that critical thinking is a key element in learning, the body of literature that addresses the development of critical thinking in university students is helpful in generating propositions related to how lecturers are fostering critical thinking skills in chemistry students. Given that chemistry has many principles, formulas and theories (DeWit, 2006; Osborne, 2014; Pinto & Prolongo, 2013; Vieira et al., 2011), individual learners will benefit more from a curriculum aimed at building thinking skills in turn, enable learners to choose and apply those principles, formulas and theories (Osborne, 2014).

Consequently, exploring the concept of critical thinking gives lecturers an opportunity to consider applying critical thinking to the teaching of chemistry in the hope of developing those same skills in students. As such, how lecturers are helping students to learn chemistry to understand, assess and use scientific knowledge (rather than memorise facts) is important. When students see the relevance of science to everyday life, lecturers have established an appreciation of chemistry and empower them to perceive chemistry as fascinating, connected and relevant.

3.2 Propositions

Research design has the following components: questions, propositions, units of analysis, logic linking data to propositions, criteria for interpreting findings, and analyses of case study evidence (Rowley, 2002). Given that descriptive studies need a proposition, this study's research questions are linked to the propositions. Thus, data collection and analysis are structured in order to support or refute the research propositions.

Propositions are helpful to increase the possibility that a researcher will be able to identify boundaries and increase the feasibility of a study (Baxter & Jack, 2008). Propositions are constructed on previous research findings with practical assumptions and are qualitative in nature. Propositions are sometimes not stated; some authors assume that readers' understanding of the review of literature is enough to recognise implied propositions (Avan & White, 2001).

Furthermore, propositions are defined as, "statements derived from theories or from generalizations based on empirical data" (Nieswiadomy, 2002, p. 90). Emerged propositions from the literature review are suggested to play a crucial role in case studies (Miles & Huberman, 1994; Yin, 2003). Yin noted that the purpose of each proposition is to "direct attention to something that should be examined within the scope of the study" (2003, p. 21). In addition, it ensures that a study remains practical within scope.

This study's propositions are:

- critical thinking is being developed in a first-year university chemistry course in the New Zealand context.

- there is constructive alignment with what was taught and the integration of critical thinking in the first-year university chemistry course curriculum, teaching approaches and assessment within the context of this current study.

Examples of the sources for this study's proposition are found in (Grussendorf & Rogol, 2018; Ziebell & Clarke, 2018).

3.3 Building a Conceptual Framework

A conceptual framework is a significant component of a qualitative study that serves several purposes, such as who will and who will not be studied (Miles & Huberman, 1994). Within a research context, a framework is a structure that provides "guidance for the researcher" (Liehr & Smith, 1999, p. 13). Wolcott stated that it is "impossible to embark upon research without some idea of what one is looking for and foolish not to make that quest explicit" (1982, p. 157). In building a conceptual framework for this current study, "intellectual bins" (Miles & Huberman, 1994) were adopted which contain events and behaviours. The researcher determined what was likely to be in the bin from a theoretical stance gained from the literature (for further detail, see Section 4.2).

The process of setting out bins and labelling them with understanding possible links between them leads to a conceptual framework. A conceptual framework explains either graphically or in narrative form, the main things to be studied (Miles & Huberman, 1994). A framework can be descriptive or theory-driven.

The underpinning theoretical framework of educational research comprises epistemology, ontology, axiology and methodology (Biedenbach, 2015; Denzin & Lincoln, 2005; Mack, 2010). A framework can be considered a paradigm: a comprehensive belief system that guides research and practice (Willis, 2007). Ontology and epistemology create a complete understanding of how knowledge is viewed, and how we can see ourselves in relation to this knowledge, along with the methodological strategies we use to determine it (Crotty, 1998).

Ontology is the study of being (Crotty, 1998), the nature of existence and what constitutes reality (Gray, 2014). Also, various ontological positions reflect different descriptions of what can be real and what cannot (Willis, 2007).

Therefore, this study presented the enacted curriculum in a university first-year chemistry course. With regards to the ontological perspective, the researcher provides a narrative of university lecturers' perceptions of their teaching and how it contributed or did not contribute to developing critical thinking.

The methodological approach in this qualitative study also employed a survey component (quantitative) which was a decision driven by the need of the study to strengthen the analytical findings (Miles, Huberman, & Johnny, 2014).

Epistemology is concerned with what we can know about reality and how we can know it (Willis, 2007). It provides a philosophical background for deciding what kinds of knowledge are legitimate and adequate (Gray, 2014). Underpinning this study is an interpretative epistemology. The researcher critiqued what was already known and transformed it into something better, in line with the recommendations in Whitehead and McNiff (2006), acknowledging that data from this study are descriptive and interpretative and could change as a result of new experiences and reflections. Data from this study are a snapshot in time, but there is not an assumption that there is a knowable objective reality (Merriam, 2009). This study was designed to learn about participants' teaching practices and understand their perceptions. It captured the lecturers' and students' realities as seen and experienced by them (Crotty, 1998). There was a recognition that individual differences come into the construct of how critical thinking (i.e. active or engaging learning) is integrated into university courses, and the social world is constructed with each person carrying a different meaning (Anderson & Arsenault, 2005).

Additionally, the methodology was influenced by the ontology and epistemological assumptions stated above. The researcher engaged with knowledge and systematically improved her understanding and creativity to establish a new knowledge of findings.

3.3.1 How to apply Paul and Elder critical thinking framework

In a research study that applied the Paul-Elder critical thinking framework to an assignment for first-year engineering students, eight elements of critical thinking were included in structured feedback and two rubrics for a problem-solving task

(Michaluk, Martens, Damron, & High, 2016). The study found that the critical thinking skills of students were enhanced because of the feedback.

Similarly, in another study, students critical thinking abilities were developed through assignments across the curriculum. A descriptive, longitudinal study of three engineering student cohorts presented an inspiring outcome for the engineering profession and public who require engineers to think critically (Ralston & Bays, 2013).

Another line of thought on the use of critical thinking framework identified a 5-step framework that can be employed practically in any teaching to successfully move students toward a more enjoyable, effective and active-learning setting which eventually benefit teachers and students alike (Duron, Limbach, & Waugh, 2006).

Critical thinking can help develop balanced inferential reasoning to improving thinking about ideas, where such critical thinking results in eliminating biases that can influence findings and conclusions. A critical thinking framework outlines a process with interactions between the stages and the need to revisit stages as information becomes clearer.

According to (Paul & Elder, 2008b, 2012c) the intellectual standards in the framework are standards which should be applied to thinking to guarantee a strong development of intellectual traits. In this process the development of quality intellectual traits may influence the intellectual standards, this is why Figure 5 has curved arrows to depict influence and the four-pointing arrow to show that one stage in the framework can impact on the other.

As earlier discussed, Figure 1 illustrates the process involved in the scientific method (Section 2.6). Figure 1 shows the graphical illustration based on the literature, the scientific method and the assumptions made by the researcher. The framework shown in Figure 1 was used in this study from the outset, in order to be selective of what was important and meaningful and what information should be collected and analysed. This process led to the conceptual framework in Figure 5. Figure 5 was created by the researcher in this thesis research study based on the interpretation of Figure 1 and understanding from (Paul & Elder, 2008b).

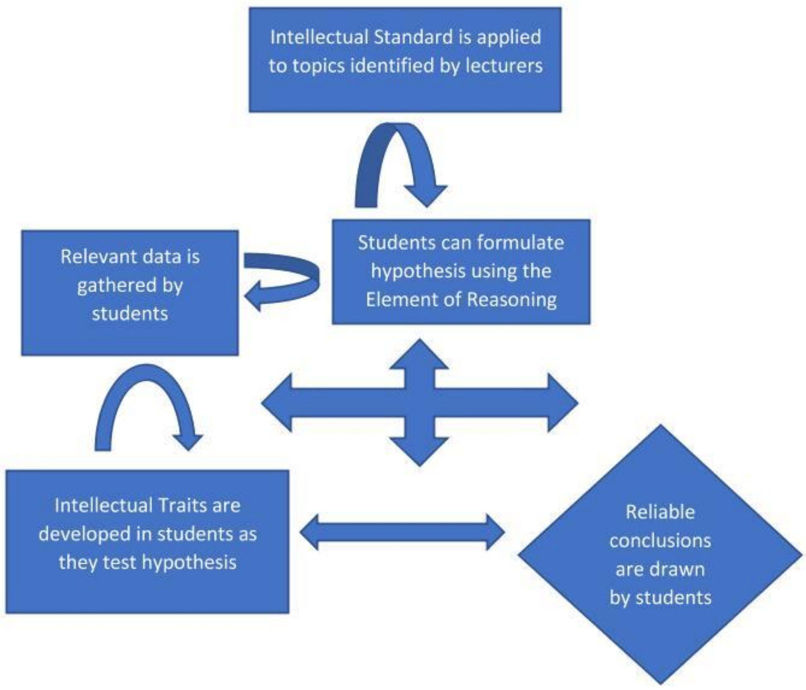

Figure 5. Conceptual framework for scientific method

The initial conceptual framework in Figure 5 was developed by the researcher using theoretical literature from Chapter 2. The framework adopted the scientific method and the Paul and Elder critical thinking framework (Paul & Elder, 2008b). The first step in the framework is the combination of questions identified in the scientific method and the intellectual standard by Paul and Elder (Paul & Elder, 2008b). When the intellectual standard is applied to the teaching of the topic planned by the lecturer, the students are empowered to formulate a hypothesis by asking questions using "The Element of Reasoning". This is the second stage in Paul and Elder's framework and enables students to gather relevant data and this process produces the last stage of Paul and Elder's critical thinking framework: the "Intellectual Traits". At this stage, the students are able to develop the skill of critical thinking as they test the hypothesis formulated which results in reliable conclusions drawn. At any point in the framework, students can revisit stages as required.

The synthesis of the conceptual framework developed to reflect the propositions previously mentioned is shown in Figure 6. Figure 6 was developed by the researcher in this research study.

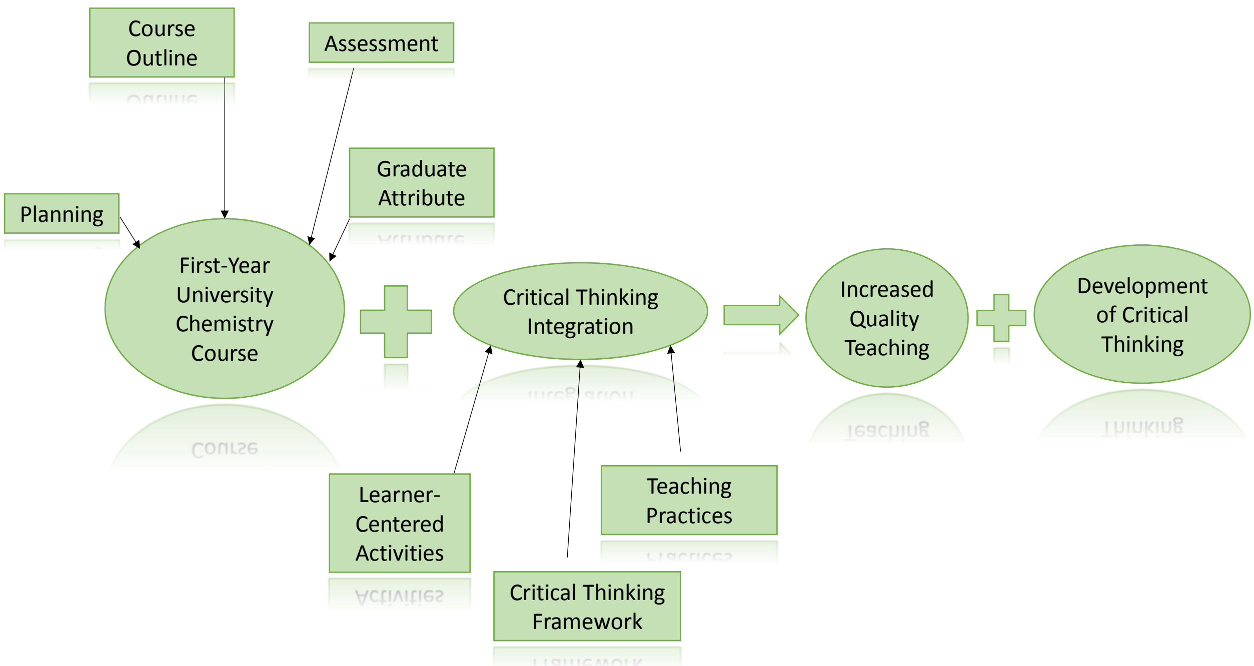

Figure 6. Synthesis of the conceptual framework

Figure 6 illustrates how the conceptual framework, which included the research proposition and understanding from the review of literature, is synthesised with the Paul and Elder critical thinking framework to assist in answering the research questions.

The aim and research questions of this study thus investigate a perceived connection or disconnect between the teaching practices of lecturers and the expected increase in the critical thinking of students, as such a complete need for developing or continuing critical thinking in university graduates through explicit critical thinking instruction long term is suggested (Grussendorf & Rogol, 2018).

3.4 Chapter Summary

The conceptual framework is a significant element in a research investigation. It is the alignment of relevant findings in the literature to establish a convincing viewpoint for why the topic of the study is important and the proposed methods to study it are suitable and rigorous (Maxwell, 2013).

This chapter established the conceptual framework of the study as a tool for launching an inquiry and producing a strong narrative that is a theory-based and data-driven argument for the importance of the research questions, the rigor of the method, and inferences for further advancement of theory and improvement of practice.

CHAPTER 4.
RESEARCH METHODOLOGY

4.1 Introduction

The purpose of this chapter is to outline the research methodology used in this study on the planned, enacted and assessed curriculum. The research approach adopted interpretivism with a philosophical realism stance. Interpretivism has been chosen because the research seeks to gain an understanding of the teaching practices of university lecturers. This study assumes that reality is socially constructed. Thus, there is no single observable reality; rather, there are multiple interpretations (Merriam & Tisdell, 2016). This chapter provides detail of the approach to this research; the methods of data generation and analysis. The research questions have been devised to examine the planned, enacted and assessed curriculum. The literature reviewed in the previous chapters highlighted the importance of lecturers adopting approaches that promote critical thinking in their teaching and how these practices impact on the calibre of chemistry graduates. In this study, the context consisted of students, lecturers, the courses and the university, where learning to be a critical thinker is an expected general learning outcome for graduates. This chapter provides details of the methodology and methods used in this study. It outlines the research design, epistemology and methods used to collect and analyse data to ensure ethical practices and to promote the validity and reliability of the study. It also provides the researcher's criteria for participant selection and the rationale for decisions about the participants.

4.2 Research Approach

This empirical study adopted a descriptive case study as a research strategy. This research design provided the logic that links the cases (i.e. data collected), and the conclusions are drawn to the study's research questions (Yin, 2003) thereby contributing to the knowledge of the use of critical thinking. This strategy is preferred because the researcher has little control over the concept of critical thinking and the real-life context with lecturers (Yin, 2003). This study examined the teaching strategies that promote critical thinking skills in a university chemistry course, what lecturers were doing in their teaching, their understandings about teaching and learning and how these understandings applied to the inclusion of critical thinking, how critical thinking was included in assessments and what students experienced. It discovered some of the obstacles and barriers that might be an issue to integrate critical thinking skills in a university teaching context. This strategy allowed the researcher to retain the holistic and meaningful features of real-life events (Yin, 2003). The methods included semi-structured interviews, course documents, a focus group, observations of university lecturers' teaching, and a survey. A survey was included in this study because, as Miles et al. (2014) argued, if we are to understand the world, researchers must face the fact that numbers and words are both necessary.

The descriptive method to case study was carefully chosen, as it permits data to be collected from several sources which are considered suitable to provide in-depth evidence (Woods, 1988), providing richer detail and initiating new lines of thinking through attention to surprises. One strength of qualitative research data is its ability to showcase human experience (Stake, 1995). Qualitative case study methodology offers tools for researchers to examine complex phenomena within their settings using a diverse data source. Also, case research allows the capturing of participants' reality in its natural context. It permits for the study of many variables and different aspects of a phenomenon, even when not previously determined. In this study, case studies were used as a valuable way of developing narratives with rich descriptions, and multiple case studies enabled differences in the lecturers' perceptions, knowledge, teaching styles, and analysis of data across cases, to verify the findings (Merriam, 1998).

4.3 Philosophical Stance

One of the key approaches that guide case study methodology was proposed by (Yin, 2003); Yin (2006). Yin discusses how case studies should seek to ensure that the topic under discussion is well examined and that the core purpose of the phenomenon is discovered. Yin (2003) bases the design of case study research on a constructivist paradigm. Constructivists claim that truth is in relation to the interpreter and that it is reliant on perspective and prior knowledge. This paradigm identifies the position of the subjective human construction of meaning without rejecting ideas of objectivity.

Constructivism is believed to inform teachers on how to guide learners (Taber, 2015). Taber argued for teaching that embraces education theory from the constructivist perspective. Additionally, active learning is encouraged "learning science is an active process of constructing personal knowledge" (2015, p. 7). Similarly, Gabel (1999) stated that to promote learning, the social constructivist theory must be put into consideration. This study has adopted the interpretive paradigm, which denotes an observed qualitative approach to research, the intent of which is to offer understandings into how given individuals, in a given context, make sense of a given practice (Basini, Garavan, & Cross, 2017). Similarly, Denzin and Lincoln (2011) stated that all research is interpretive; it is guided by the researcher's disposition to the world and how it should be studied.

Approaches to qualitative data analysis are classified into three types: interpretivism, social anthropology and collaborative social research (Miles & Huberman, 1994). Interpretivism argues for the use of conceptual orientations as a guide during interviews. Social anthropologists find relationships and patterns to provide an inferential explanation to the society under study. Therefore, in this current qualitative case study, the researcher acknowledges that interpretivism cannot be bias-free.

A case study approach was chosen because it enables descriptions about how lecturers are developing critical thinking in a first-year university chemistry course, situated in a particular context of West University and the first-year chemistry course, students, and the learning environment. The lecturers were observed teaching during lecture sessions. It would have been impossible for the researcher to have a true picture of the subject of interest without considering the context within which it occurred. The case as the unit of analysis (Miles & Huberman, 1994) analyses the individual lecturer's holistic experience in developing critical thinking in their first-year chemistry course. The cases will not determine or test the critical thinking skills of either the lecturers or the students. The type of case in this study is descriptive in nature because the thesis aims to describe the concept critical thinking and how it has been integrated into teaching within the real-life context in which it occurred (Yin, 2003).

Similarly, the case is "intrinsic" (Stake, 1995) because the intent is to understand the case better. The purpose is not to build theory (Stake, 1995), as cases are context specific. Rather, since all the lecturers are in the same setting and teaching into the same course, they will be considered as nested cases which inform the overall case for its descriptive detail (Yin, 2003).

This study researches the following three questions:

1. What are university lecturers' perceptions of critical thinking?

2. How is critical thinking being planned, enacted and assessed in the first-year chemistry courses at this university?

3. What factors, if any, do lecturers perceive as obstacles to fostering critical thinking in their course?

4.4 Analysis of the Case Studies

To highlight the systematic approach to data analysis, Stake describes categorical aggregation and direct interpretation as types of analysis (1995). The unit of analysis is the basis for the case (Rowley, 2002). The case study database of this study includes various evidence from different sources: document, lecture observation, interviews and focus group. Data analysis of this rich resource is based on examining evidence to assess whether the evidence supports the initial propositions of the study. The strategy for analysis uses the research proposition that encapsulates the objectives of the study, and which have shaped the data collection. The researcher trawled through the evidence, seeking corroboration and then recorded relevant evidence and made a judgement on whether the positions have been substantiated.

The choice of research method was reached through careful consideration of the multiple research options available, the main aim of the study, and the implications of the epistemological stance. In order to articulate the research method, as well as to elucidate and situate the epistemological stance, some clarification is provided on the researcher's choice of method and methodology. The researcher argues that reality is socially constructed. It was important to understand that as I observed lectures, provided the survey and interviewed lecturers; I viewed these processes as a socially constructed attempt to define the reality of planned, enacted and assessed curriculum in a tertiary chemistry course. It is important to note that the data collection process included acquiring approval from the Human Ethics Committee of West University (Owen, 2014).

The qualitative case study methodology described by Yin (2009), in this research involved observation (Driscoll & Perdue, 2014), focus groups (Merriam, 2009) and document analysis (Bowen, 2009). A survey assessed the relationship between the planned and enacted curriculum (Creswell, 2013; Creswell & Plano, 2011). Using surveys was for validating the results of the students and lecturers within the contexts of the university chemistry course. By using multiple sources to study the same problem, the study was designed to detect recurrent patterns or consistent relationships among variables and reduce the inherent weaknesses of a study dependent on one data source. Also, it integrated the two sets of data and then drew interpretations based on their combined strengths to understand the research problem (Guetterman, Fetters, & Creswell, 2015). Thus, the design provided the roadmap for this study to find answers to the research questions as validly, objectively and truthfully as possible (Kumar, 2014).

Qualitative analysis, like its quantitative counterpart, relies on identifying key elements in the phenomenon under study, these key elements in the data are called themes. Themes formed in this study are presented in Chapter 5 and 6 of the findings. Each of these themes is described in detail (Miles & Huberman, 1994) and tailored specifically to the one New Zealand university context. These themes would be compared with the definition of critical thinking adopted in this study according to Paul and Elder (2008b), (Vardi, 2013) and the experts as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment" (P. A. Facione, 1990).

4.5 Educational Context

The study focuses on the first-year university chemistry course, including how teaching was undertaken. Within the case-study (i.e. the university), the lecturers served as an embedded unit of nested case analyses. Also, because the objective of the study was to capture the events surrounding the teaching of this first-year chemistry course, the researcher investigated, observed and analysed how critical thinking was integrated into teaching (Yin, 2003).

In order to protect the anonymity of the New Zealand university, citation information is not included. Pseudonyms have been used for all the participants. The pseudo-anonymity name for the university is "West University" throughout this thesis. The Pseudonyms for participant lecturers are Joan, Isaac, Amanda, Ben, Patrick, Stella, Gavin, Denise and Patrick. The student participants' names were also confidential. 9 lecturers in the chemistry department at West University taught into CEM1880 (Learning Chemistry I) and CEM1881 (Learning Chemistry II) with cohort student numbers of around 420 and 320, respectively, in the first year. Eight lecturers volunteered and were developed as nested case studies for this study. First-year students were selected because the researcher wanted to add something new to the body of knowledge as there was little previous research of this nature on first-year university chemistry courses in New Zealand. Additionally, research has shown that 70% of senior high school graduates lacked competence in critical thinking skills (Chartrand, 2010) and this study was likely to create this awareness amongst university lecturers, particularly in focussing their awareness on teaching practices, including assessment.

4.5.1 Learning Environment

There are two first-year chemistry courses in West University, namely CEM1880 and CEM1881. CEM1880 is the compulsory first-year chemistry course, the mainstream course for science and major engineering students in their first-year undergraduate degree with an enrolment of 420 students. CEM1881 is the first chemistry course for non-mainstream chemistry students, those not taking engineering or chemistry in their first-year undergraduate degree (for example, for students majoring in Biological Sciences or Forestry), students with little or no prior background in Chemistry, fewer than 14 credits in Year 13 examinations, mature students who did chemistry over five years ago, and those who wanted to take chemistry as an elective from other departments. There were 320 students enrolled in the course the year the data were collected.

From the general course information, both CHEM 8880 and 8881 are first-semester courses with three component that included the lecture, laboratory class and assessment. The content of the CHEM 8880 course included detailed course description, goals of the course, learning outcomes, lecture course outline, prerequisite, details of the course coordinator, the lecturers, timetable, textbooks, problem manual, web-based resources, past tests and examinations. In the timetable, there are 36 lectures and 12 tutorials. The lectures took place in a traditional lecture theatre. At the same time, the laboratory sessions had seven experimental laboratories, two problem-solving workshops and a compulsory lab orientation and safety instruction class lead by lab demonstrators. The assessment breakdown was labs 12%, post-lab quizzes 3%, Best choice online-problems 5%, mid-semester test 30% and the final exam 50%. On the other hand, CHEM8881 has no prerequisite, and the assessment breakdown was lab sessions 15%, Best choice online-problems 10%, mid-semester test 25% and the final exam 50%.

4.6 Planning Stage

To begin this process, the researcher identified the West University in February 2016 at the time of data collection planning as a suitable location, as mentioned in Chapter 1 (see Section 1.2) to provide a rounded, detailed narrative of the teaching practices from a New Zealand context. An application was made to the university's Human Ethics Committee for approval of the research. The committee was provided with a letter of introduction, details about the study to seek their informed consent, and permission to conduct the study at the university. The researcher also prepared letters of introduction, information sheets and consent forms for the lecturers and students that met the ethics committee's criteria (see Appendices 3-6). See Appendix 7 for ethics approval letter.

After approval was obtained, the next step was to seek approval from the University's research group, who approves students' participation in study surveys at West University. The research group was provided with a letter of introduction, details about the study and a copy of the ethics committee approval letter. The survey reference group approval is in Appendix 8.

Following the approvals, with the help of the researcher's principal supervisor, a meeting was arranged with the chemistry course coordinators to introduce the researcher and to provide them with information about the study and what participants in the study would be involved in if they decided to volunteer to take part. A detailed discussion of the study was undertaken with the course coordinators for the two courses for first-year chemistry run by the chemistry department of the West University. The meeting provided an opportunity for the coordinators to ask questions and clarify any concerns. To make individual recruitment and contact run smoothly, the coordinators agreed to promote the study within their teams. The reason for inviting all 9 lecturers as participants was to obtain a greater understanding that can be compared across all involved in teaching the first-year courses. Other reasons were for validity and rigour.

Additionally, the researcher applied the concept of data saturation (Boddy, 2016). According to Boddy, one interview is never adequate, maximum samples of 12 may be adequate in a homogeneous population, and any sample above 30 is large and requires justification. Similarly, Guest, Bunce, and Johnson (2006) found data saturation became obvious at six and apparent at 12 interviews. In this study, eight interviews were carried out.

4.7 Recruiting Participants

An email was sent to the nine departmental lecturers with a letter of introduction, an information sheet about the voluntary nature of participation, a consent form and a copy of the Human Ethics Committee approval. One of the lecturers (Amanda) chose not to participate in the interview and survey but did allow lecture observation. No report was presented on Amanda in this study, as the observations by themselves would not form a complete case of the lecturer or present the authentic findings for Amanda. Students were also invited to participate via each course's online portal which was managed by the course coordinators. The course coordinators encouraged each volunteer lecturer to announce the study in their classes to encourage student participation. The announcement made clear that the students' participation was voluntary and that their responses were confidential and would not negatively affect their chemistry grades. When inviting the participants, the purpose of the research was clearly explained.

4.7.1 Implementation Stage

In the follow-up phase of the study, the implementation of the methods began on July 2016 with document analysis and the lecturers' survey. There were some unanswered questions through the findings of the document analysis and lecturers' survey. As such, further investigation was required and carried out with lecture observations and interviews. The focus on students was the last stage of data collection with a survey and a focus group to seek their insights and descriptions of their experiences.

4.8 Data Collection

On account of increasing data validity, the researcher was aware of the use of multiple sources of evidence, maintaining a chain of evidence and ethical consideration in data collection. This helped to grasp the involvement and perceptions of the participants. Therefore, this study adopted Miles et al. (2014) data collection design. This involved an integrated collection of both qualitative and quantitative data to understand the concept. A step by step data description for each method is presented in the following sections. Data were gathered from multiple sources at various times during the study, such that the case study's findings were based on the convergence of information.

The following sections explain the data collection methods under the headings: document analysis, survey, interview, observation and focus group.

4.8.1 Document Analysis

A document is a ready-made source of data (Merriam, 1998). Merriam (2009), states that a document refers to a broad range of material of significance to the study at hand and documents allow cross-referencing interviews and observations. Document analysis helps to uncover meaning, develop understanding and discover insight relevant to the research questions (Merriam, 1998). Additionally, Bowen (2009), described document analysis as a systematic procedure for reviewing or evaluating documents, both printed and electronic. Bowen believes that, like any other analytical methods in qualitative research, document analysis requires that data be examined and interpreted in order to produce meaning, gain understanding, and develop empirical knowledge. He further claims that documents can serve five broad purposes as part of a research undertaking. First, documents can provide data on the context within which research participants operate, bearing witness of the past occurrence based on the reported document.

Second, the information contained in documents can suggest some questions that need to be asked and situations that need to be observed as part of the research. Third, documents provide supplementary research data which can be valuable additional knowledge. Fourth, documents provide a means of tracking change and development, and lastly, the document can be analysed as a way to verify findings or corroborate evidence from other sources (Bowen, 2009). Caulley asserts that one of the advantages of document analysis, in alignment with Prior (2003)'s similar claims about documents in research, is that "though document analysis is routinely carried out in program evaluation, its full potential is rarely tapped" and the resources and "literature on the subject of document analysis are very meagre" (Caulley, 1983, p. 28). Additionally, in Bowen (2009), a university's identity is defined through documents; this has been a staple in qualitative research for many years. Prior (2003) states that any university is in its documents and not the buildings.

The researcher thoroughly gathered information from a relevant document based on its usefulness to answering the research questions. Two categories of documents were used: the internet and physical evidence. The university under study and its chemistry department had useful information. The graduate attribute was extracted from the university's website, while the course outlines and past examination paper was collected from the two topic coordinators. This information was then augmented with data from interviews and observations (Hancook & Algozzine, 2011), thereby validating the interview and observation data.

The document analyses were carried out to construct an informed description of the planned, enacted and assessed curriculum. It was important to find out how the department interpreted the university's graduate attributes (see Section 1.4.1) and the implementation process by the university and the department. The documents provided important contextual information about the intent of the university for graduate students who can use transferable skills such as critical thinking. The documents described for students what the department and individual lecturers expected. The researcher ensured that the documents were reported validly and honestly.

CHEM1880 0.125 EFTS, 15 points, first-semester general course information outlined in the content, consisted of three sections including laboratory classes, assessment and learning objectives. Other details were course description, goals of the course, a summary of course content, learning outcomes, lecture course outline, prerequisites, course coordinator, lecturers, timetable, textbook, problems manual, web-based resources, policy on 'dishonest practice', aegrotat applications, past tests and exams, disabilities, academic advice and staff-student liaison. The assessments were:

- Examination and test
- Pre-lab timelines and quizzes
- BestChoice on-line problems
- Marks and grades

The grades are divided as follows:

- Laboratory (including safety quiz and timelines): 12%
- Post-lab quizzes: 3%
- Bestchoice on-line problems: 5%
- Mid-semester test: 30%
- Final exam: 50%

The laboratory classes section had details on the laboratory schedule, purchasing lab coats and safety glasses, pre-lab timelines and quizzes, laboratory absences, laboratory assessment and laboratory safety.

CHEM1881 0.1250 EFTS, 15 points, first-semester general course information outlined included a description, the course coordinator, assessment, timetable and the academic staff. The assessment percentage weighting was:

- Term test: 25%
- Laboratory: 15%
- BestChoice: 10%
- Final Examination: 50%

4.8.2 Survey

A question is a form of research instrument used by participants in a survey (Creswell, 2012). Surveys collected a lot of information about the lecturers and students. The reason for collecting survey data from lecturers was to obtain a descriptive statistic of their perceptions about critical thinking and how they deliberately or otherwise engaged students in critical thinking as an active learning approach to teaching. The reason for collecting survey data from students was to obtain a descriptive statistic of their critical thinking experience.

The survey structure was such that the questionnaire in this study was divided into three sections for both the lecturers and students (Appendices 13 and 14). The first section gave the study information, participants' demography, and electronic consent for the students. The lecturers had the same, except that the demography was at the end of the survey. The second section contained open-ended questions to determine the understanding and the perceptions of lecturers and students related to critical thinking. The final section was made up of attitude questions; a Likert-scale was used for all questions.

4.8.3 Survey Instrument

The two forms of questionnaires revised to suit this current study by the researcher from previously developed samples were: the University Chemistry Student CT Skills Test (UCSCTST) and the University Lecturer CT Strategy (ULCTS). The UCSCTST survey instrument was developed because other previously reported surveys were designed for primary or secondary aged students, most of which were used under an intervention study of pre-test/post-test. Established instruments for university students previously used by other researchers related to critical thinking were interview focused rather than based on the use of surveys, or they have used critical thinking ability tests. Some of these instruments are the Critical-thinking Assessment Test (CAT), developed by Center for Assessment and Improvement of Learning, the California Critical Thinking Skills Test (CCTST), and the Intellectual Trait Inventory created by the Critical Thinking Foundation (Appendix 15), the Cornell Critical Thinking Tests, the Ennis-Weir Critical Thinking Essay Test (Ennis & Weir, 1985), and the Watson-Glaser Critical Thinking Appraisal (Watson, 1980). The California Critical Thinking Skills Test (CCTST), the Critical Thinking Interview Profile for College Students (CTIPCS), and the Intellectual Trait Inventory were mainly adopted in this study to construct the survey instrument. The ULCTS was developed based on document analysis and review of the literature. This was done to suit the study's primary aim and research questions. Themes from the literature and critical thinking indicators mentioned in Chapter 2, also informed the development of the survey instrument in this study (the surveys are appendices 13 and 14). Approval was obtained to adopt the Critical Thinking Interview Profile for College Students (CTIPCS) as a survey instrument from the critical thinking foundation (Appendix 17).

The online data collection software, Qualtrics, was used to collect the quantitative data. Data collected with the UCSCTST and ULCTS were done by uploading the questions on Qualtrics. Qualtrics was adopted for the survey part of the research because Qualtrics was easy to set up, easy to administer and provided the simple statistical analyses needed to understand better what the university lecturers' perceptions of critical thinking were and to determine whether critical thinking is being planned, enacted and assessed at the university. Qualtrics is one of the new sophisticated and customised survey tools available in recent years. Qualtrics can accommodate both open-ended and closed questions, which helps to achieve the overall aim of this study of being able to capture key information. A survey link was generated and sent out to participants. The survey was open for 30 days. Multiple reminders were sent via email to both students and lecturers.

For ULCTS, it was essential to determine how lecturers were developing critical thinking in their students. The 27 questions were designed to investigate the teaching practices of the university lecturers and their perception of critical thinking (see Appendix 14). Questions 1 and 2 were open-ended without any prompts or examples, while questions 3-9 aimed to elicit information about teaching strategies. The rest of the questions were designed to display the university lecturers' perceptions of critical thinking. Following these questions, participants were asked to indicate their age, years of teaching experience, qualification, and what first-year chemistry course they taught.

The student participants were asked a variety of questions about their learning and judgement on developing critical thinking. Out of the 33 items for UCSCTST, seven items addressed the understanding of critical thinking (Appendix 13), the importance of critical thinking and developing critical thinking. It was also essential to ascertain if students were developing critical thinking through CEM1880 and CEM1881; six items addressed how students viewed the way their critical thinking skills were being extended through the chemistry course. The rest of the questions were on the students' conceptualisation of critical thinking (attitude and perception).

These surveys provided a detailed and quantifiable (student survey only) description of the characteristics under investigation (Gray, 2009), and the surveys involved the use of both closed and open-ended questions. During the study, the researcher kept a personal research journal of interviews, observations, and focus group experiences, and thoughts. This journal assisted the researcher during the analysis of data (Flick & Gibbs, 2007), and it was constructed using handwritten notes (Yin, 2014).

4.8.4 Interviews

An interview is a powerful way to gain insight into educational issues by understanding the experience of individuals whose lives reflect those issues. As a method of inquiry, interviewing is most consistent with people's ability to make meaning through language. It affirms the importance of the individual without denigrating the possibility of community and collaboration (Seidman, 2006, p. 14). However, Driscoll and Perdue (2014, p. 109) argue that an interview is an "accurate depiction of what is being evaluated". Accuracy depends on how aware the participants are of their own strengths and what knowledge they have in relation to the subject under study.

Interviews are an important source of information in a case study research. Yin (2003) argues that it is one of the most important data sources. Interviews provided this study with richly detailed data and the opportunity to test highly nuanced explanations of lecture observations (Abowitz & Toole, 2010). The semi-structured method of interviewing allowed the interviewer to have a mix of more and less structured questions, specific to each case study, more opportunities to probe beyond the answers and explore exact wordings from participants (Merriam, 1998).

Interviews with participants in this study were conducted by the researcher in the lecturers' offices, which provided auditory privacy. The interviews were conducted one-on-one. At the start of the interviews, in an attempt to make each interviewee feel as comfortable as possible, the researcher spent time on the introduction and informal chatting to establish rapport and to put the participants at ease (Pitts & Miller-Day, 2007). Participants were reminded of the purpose of the study and that the details of interviews would be kept confidential. Leading questions were avoided to prevent the researcher from biasing answers or interrupting participants from saying what they wanted to say (Yin, 2014).

Before commencing the interview, participants were made aware of the right to interrupt and ask if a question is not understood and that they were allowed to not answer any question if they did not want to. Interviews lasted from 55 to 120 minutes and not the initially planned 30 to 60 minutes that was stated in the information sent to the participants before the interview. Interview questions used are in Appendix 1. With the participants' permission, the interviews were recorded on a digital recorder. Participants could ask to stop the digital recording at any time during the interview. The interview schedule comprised semi-structured questions to identify the variety of learning approaches to teaching and explore the lecturers' perception of critical thinking. The participants were also asked to provide feedback on barriers or obstacles to achieving the aim of developing students' critical thinking.

Interviews were not restricted to only pre-determined questions. While the researcher had prepared a list of questions, how the interviews unfolded depended on the answers given by individual participants. After hearing answers to the initial questions, there were follow-on questions developed on the spot or prompted by the participants for additional information. The interview process was dynamic in that it was shaped by the responses of the individual participants (Creswell, 2012). When participants appeared not to understand interview questions, the researcher checked their understanding of the question and if necessary, sought to explain the meaning of the question, reword it, or ask the question in another way. This was considered essential in order to obtain meaningful and credible answers. There were eight participants in this study who were lecturers. A list of lecturers' interview questions can be seen in Appendix 1. The 13 pre-determined questions were developed using questions unanswered from the document analysis, observations and current findings from the literature. Themes from the literature also informed the construct of the interview questions.

4.8.5 Observations of Teaching

Observation involves noticing what people say, do, their location, and the dates on which the data is collected (Chandrasegaran, 2008; Driscoll & Perdue, 2014). It is a process of exploring or investigating the participant's reality. In this study, data were collected using observation while the chemistry lecturers taught to experience first-hand how their classroom and teaching integrated critical thinking. Lecture observations allowed this research to directly study non-verbal behaviour (Abowitz & Toole, 2010).

Prior to data collection, a lecture observational guide (LOG) was developed by the researcher to measure CEM1880, and CEM1881 lecturers' planned and enacted curriculum. In other words, the teaching strategies, teaching activities, preparation related to the content, and how critical thinking was intended to be developed made up the LOG. The LOG was developed with the guidance of the critical thinking indicators derived from the *Classroom Observation Protocol for Undergraduates* used by M. K. Smith, Jones, Gilbert, and Wieman (2013); *The Teaching Practices Inventory* used by Wieman and Gilbert (2014); the *Developing Students' Critical Thinking in the Higher Education Class*, HERDSA Guide developed by Vardi (2013); the *Reformed Teaching Observation Protocol* (RTOP) (Piburn & Sawada, 2000; Sawada et al., 2002); and the West University

Chemistry Department General Course Manual for each course learning objectives. (Appendix 9.)

The LOG had 4 sections with questions and statements that were measured from a scale 0 to 4 ("never occurred" to "very descriptive"). The scale was interpreted in the case study and discussion as the degree of closeness to whether an event never occurred or occurred. The first section was the background information; this provided the researcher with accurate profiling of the lecturers during data analysis. The second section was to record the lecturers' teaching strategies or activities; this data provided the researcher with specific teaching practices of the lecturers reported in the case studies. The third section was related to the lecturers' course content; the researcher used this section to compare if the lecturer taught what was in the course outline and specifically for the topic observed. The last section was related to specific critical thinking focused teaching activities or strategies that the researcher observed used by the lecturers. On completion of the guide, the process of observation was carried out at different dates and times depending on the chemistry timetable and who was teaching. Each of the 8 lecturers was observed for a minimum of three teaching sessions. Each observation lasted between 50 and 55 minutes with the researcher's notes providing the main data. Additionally, the researcher used the university's video recordings of lectures by listening to some of the lectures as supplementary observations. These observations allowed for the verification of participants' interview reports.

4.8.6 Focus Group

The intended focus group in this study were the students from both CHEM1880 and CHEM1881. Focus groups frequently have different understandings and views about a subject matter or experience. According to Rabiee, "focus groups could provide information about a range of ideas and feelings that individuals have about certain issues, as well as illuminating the differences in perspective between groups of individuals" (2004, p. 656). The distinctiveness of a focus group is its ability to create data based on the collaboration of group communication (Green, Draper, & Dowler, 2003). Focus groups allowed the participants to provide information and different opinions with real-life evidence

(Barbour, 2017). This process shifted the role of the researcher with the group as the focus and in control (Nyumba, Wilson, Derrick, & Mukherjee, 2018).

Although data were intended to be collected using a focus group with volunteer students who were enrolled in the two first-year chemistry courses (CEM1880 and CEM1881) for the semester during which the data were collected volunteers were only three students from CHEM1880.

The interview location was a meeting room in the university within the chemistry department. The interview was audio recorded on a digital voice recorder with participants' permission. The interview guide of open-ended questions is presented in Appendix 2. Notes were also taken with participants' permission. The participants were asked questions to provide feedback on the learning approach to teaching experience in the chemistry courses. All participants were aged 18 and above. The ten pre-determined questions were developed by the researcher using the Critical Thinking Interview Profile for College Students (CTIPCS) developed by the Critical Thinking Foundation. The CTIPCS was re-created by the researcher to suit this study in order to answer all the research questions. Approval was obtained from the Critical Thinking Foundation to use CTIPCS. Themes from the literature were also part of the focus group discussion. There were three participants, and all were CEM1880 students. The focus group session lasted for 60 minutes.

4.9 Summary of Data Collection

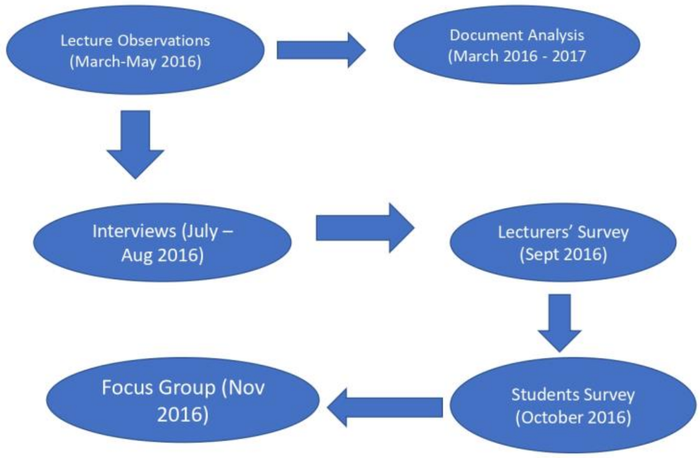

Figure 7. Overall Research Design

Figure 7 illustrates the overall research design, indicating when data collection occurred. All data collection were carried out using the document analysis, survey, observation, interviews and focus group. The resulting data was carefully developed into the case studies. The eight case studies were compared with each other to identify commonalities and differences (detail is provided in Chapter 6).

The case study allowed the researcher to experience proximity with this real-life setting to develop rich and thick descriptions and comprehensive understanding (Merriam, 1998). Information for this study was collected from multiple sources and triangulated to develop case studies. Figure 8 was developed by the researcher in this research study. Figure 8 displays the intercorrelations among the data collected, indicating the various data source mapping of this study and the elements involved in consulting these sources that would be reported later. The 3rd level linkage between qualitative data and survey data as proposed by Miles et al. (2014) was adopted. The document analysis and survey findings are reported separately in the next chapter.

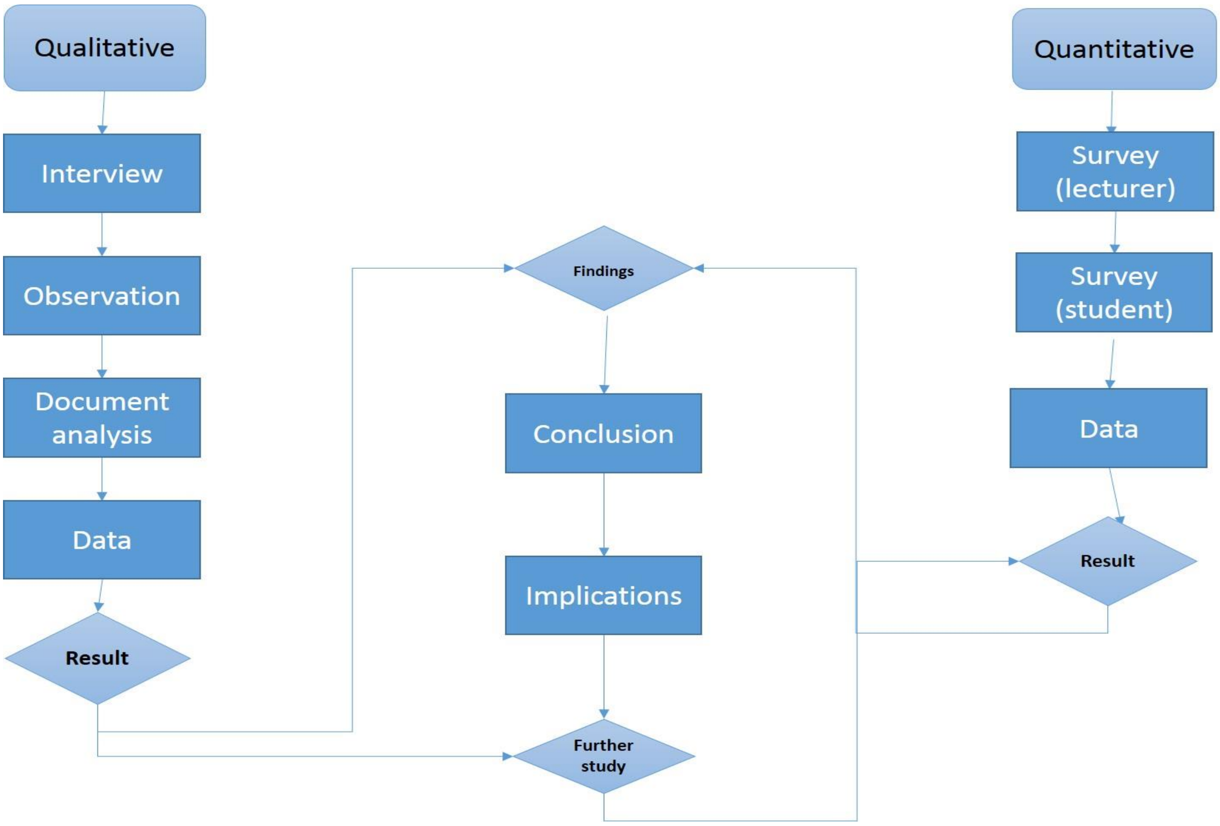

Figure 8. Showing connections between sources of data

4.10 Data Analysis

This section presents the step by step data analysis method and how this is connected to the findings in the next chapter. This section is a discussion of the data analysis techniques that were used in this study.

Thematic analysis was used to analyse qualitative data obtained through interviews, observations, focus group and document analysis. Braun and Clarke (2006, p. 79) provided a definition of thematic analysis as: "a method for identifying, analysing and reporting patterns within data". On account of the use of thematic analysis, the aim of this study was to categorise, discover patterns rigorously, highlight themes from data and apply logic with the use of Paul-Elder critical thinking framework and NVivo. In this study, all interview data were imported into QSR NVivo 10. In NVivo, coding is assisted by structures called "nodes" (appendix 19) which provide the storage capacity for references to the coded text (Houghton, Murphy, Shaw, & Casey, 2015). The themes were checked and re-checked with two additional raters for consistency of allocation of codes and allocation of codes to themes.

Broad coding aims to uncover and develop concepts, and the text must be opened up, so that thoughts, ideas and meanings contained in it can be exposed (Miles & Huberman, 1994). On the contrary to what was intended, the Paul-Elder critical thinking framework adopted as a basis for this study was not used for data analysis because the lecturers were not engaged in the use of any framework for integrating critical thinking into their teaching practices.

For this reason, Figure 9 illustrates an overview of the initial synthesis. The figure was developed by the researcher in this thesis research study to reach an in-depth presentation of the data analysis. This synthesis was generated since the Paul-Elder critical thinking framework could not be used as intended. The synthesis helped with the development of the cases in Chapter 6. The flow chart illustrates the resulting synthesis that emerges from all the various data collected. The figure consulted all the lecturer-related data with the document analysis and student surveys analysed. The definition of critical thinking was consulted in data analysis and in synthesising the themes and the development of the case study.

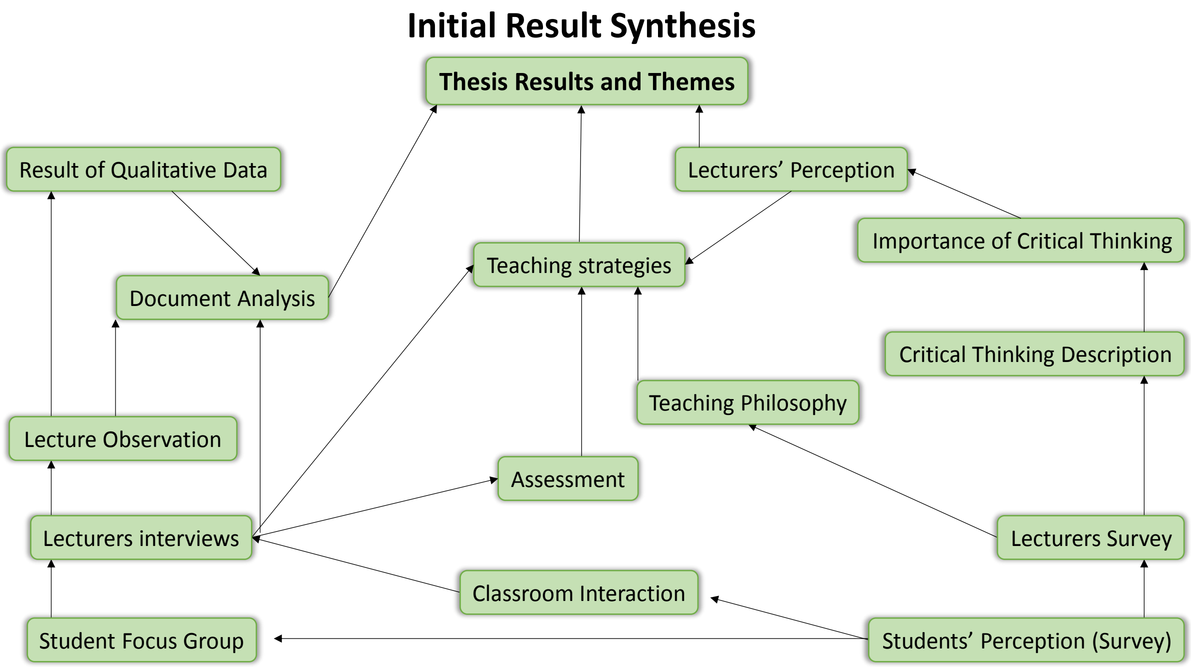

Figure 9. Overall Initial Result Synthesis

The analysis provided the context for the presentation of the findings and was integrated into the final stages of the write-up, in the discussion and concluding chapters. The case study on the lecturers is presented in Chapter 6.

4.10.1 Document Analysis

The analysis of the documents method was used because the information provided meaningful answers to the study research questions. This section explained why and how the course outlines were analysed in relation to the university's graduate attributes and the 2016 examination paper. This study analysed only the following documents: the university's graduate attributes; the chemistry course outline; and the 2016 examination paper.

In this study, document analysis focused primarily on the messages contained in the documents, which is the standard approach. The researcher concentrated on keywords as "verbs" throughout the analysis and reported findings. However, the exact correspondence or focus in each item (question) was not used but rather the close agreement was used. This content analysis adopted the coding scheme. Following the coding, the researcher used interpretive analysis to identify vagueness and translate meaning. The purpose of this document analysis was to determine and report on the alignment of the enacted curriculum with the assessment.

Analysis of verbs in CEM1880 course outline

The researcher analysed the ten topics identified in the course outline for the semester against the assessment to help understand the assessed curriculum. In the topics as identified below when divided into blocks of units with learning objectives, the active words (as verbs) used were: define, understand, know, distinguish, describe, state, expand, calculate, predict, estimate, rationalise, explain, demonstrate, determine. These verbs were used in sentences such as: be able to describe what is meant by the valence electrons of an atom in terms of the atom's electronic configuration; state the gas laws of Boyle, Charles, and Avogadro; know how the gas laws are combined in the ideal gas equation; explain the relative reactivities of different gases, based upon bond order arguments; understand the definition and importance of state functions in thermodynamics; know how to calculate the work done on a system expanding or contracting against external pressure.

The topics stated in the section lecture course outline of the document were:

- Atoms and the Periodic Table (2 lectures)
  - Revision of atomic structure, atomic mass, quantum numbers and atomic orbitals. Electronic configurations, the aufbau principle and Hund's rule.
  - The periodic table - periodicity, electronegativity, ionisation energy, electron affinity, etc.
- Chemical Bonding (2 lectures)
  - Chemical bonding: ionic, covalent and metallic bonding.
  - Lewis structures and the octet rule.
  - Molecular geometry, VSEPR theory.
- Reduction and Oxidation Reactions (2 lectures)
  - Redox and related reactions, oxidation numbers, balancing redox equations.
- Properties of Gases (5 lectures)
  - Intermolecular forces, kinetic versus potential energies and states of matter.
  - Gas laws (units of pressure, Boyle's, Charles's and Avogadro's laws).
  - The ideal gas equation (density calculations, molar mass of gaseous substances, gas stoichiometry).
  - Quantities and dimensions (IUPAC conventions and SI units).
  - The kinetic theory of gases.
  - Dalton's law of partial pressures.
  - Grahams law of effusion.
  - Global warming and physical principles of carbon capture technologies.
  - Atmospheric ozone depletion and reactivity of gas molecules.
- Introduction to Thermodynamics (5 lectures)
  - Systems, states and state functions; heat and work; pressure-volume work.
  - First law of thermodynamics; conservation of energy; internal energy and enthalpy.
  - Calorimetry; heat capacities Cp and CV.
  - Thermodynamic cycles as a generalisation of Hess's law and Kirchhoff's law; standard states; use of tables of state functions.
- Kinetics (5 lectures)
  - Reaction rates and rate laws.
  - Experimental kinetics measurements.
  - Concentration-time plots and the integrated rate equations for zero-order and first-order processes.
  - Activation energies; the Arrhenius law and temperature dependence of reaction rates.
  - Mechanisms of complex reactions, molecularity and catalysis.
- Chemical Equilibrium (3 lectures)
  - Equilibrium constants.

Calculations of equilibrium concentrations of reactants and products.
Le Chatelier's principle. Reaction quotients and the direction of spontaneous change of a reaction.

Thermodynamics II (5 lectures)

The concept of entropy changes as driving force.
Second law of thermodynamics; calculations using entropy as a state function.
Gibbs energy; relationship of Gibbs-energy change to entropy change.
Relationship of the standard Gibbs-energy change to the equilibrium constant. Temperature dependence of the equilibrium constant.

Aqueous Chemistry (3 lectures)

Structure and bonding of water. Intermolecular forces, hydrogen-bonding.
Physical properties of water. Polarisability, dielectric constant.
Ice and other hydrogen-bonded systems.
Ion hydration, mobility and hydrolysis. The dissolution processes.
Water as a solvent for: non-polar covalent, polar covalent, hydrogen-bonding covalent and extended lattice covalent compounds, metals, gases, and ionic solids.
Qualitative solubility predictions.

Acid-Base Equilibrium (4 lectures)

Acids and bases. Self-ionisation of water. Amphoterism.
Calculations of pH in solutions of acids, bases, salts, titrations and applications of the buffer equation.

The 2016 examination paper was in two parts. Part A contained 55 multiple-choice questions, and part B was non-multi-choice-questions. Questions A1 – A5 were related to Quantitative Analysis by Gas Measurement. Questions A6 – A25 covered various topics, such as the First Law of Thermodynamics, molecular interactions and the gas laws, chemical equilibrium, Boyle's law, rate reaction, rate law, first-order reactions, equilibrium constant, and Gibb's energy. Questions A26 – A30 were related to the reaction system at equilibrium. Questions A31 – A36 were related to calorimetry, enthalpy change, entropy change, the equilibrium constant, the Second Law of thermodynamics and Gibbs energy. Questions A43 – A45 relate to reactions for which $\Delta_r H = -100$ kJ mol^{-1} and $\Delta_r S = -100$ J K^{-1} mol^{-1} at the temperature indicated in the question. Questions A46 – A55 were on aqueous chemistry. In part B of the paper, Questions B1 – B5 were related to kinetics, molecularity, the thermodynamic equilibrium constants, Dalton's law of partial pressures, water as a solvent, and acids and bases.

Some of the topics described above were not assessed in the 2016 examination paper, such as Hess's law and Kirchhoff's law, Graham's law of effusion, the

Arrhenius law, and self-ionisation of water. There were more questions on chemical equilibrium than any other topic, followed by water as a solvent and salts and buffer solutions.

The ‘active word’ is the verb. What is expected from the student to achieve in their learning objective is the ‘verb’ in focus. After analysis, these verbs were categorised into ‘themes’ of verbs. For example, be able to state the first law of thermodynamics in a practically useful form and understand its equivalence with the principle of conservation of energy; the action words or verbs in this learning objective are ‘state’ ‘understand’. The emergent verbs from the course learning objectives were: define, understand, know, describe, state, use, be aware, assign, state, derive, calculate, predict, estimate, provide, rationalise, list, solve, demonstrate, determine, and recognise.

For example, in the examination of the course outline, under the learning objective, the researcher observed that it was stated under the topic on Kinetics (first-order reactions) that at the end of this topic a student should be able to:

- Use the initial conditions of a first-order reaction to determine the concentrations of the reaction components after some elapsed time;
- Define what is meant by the term’s lifetime and half-life of a first-order reaction; and
- Determine the half-life of a first-order reaction from the rate coefficient or vice-versa. (CEM1880 Course Outline)

The questions related to the first-order reaction in the 2016 examination paper on page 5 (questions 16 and 17), were as follows:

> 16. For a reaction A(aq) $\rightarrow$ B(aq), the concentration of A is observed to decay exponentially. What is the order of the reaction?
>
> (a) 0th order; (b) 1st order; (c) 2nd order; (d) cannot tell.
>
> 17. For a reaction R(aq) $\rightarrow$ P(aq), the rate coefficient is 3.1×10^{-4} L^2 mol^{-2} s^{-1}. What is the overall order of the reaction?
>
> (a) 0th order; (b) 1st order; (c) 2nd order; (d) 3^{rd} order.

The choice of words (i.e. verb) was introduced at this stage by the researcher with the coding scheme. The learning objective verbs used 'define' and 'determine', and the examination verbs were 'what' or 'what is'.

Another example is in equilibrium calculations under the topic of chemical equilibrium. The two-learning objectives stated:

1. Know how to calculate the equilibrium constant from the final (equilibrium) concentrations (or partial pressures) of one component and the initial conditions of the reaction system; and

2. Know how to calculate the concentrations (or partial pressures) of components in a system at equilibrium, given the initial state of the system and the value of the equilibrium constant.

The questions asked in the 2016 examination paper were on other aspects of the topic, and no particular question on the verb 'calculate'. The questions were

26. How does the system respond if NO2(g) is added at constant temperature and volume?

(a) There is a net shift in the direction of the forward reaction.

(b) There is no net change.

(c) There is a net shift in the direction of the reverse reaction.

(d) This cannot be decided without further information being given.

36. The thermodynamic equilibrium constant, K, for this reaction will be equal to 1:

(a) At 0 K.

(b) At a temperature between 0 K and room temperature.

(c) At or above room temperature.

(d) Cannot say.

Analysis of verbs in CEM1881 course outline

Like CEM1880, the first step in the document analysis examined the language used or use of words (i.e. verbs) in the course outline. In CHEM1881, the emerged themes of verbs were not aligned with the examination paper because the only examination paper analysed was for CHEM1880. Instead, the verbs used for the learning objectives were compared with those of the learning outcomes. For example, as established in this section, the themes from the learning outcomes are developed, demonstrate, understand, describe, explain. Instead, the topics in the block 1 for CHEM1881 did not identify any learning objectives like the ones in CHEM1880. However, from the information provided in Block 2, one can say: CHEM1881 will explore, develop, understand, examine. In this case for Block 2, the learning outcomes and the learning objective had the highest match. Again, for Block 3, the learning objectives were not clearly outlined. However, from the information provided for the block, these themes emerged: examine, describe, predict, discuss, distinguish. These themes do not match the learning outcomes.

The CEM1881 document on the first page referred to the document as "General Course Information" with a description section that stated

> "Chemistry plays an essential role in the modern world; we are dependent on chemistry to provide interesting new materials, medicines, dyes and a host of other things. We also need the principles of chemistry to understand many of the phenomena of the world around us, including how life works. We will be studying examples of chemistry in everyday life, especially associated with biology and materials" (CEM1881 course).

Other general information followed, such as lecturers' details, laboratory schedule and assessment times. After the information section, there was the goal of the course, the learning outcomes and the topics. The topics were in 3 blocks, with the first consisting of Introduction to Atoms, Chemical reactions, periodicity and bonding, and Material properties and bonding. The second block was related to the chemistry of life with Aqueous Chemistry, Equilibria, Acid-Base Chemistry, Organic Chemistry and Redox Chemistry. The last block contained Thermodynamics and Kinetics, and Chemical Kinetics.

The coding scheme analysis was carried out with a critical examination of the chosen verbs in the learning outcomes, description of the topics and the 2016 examination paper. The learning outcomes were:

- Develop problem-solving and data analysis skills.
- Demonstrate an understanding of the world at an atomic scale.
- Show an understanding of scientific nomenclature.
- Describe the aqueous chemistry that underpins life.
- Demonstrate an understanding of chemical experimentation, including data collection and analysis.
- Explain the physical basis of chemical reactions, including basic thermodynamics and kinetics.

The following themes emerged from the learning outcomes: demonstrate, describe and explain. There were no identified learning objectives for the block of topics. There was limited description of the scope of topics in block 2 and 3. Block 2 stated:

> "…there are two facts that we know about the chemistry of life; it consists largely of organic molecules and their reactions in water. During the second block of CEM1881, we will explore in more detail what organic molecules are, their properties and develop our understanding of the types of chemicals that are important in biological systems. We will examine the chemistry of water and molecules dissolved in water, what we call aqueous chemistry. We will see how the combination of these separate parts of chemistry allows an increased understanding of the chemistry of life. Specifically, we will examine the topics shown below". (CEM1881 Course Outline)

Block 3 stated:

> "These lectures will introduce more quantitative ways of looking at physical and chemical processes. We will discuss the energy changes that accompany different processes and the way that that is reflected

in the changes in enthalpy or 'heat', (enthalpy changes are a technical term for discussing energy, or heat, changes at constant pressure). We will note the distinction between the thing undergoing the change, the system, and the rest of the universe, the surroundings. Processes ('systems') that take in energy are endothermic, whereas those that give our energy are exothermic. As examples, processes which involve breaking chemical bonds are endothermic, whereas those which form chemical bonds are exothermic. The examples that we will study include phase transitions of water (ice melting and water boiling); the energetics of forming an ionic salt from the constituent elements; and the energetics of dissolving ionic solids in water.

Other topics that will be covered include The First Law of Thermodynamics, Hess's Law, and Born-Haber cycles. Processes may go forwards or backwards depending on the conditions (e.g. ice can melt, or water can freeze). The direction in which processes tend to occur is the basis of the Second Law of Thermodynamics - favourable processes involve an increase in the disorder of the universe. This is quantified by the thermodynamic term entropy, S. We will consider entropy in a qualitative way in order to predict whether a process is likely to occur. Chemical processes are generally speeded up by increasing the concentration of reactants and/or the temperature. These features can be understood in terms of the collision theory of chemical reactions. Collisions between molecules are more frequent if the concentration of molecules is greater. We will examine how the rate of a reaction depends on the concentration of one or more reactants in different systems and methods that can be used to quantify and describe this relationship" (CEM1881 Course Outline).

The examination paper had two parts: part A, contained nine questions (non-multi-choice); and part B, containing 45 multiple-choice questions, which are answered by filling in the gap and circling the answer. Part A covered topics such as boiling point, atoms, aqueous solution, equilibrium, oxidation, heat capacity, enthalpy, rate law, the rate constants, acids and bases. Part B questions were related to wider topics such as solubility, boiling point, Le Châtelier's principle, the First and Second Law of Thermodynamics, aqueous solution, equilibrium, oxidation, rate law, acids and bases, and activation energy.

To show the association between the course outline and examination paper, the themes from both were cross-checked for similarities. As such, in addition to the emerged learning outcome themes, the themes drawn from the topic description were: examine, explore, develop, and discuss. The combined themes were: demonstrate, describe and explain, examine, explore, develop, and discuss. Themes from the examination paper were: explain, choose, use, expression, calculate, draw, indicate, classify, complete, state, give, define, choose, and determine. The only aligned verb was: "explain". This demonstrated a mismatch in comparison if there is only one verb that matched.

4.10.2 Analysis of Interviews

Thematic analysis was adopted by examining each piece of information related to the research questions. Potential answers were categorised into themes.

For the purpose of interview thematic analysis, the researcher employed Interpretive Phenomenological Analysis (IPA) of the data as described by J. Smith and Flowers (2009), which is inductive in nature. IPA does not include a single step of data analysis, but must include the following characteristics: (a) movement from what is unique to a participant to what is shared among the participants, (b) description of the experience which moves to an interpretation of the experience, (c) commitment to understanding the participant's point of view, and (d) psychological focus on personal meaning-making within a particular context (J. Smith & Flowers, 2009).

Audio recordings from interviews were transcribed. The digital recording for all interviews was transcribed and saved into a Microsoft Word document. NVivo 10 for Windows was used to organise data by coding into nodes which provided easy retrieval of the emerging themes (NVivo 10, 2017). Once transcribed, the researcher sent an e-mail to the participants for member checking and adjusted as necessary from participants' feedback that resulted in minor adjustments. Stella and Denise requested a few statements made to be regarded as "off-record". The researcher has removed these statements for confidentiality as a demonstration of the commitment to understanding the participant's point of view. Data that occurred most repeatedly were highlighted in the reporting of findings as themes that emerged (Sarantakos, 1993). These themes developed as a movement from what was unique to a participant to what was shared among the participants (J. Smith & Flowers, 2009).

Additionally, the transcribed interviews were read and re-read several times to immerse into the data. Following the IPA process, the researcher conducted an initial noting, which included descriptive, linguistic, and conceptual comments (J. Smith & Flowers, 2009). The first stage of analysis in IPA is developing a set of descriptive comments on the interview transcript. The purpose of descriptive comments was to describe the content of the data. Secondly, in making descriptive comments, the researcher identified key descriptions and emotional responses. During the third level of analysis, the researcher moved into a more interpretive stage of analysis in making formative comments. At this stage, the researcher began to develop insight into the data that allowed the development of themes in the next stage of analysis. After the completion of the preliminary noting on each participant's responses, the researcher searched for emerging common themes across all participants by examining separate sections of the transcripts (Cooper, Fleischer, & Cotton, 2012).

Additionally, to ensure confidentiality, the researcher carried out the following: (1) did not use actual names that may be linked to the participant's identity in the transcripts; (2) transcribed interviews in a private setting and headphones were used to ensure privacy and confidentiality; (3) secured all electronic recording devices, notes, and transcriptions containing data obtained in the research in a password protected computer only accessible to the researcher; and (4) participant's identity written on any notes was destroyed after the interviews.

4.10.3 Analysis of Observations

The lecture observations were analysed using the Lecture Observation Guide (LOG) developed by the researcher (Appendix 9). Observations of lectures and video recordings of lectures served as a reference for indicating what occurred. The LOG helped to examine the enacted curriculum against what was planned. As explained earlier in Section 4.7.4, the LOG examined the lecturers teaching, coverage of the course content, and strategies for developing critical thinking in the students. These criteria were measured, ranging from "never occurred" to "very descriptive" accounts.

4.10.4 Analysis of Surveys

The survey analysis for both lecturers and students adopted the first level of qualitative-quantitative linkage (Miles et al., 2014). The first stage is known as "quantizing". This is where information can be counted directly and converted into magnitudes of ranks or scales. In this study, magnitudes and scales such as "moderate" and "extremely" were employed to check the degree of agreement. Data from lecturers' and students' survey questionnaires were analysed using descriptive statistical methods, which included percentages, response count and graphs. Descriptive statistics is concerned with describing the population under study. The data could then be presented in a meaningful way, like charts, graphs, and tables. In this study, these artefacts were used to summarise the university lecturers' perceptions about critical thinking, and how teaching was planned, and enacted and learning assessed for these chemistry courses. Other functions of descriptive statistics adopted in this study were used to explain the data.

Descriptive statistics were obtained in this study with the use of Qualtrics software. Each question has what Qualtrics calls visualisation (Qualtrics, 2019), where a statistical report was generated. Available tabs ranged from a simple table, bar chart, line chart, pie chart, broken-down bar, statistics table, and gauge chart. The statistic table comprises minimum, maximum, mean, standard deviation, variance and count. Labels were available too, depending on the statistical report needed to be generated, such as percentage, response count and category name. In this study, the broken-down bar with the response count was used for the lecturer survey because the sample size was small. For the students' survey, simple percentages were generated because the students' response count for CEM1880 that completed the survey was 54 and for CEM1881 was 34, which made up an appropriate sample size for percentages. Data obtained from the questionnaire were analysed using simple descriptive statistical analysis (Chapter 5) and presented as part of the narrative in the case study presented in Chapter 6.

4.10.5 Analysis of Focus Group

The analysis of focus group data can take a wide diversity of procedures, and there is no best method. Rather, the analysis must be carefully chosen and match the research intent (Rabiee, 2004; Stewart, 2006). The focus group analysis was similar to the analysis of the interviews with the lecturers. Any proper analysis of focus-group data should consist of the most important themes, the most noteworthy quotes and any unexpected findings.

Breen (2006) and Krueger (2015), believe that in extracting themes from the focus group similar to interviews it is important to take note of the frequency and extensiveness of comments, specificity, depth and intensity of reported statement and 'more seriousness should be given to such quotes' (Breen, 2006, p. 472). The analysis of focus group interview data was determined by the research questions and the purpose for which the data were collected, which is to meet the primary aim of this study.

4.10.6 Analysis of the Graduate Attributes

West University, expects the following graduate attributes from their students:

- Bicultural competence and confidence
- Community engagement
- Employability, innovation and enterprise
- Global awareness. (West University)

This study took particular interest in the graduate attribute "employability, innovation and enterprise" because one of the elements was to ensure a rich learning experience for our students that enables them to develop:

- Analytical, critical thinking, and problem-solving in diverse contexts.

This critical component is to be adopted by all the courses and the departments in the university as a learning outcome. The Graduate Attribute document provided information on to write learning outcomes and assessment that would foster this component in students.

In spite of the outline in the graduate attribute for the university, from the analysis of course outlines and the examination paper, at the departmental level, there were no specific references to the graduate attribute in the planning, enacting and assessing of the curriculum. Although the CHEM1880 outline did identify the following as learning outcomes, there was no detail of how the curriculum intended to achieve them.

- Develop skills in the critical analysis of chemical information
- Develop problem-solving skills in chemistry.

4.11 Summary of Data Analysis

Given the above, Table 1 and Figure 7 illustrates how the data collected were analysed. Table 1 and Figure 7 were created by the researcher in this study. As shown in the tables, in order to answer this study's research questions, documents, surveys, interviews, observations, and a focus group were methods used to collect data. The survey with the use of Qualtrics which generated the data analysis. The time and date of when each of the 8 lecturers was interviewed are provided. Table 1 showed the detailed dates when each lecturer was observed; the minimum teaching observation was three for each lecturer. The last column on the table shows the focus group information. Table 1 is the summary of data collected for analysis, developed by the researcher in this research thesis. Figure 7 presents who were observed and when, including who completed the lecturers' survey.

Table 1. Summary of data

Research questions	What are university lecturers' perceptions about critical thinking? How is critical thinking being planned, enacted and assessed at the university? What factors, if any, do lecturers perceive as obstacles to fostering critical thinking in their course?
Document analysis	University's Graduate Attributes CEM1880 Course outline CEM1881 Course outline 2016 Examination paper
Online survey for lecturers	28/09/2016, 6 Responses, 5 Completed
Online survey for students	CEM1880 21/10/16, 93 Responses, 54 Completed CEM1881 14/10/16, 46 Responses, 34 Completed
Lecturer interviews	30/08/16, Joan, 1hr 10mins 30/08/16, Aaron, 2hrs 07/07/16, Ben, 48mins 25/08/16, Isaac, 1hr 26/08/16, Patrick, 40mins 17/08/2016, Denise, 55Mins 23/08/2016, Gavin, 1hr 20mins 16/08/2016, Stella, 49mins
Lecture observation	29/02/16 to 18/06/16, plus recorded lecture (25/08/2016)
Focus group	3/12/16, 3 volunteer participants (all from CEM1880)

4.12 Ethical Considerations

This research was in line with West University policy, and ethics approval was obtained. Throughout this study, research ethics were duly observed. Ethics and the internet, ethics and research reports, ethics and qualitative research, ethics and good practice in the survey, ethics in lecture observation, ethics using digital technology and ethics in analysing and reporting were all considered (Gray, 2009). Written permission was obtained to use the online research instrument from the developer (see Section 4.7.2).

Before fieldwork began, approval was sought and obtained from the university human ethics committee and the university research academic group. The researcher outlined to the committee's satisfaction how the recruitment and involvement of participants would be by informed consent and voluntary participation and how any data collected from participants would be kept confidential and their names recorded as pseudonyms. No one could participate in this study without first voluntarily giving his or her informed consent. No participant was under 18 years of age. Copies of the letter of introduction, information sheet and consent form are Appendices 3 to 6.

Informed consent was a requirement for anyone wanting to participate. The researcher ensured informed consent, avoided deception, provided clear communication with participants and respected the privacy of participants. They were informed that their identity would be protected, what they said in an interview would be treated with confidentiality and information collected would be securely stored without their name on it and only accessible to the researcher and the researcher's principal supervisor. Participants were told they could decline to answer questions and could withdraw from the study at any time without any negative consequences. They were informed that the researcher would be writing papers, publications and presentations about the findings of the study, but their names would not appear on it. Particular care was taken to ensure the confidentiality of all data gathered for this study, along with the anonymity of participants and the university in publications of the findings. Names and identifying details in any verbal, written or published reports were changed into pseudonyms. A copy of the interview transcript was made available to participants to check for accuracy.

A copy of the report on the findings of the study will be made available to participants and the research site used. All the data were securely stored in password-protected facilities and locked storage at the researcher's university for 5 years following the study. It will then be destroyed. Participation in this study was voluntary. Participants had the right to withdraw from the study at any time without penalty. The research had no participants withdraw from the interview, although Isaac and Joan did not complete the survey because of their busy schedule (but were happy to be part of the case study). The research therefore did not need to remove any information relating to these participants. There was no record of Amanda in the case study, although she gave permission to observe her lectures.

Protecting the participants privacy and identity when recruiting and working with the participants was recognised as important. Also, for participants to be willing to discuss their perceptions, it was recognised that it was important to establish rapport and trust and address worries, fears and any suspicion. In this study, when recruiting participants, they were fully informed of the study, its purpose and what would be expected of them as participants, and no effort was made to pressure or coerce them into volunteering.

4.13 Ensuring Rigor, Quality and Credibility of Data

The researcher confirmed the case study findings by soliciting scrutiny of the final report from an expert on critical thinking. Additionally, to attain reliability and ensure the rigour of the study, the researcher observed the criteria recommended by Lincoln and Guba (1985) for judging qualitative research: credibility, member checking, reflexivity, auditability, transferability and confirmability, and dependability. Several procedures were followed to ensure credibility, for example, direct quotation. Furthermore, confirmability was achieved by member check.

4.13.1 Reflexivity

It is important to minimise biases in the way we look at and interpret the experiences of others. To counter possible biases in this study, the researcher has written her own story about her learning journey at the university in Chapter 1. I recognise that I have not been provided with a learning experience that entailed critical thinking activities embedded in teaching. Thus, I have not experienced student-centred learning approaches during my four-year undergraduate chemistry degree. I had to guard against thinking that every university chemistry student is experiencing the same.

4.13.2 Auditability

The researcher made explicit the methodology and the methods in this study. This detail was provided in order to enable other researchers to replicate the study (Beck, 1993).

4.14 Chapter Summary

To summarise, Table 2 illustrates the positioning of the research questions with the instruments and the data collection that were taken for this study.

Table 2. Alignment of research questions with data instrument

Research questions	Instruments Used	Data Collection & Analysis
What are university lecturers' perceptions of critical thinking?	Interview Lecture Observation Lecturers Survey	A semi-structured interview guide was created by the researcher was employed to answer the research question. Interviews were audiotaped, transcribed and verified for accuracy through member checking and peer review. Informal observations were conducted at West University. The researcher had field notes, documenting the teaching practices. Twenty questions were created by the researcher relevant to the study and geared towards the research questions, specifically to confirm what was said at the interviews or observed during the teaching.

Research questions	Instruments Used	Data Collection & Analysis
How is critical thinking being planned, enacted and assessed in the first-year chemistry courses at this university?	Interview Lecture Observation Lecturers Survey Document Analysis Student Focus Group Students Survey	The review provided a range of materials to analyse that was relevant to the study. Documents analysed included CHEM1880 and CHEM1881 general course information and examination paper for CHEM1880 and the University's Graduate Attributes. One focus group interview was conducted by the researcher to answer the research question. The group interview was audiotaped, transcribed and verified for accuracy through member checking and peer review.
What factors, if any, do lecturers perceive as obstacles to fostering critical thinking in their course?	Interview Lecture Observation	

The research was conducted through an interpretivist approach with the use of the research questions. It provided details of methods and methodology. It utilised both qualitative and quantitative methods. This chapter outlined the study's research design, epistemology, recruitment of participants, data collection (semi-structured interviews), lecture observations, document analyses and survey, how data were analysed and what was done to ensure quality and credibility of this study. This study assumes that reality is socially constructed, where there is no single observable reality, instead there are multiple interpretations (Merriam & Tisdell, 2016).

The following two chapters present the study's findings. Starting with the context of the study that calls on the finding of the document analysis in Chapter 5 and then the combined sources of data as case studies in Chapter 6.

CHAPTER 5.
CONTEXT OF THE STUDY

"It is commonly accepted in the academy that developing a critical thinking capacity will make students more effective thinkers and that this is a desirable trait for graduates to have no matter what path they take after graduation" (Egege & Vered, 2019, p. 66).

5.1 Introduction

This chapter presents the data about the drivers and background factors that influenced what the lecturers did in their course. A combination of the drivers answer each research question (See Table 2, Section 4.14). Yin (2003) presents four types of structure for the purpose of a descriptive case study: linear-analytic, comparative, chronological and unsequenced. In applying the linear analytic structure, the researcher reviewed relevant literature on teaching critical thinking in higher education. Themes such as the variability in the definition of critical thinking, teaching strategies, teaching philosophy and assessment were developed. This study also involved developing a descriptive element, such as document analysis to provide context information and student feedback. The compositional structure developed as part of this study followed the single narrative to describe and analyse the case at the department level, which is further augmented by nested individual case narratives in Chapter 6.

This chapter reports the findings of the study drawn from the document analysis, the student survey to provide a rich view of the context, and lecturers' individual survey report to create a background for the cases in Chapter 6. This chapter has prepared, organised and analysed the quantitative data using descriptive statistics. The descriptive statistics indicate general tendencies in the data in accordance with (Creswell, 2012) and are presented in two parts.

Part one reports the findings of the document analysis examining the three key documents of the graduate attributes, course outlines and an examination paper. This section provides contextual information about the planned, enacted and assessed curriculum concerning the claim that graduates would be able to critically evaluate and apply this knowledge to topics or issues within their majoring subject and how the CEM1880 and CEM1881 courses enact the development of this attribute.

Part two presents the findings of this study drawn from the student survey investigating students' perceptions related to the development of their critical thinking they have experienced. In order to protect the anonymity of this university (West University as pseudonym), exact citation information on the Graduate Attributes, Course Outlines for CEM1880 and CEM1881 and the examination paper were not included. It is noteworthy to state that the researcher acknowledges that there is no assumption that critical thinking is a good thing aside from what has been reviewed in the literature and what was reported both by the lecturers and the students. Similarly, the researcher recognises that different people conceptualise critical thinking in different ways.

5.2 Document Analysis

This section discusses document analysis, which provided the context and drivers for the assessment. Document analysis can provide a window into a variety of dimensions of a case study beyond the propinquity of interviews and lecture observations (Olson, 2010). Olson also stated that documents serve as a record of human activity and provide a valuable source of data in case study research. As such, this section presents the examination of three documents: the university graduate attributes, the CEM1880 course outline, and the 2016 examination paper (which is the examination paper at the time of the study). Only the CEM1880 course outline is presented because the CEM1881 course outline did not provide detailed information beyond the topics planned (see Appendices 10 and 11). Document analysis helps to answer research question two; how is critical thinking being planned, enacted and assessed in the first-year chemistry courses at this university?

The verbs used to describe learning outcomes and for the stem of assessment were the focus of the document analysis. Most of the examination items still asked questions based on the learning objectives, although not with the precise language used in the course outline. There were more multiple-choice type questions than the thought-provoking questions that could result in critical thinking and elaboration on answers, as suggested by Paul and Elder (2008a).

5.2.1 Graduate Attributes

'Graduate attributes' are a part of a university policy document. Crosthwaite et al. (2006) defined an "attribute" as a statement or a set of requirements by the university. Attributes can bring opportunities and guidelines for educational innovation (as discussed in Section 1.4). As defined by Page, Trudgett, and Bodkin-Andrews (2018, p. 2), graduate attributes refer to the "means for developing employability skills and an avenue for institutions to demonstrate to employers and potential graduates the requisite skills that will be developed during a degree". They believe that graduate attributes tend to emphasise a range of generic abilities, such as critical thinking.

Graduate attributes are the qualities, skills and understandings a university community agrees its students should develop during their time with the institution (Bowden et al., 2000). These attributes include, but go beyond, the disciplinary expertise or technical knowledge that has traditionally formed the core of most university courses. They are qualities that also prepare graduates as agents of social good in an unknown future.

In this study, West University, the New Zealand university in which this study was carried out, expects the following graduate attributes from their students:

- Bicultural competence and confidence
- Community engagement
- Employability, innovation and enterprise
- Global awareness. (West University)

These expectations were reported by the university as being in alignment with the New Zealand Government initiative outlined for universities and tertiary institutions to produce graduates who are better prepared to positively contribute to the rapidly changing workplace. The government's ultimate objective is for graduating students to possess the transferable skills and knowledge that match labour market demand, leading to better employment outcomes for graduates. These graduate skills are clearly adopted into the Graduate Attributes for West University.

This study took particular interest in the graduate attribute “employability, innovation and enterprise” because West University’s elaborated goal for this attribute was “to try to ensure a rich learning experience for our students” that enables them to:

- Work effectively and professionally with diverse communities.
- Communication.
- Analytical, critical thinking, and problem-solving in diverse contexts.
- Digital literacy.
- Innovation, enterprising and creativity.

Critical thinking requirement

The university document explained that the critical thinking component (“analytical, critical thinking, and problem-solving in diverse contexts”) as “the core business of any university and suggested that graduates will know and can critically evaluate and, where applicable, apply this knowledge to topics/issues within their majoring subject” (West University). This critical component is to be adopted by all the courses and the departments in the university as a learning outcome. The graduate attributes require students to evaluate problems using transferable skills such as critical thinking. The ability to critically evaluate as reported in the university’s document aligns with the literature on why critical thinking is important and the definition of critical thinking (refer to Chapter 2).

West University’s Graduate Attribute document outlined how critical thinking, along with other graduate attributes, should be planned, enacted and assessed at the university. In planning the implementation of critical thinking, learning outcomes should be determined and aligned to assessment (West University). The Graduate Attribute document provided how to write learning outcomes with examples and stated that the university’s tool for developing learning outcomes is Bloom’s Taxonomy.

Learning outcomes and assessment

The university’s graduate attribute document identified common problems with writing learning outcomes and stated that “well-written learning outcomes could make assessment writing a lot easier” (West University). This aligned with the literature (see Section 2.10). The problems stated in the graduate attribute document were:

- Non-specific (e.g. "Students will understand...": understand to what level?).
- Difficult to measure on an assessment (e.g. "Students will appreciate...").
- Not assessed.
- Assessed, but not taught (e.g. Communication skills in a presentation).
- Too many or too few learning outcomes (rule of thumb is around 5 per course and 3 per lecture) (West University).

Two of these problems (“not assessed” and “assessed, but not taught”) were revealed in the case studies. Patrick reported that he taught what was not identified in the course learning objective and this led to student failure. Also, one of the findings from the case studies was that most of the lecturers (except for Denise and Isaac) were not aware of the verb (language used) in assessment items. Therefore, the assessment items were not deliberately aligned with the learning outcomes for the chemistry courses (lecturer statements are discussed in further detail in Chapter 6). In other words, some learning outcomes were not assessed.

Authentic assessment

Other types of assessment identified in the university’s document are “authentic assessment”. The authentic assessment was identified as “intellectually meaningful tasks” such as case studies, reflective activities, role play and student mentoring (West University). These reported activities are identified in this current study as critical thinking indicators used to investigate how lecturers were using them as tools to develop critical thinking in their students (Section 2.8).

Properties of authentic assessment stated in the university’s document were:

- More open-ended than traditional assignments
- Not always a right answer
- Not always a clear procedure to follow

These properties are not shared with CEM1880 and CEM1881 assessments. Most of the lecturers had adopted the multiple-choice type of assessment that they had used for many years, as reported by Aaron, Stella, Joan, Denise, Patrick, Gavin and Ben (discussed further in case studies). In the interview with Isaac, he expressed interest in a more detailed approach for assessing students (Section 6.8).

Authentic tasks were also highlighted in the university’s document as: “an assignment given to students designed to assess their ability to apply standard-driven knowledge and skills to real-world challenges”. One of the characteristics of authentic task mentioned, was the student-centred approach and recall of content by way of quizzes, was discouraged. Denise was observed using quizzes in all her lectures (Section 6.3).

From the scan of the literature, the sole use of content recall quizzes was not found as an approach to foster student critical thinking. Mueller (2018) identified student-centred learning as an approach to develop students’ critical thinking (see Section 2.6). Similar to the university’s document already identified, Mueller (2018) described continuums of attributes as traditional assessments and authentic assessments. Where the traditional is towards the left of the continuum and authentic assessments to the right end.

Where authentic assessment is encouraged, and authentic tasks require students to *construct* responses, rather than to *select* them, as is the case in traditional assessments.

The graduate attribute document as a guide to the chemistry department's document which identified that the selected responses (multiple-choice tests, true-false, matching, fill-in-the-blank, label a diagram) are not the best approach to ask students to recall or assess their application of knowledge (West University). However, as discussed in detail in Section 4.2.3 (examination paper), the university's examination items were characterised by all the selected responses suggesting a traditional assessment approach by the chemistry department.

Three out of the four stages in the design of West University's constructive alignment outlines that:

1. Describe the intended learning outcome in the form of a verb (learning activity), it is an object (the content) and specifies the context and a standard the students are to attain. Intended learning outcomes are statements that predict what learners will have gained as a result of learning. From the students' perception, the outcomes approach communicates what they are expected to be able to do and the criteria that will be used to assess them.

2. Create a learning environment using teaching/learning activities that address that verb and therefore, are likely to bring about the intended outcome.

3. Use assessment tasks that also contain that verb, thus enabling you to judge with the help of rubrics if and how well students' performances meet the criteria (West University).

Learning outcome verbs and the use of the verbs contained in the assessment are discussed further in the analysis of the examination paper (Section 5.2.3).

The university graduate attribute document suggests that critical thinking should be enacted using constructive alignment pedagogy. The document states, "the attributes can be integrated well using constructive alignment pedagogy" (West University). Accordingly, constructive pedagogy is the ability of a lecturer to reflect on their teaching practices to inform subsequent planning and enacting of the curriculum. The document referred to Biggs (2003b) Constructive Alignment

Theory and states: “Constructive alignment informs how we teach graduate attributes, as well as our chosen disciplines, by providing a framework and way of thinking about our teaching which helps us develop curriculum areas now and, in the future” (West University). It is noteworthy to state that Biggs has been known for his work on quality university teaching and promoting the integration of critical thinking into tertiary learning (see Sections 2.5 and 2.6). To illustrate constructive alignment, there were examples that strongly suggested the use of teaching and learning activities: “it is important to align learning outcomes with teaching and learning activities, and assessment tasks and criteria” in (West University). However, most of the lecture observations revealed that lectures were the primary mode of teaching with a limited variety of teaching and learning activities included within the lecture format (Table 25).

The ongoing support stated in the university’s document did not identify any form of critical thinking training to support lecturers in being able to plan, enact and assess the curriculum. However, there seemed to be a plan in place by the university to ensure that best practice is shared across all colleges (West University).

In summary, the analysis of the graduate attributes document suggested that students should graduate being able to critically evaluate and apply their knowledge within their majoring subject. This implied that there would be a connection between the graduate attributes and the course outlines (analysed in the next section), to enable implementation and assessment of the attributes. The graduate attributes were analysed comparatively with the study’s critical thinking definition.

5.2.2 Course Outlines

The planned and assessed curriculum, as suggested in the research literature, identifies that critical thinking develops as part of a process when there is alignment between curriculum, instruction and assessment (Kurz et al., 2010; Ziebell & Clarke, 2018). Curricular alignment is a dynamic and multifaceted process that requires clear connections to be established between the planned, enacted and assessed curriculum.

The term ‘course outline’ refers to a document that guides students and lecturers on expectations. It works as a reference for colleagues, administrators, and accreditation agencies. In some cases, a course outline determines what knowledge and skills students should have after completing a course. A course outline often includes a course description, course goals, learning objectives, learning outcome, assessment, assessment plan, scheduled activity, plagiarism announcement, and reading list. A course outline consists of the planned, enacted and assessed curriculum.

The CEM1881 course outline (Appendix 10) described the course and the assessment plan. Assessment methods identified a weekly “best choice” (multiple choice) graded assessment, laboratory (practicals), a term test and final examination. The CEM1881 outline did not identify learning outcomes. The course outline’s lack of learning outcomes does not align with the university’s stated expectation of writing learning outcomes (Section 5.2.1 and Appendix 11). However, the document did state that the course will develop a foundation for understanding molecular systems and progressing in sciences that utilise chemical understanding.

The content in Table 2 was generated from the analysis of the course outline. The course outline for CEM1880 (Appendix 10) similarly listed the planned topics to be covered in the course description section. The course description section had information under the subtitles: “prerequisite for the course”, “lecture course outline” and “assessment plan”. The course outline identified the learning outcomes as:

- Develop skills in the critical analysis of chemical information.
- Develop problem-solving skills in chemistry.
- Enhance applied mathematical skills relevant to chemistry.
- Develop a working understanding of the selected topic. (West University)

In the research literature, critical thinking is indicated as promoting learning when it is related to the course outline and assessment. To achieve this connectedness, planning is required on the part of the teacher and must be promoted or integrated throughout the course (Bean, 2011). However, the CEM1880 outline did not explicitly suggest or identify the place of critical thinking connected to the graduate attributes of the university, and there was no stated alignment of how these are assessed in the examination paper. In other words, the alignment between the course learning outcomes and what students are asked in the examination items for them to demonstrate the application of knowledge and skills, especially critical thinking, did not align with the university's graduate attributes. The course outlines were analysed comparatively with the study's critical thinking definition.

A summary of the CEM1880 course outline, including assessment analysis, is displayed in Table 2. In this research study, Table 2 is the summary of learning objectives and examination verbs, developed by the Researcher from the CEM1880 course outline. The course outline document stated what the learning outcomes, assumed material, mathematical preparation, learning objectives and assessment were. For this analysis, the 2016 examination paper items were analysed for the "assessment verb", given that there were other assessment tasks. Table 2 further reports the findings of the examination paper and its alignment with the learning objectives and the course document.

Questions asked in the examination paper related to the verb used was compared with the learning objectives statement in the course document. The learning objective verbs and the examination verbs were adopted to highlight the relationship and alignment. The assessment verbs are discussed in the next section.

Table 3. Summary of learning objective and examination verbs

Learning outcome	Assumed material	Maths preparation	Lecture outline	Learning objective verbs	Assessment verbs
Develop skills in the critical analysis of chemical information.	Mole concept; relative atomic mass; molar mass; chemical stoichiometry.	Be capable of performing simple numerical manipulations, including cross multiplication.	Atoms and the periodic table, chemical bonding, reduction and oxidation reactions.	Define, describe, understand, state, use, identify, expand, construct, how, predict, assign, distinguish, decide, **calculate**, derive, know	Give, circle, estimate, sketch, which, draw, rationalise, complete, balance, write, **calculate**, what, assume
Develop problem-solving skills in chemistry.	Basic principles of atomic structure; electron configurations; quantum numbers; periodic table; atomic and ionic radii.	Have knowledge of logarithms and exponentials.	Properties of gases, introduction to thermodynamics, kinetics, chemical equilibrium, thermodynamics II.	Predict, state, know, estimate, provide, rationalise, calculate, define, **explain**, list, understand, determine, demonstrate distinctions	Distinguish, **explain**, describe, rearrange, give, how, define, the difference between, compare and contrast, estimate, why
Enhance applied mathematical skills relevant to chemistry.	The basic principle of the conservation of energy; bond energy.	Some acquaintance with basic calculus (gradient and differentiation, area and integration).	Aqueous chemistry, acid-base equilibrium.	Understand, rationalise, know, significance, determine, describe, provide, define, predict, use, classify, calculate, derive, recognise, estimate	Identify
Develop working understanding of (all topics for semester)	Oxidation and reduction.	Be familiar with the use of SI units.			

5.2.3 Examination Paper

Investigating the examination paper at the time of the study demonstrated how critical thinking was being assessed in the course at West University. The paper under examination was the 2016 examination paper for both CEM1880 (Appendix 12).

The examination paper was selected as part of the document analysis to identify connections between the planned and assessed curriculum. Close critical reading probed close similarity of language related to what questions were asked and how they were asked. This was done to reflect on and inform what actual words in the assessment linked to the verbs as presented in the learning objectives. Table 2 clearly shows that while "critical" appears in the Learning Outcome statement "Develop skills in the critical analysis of chemical information" the recall of content knowledge and understanding was the main focus of the examination as indicated by the verbs in the exam column. As well there were very few verbs used in the Learning Outcomes, (only "distinguish" and "demonstrate distinctions") which translated into "compare and contrast" in the verbs used in the exam.

Some of the clusters of verbs used in the examination questions were "rearrange", "circle", "sketch", "which", "draw", and "complete". The verbs in the questions provide an indication of the questioning difficulty level, as suggested by Paul and Elder (1998); Paul and Elder (2008a) (Section 2.4). For example, question A38 of the examination:

> The second law of thermodynamics is concerned with the Gibbs energy of:
>
> (a) The system only.
>
> (b) The surroundings only.
>
> (c) The system and the surroundings.
>
> (d) Neither the system nor the surroundings. (West University)

There was a misalignment between the planned curriculum and the assessed curriculum. Specifically, the course outline stated in the learning objectives that students would presumably be able to "define Gibbs Energy" and stated that this would be assessed in the exam paper, which is not the case. That is, students did not need to provide a definition but, rather, needed to demonstrate an understanding of the law to know which answer was correct. If this is the case, then students could guess the correct response without engaging in critical thinking. Also, if attention had been given to the verb in the assessment, by increasing the level of difficulty of the questions, then the stem of the assessment item would have prompted critical thinking in the students. Instead, this analysis has found a mismatch between the questions and the course learning outcomes in terms of what is assessed. Interviews with the lecturers revealed that critical thinking was not planned for assessment in the examination or examination paper (interview report in chapter 6).

The relationship between this analysis and critical thinking suggests that the verbs used do not assess students' critical thinking and therefore there is limited evidence to suggest that students' critical thinking skills were assessed in this examination. The examination paper was analysed comparatively with the study's critical thinking definition.

In another example of a misalignment between the planned and assessed curriculum concerns the topic of chemical kinetics. The learning objective stated that students will:

- Be able to use rate coefficient at a different temperature to determine the activation energy of a reaction.
- Be able to define what is meant by the rate of a reaction.
- Know the factors that influence the rate of a reaction.
- Be able to describe methods by which changing concentrations are monitored experimentally.
- Be able to define the terms rate law, rate coefficient (or rate constant) and reaction order. (West University)

The question asked was:

> Calculate the rate coefficient for this reaction. What are the units of this rate coefficient? (question B1, F)

According to Bloom's Taxonomy, as recommended by the university, this question would only require three levels from the students: "remember", "understand" and "apply", while lacking "analyse", "evaluate", and "create". The question also did not give "breath" as seen in intellectual standards of Paul and Elder critical thinking framework (Paul & Elder, 2008b). As such, the assessment item would not assess critical thinking meaningfully in students.

In the 2016 examination paper, there were no questions that reflected some of the learning objectives (Appendix 12). For example, the objective - "define the atomic number, mass number, isotope, Avogadro's number and the mole", was not reflected in any questions. What the objectives indicate is a strong emphasis on recalling information.

As shown in Table 2, for the topics covered in the course outline, most of the learning objective verbs would not have led to fostering critical thinking with planning for the delivery. Where they did (e.g. "critical analysis"), they were not reflected by the assessment verbs. The majority of the assessment verbs used did not suggest that critical thinking was required. This finding is important because it rationalised that if there was very little relationship between the planned, enacted and assessed curriculum, critical thinking skills were not a focus of the outlines nor assessments and, therefore, were not being developed in students.

Table 2 clearly shows where these misalignments are when you compare the column that clearly outlines the "learning objective verbs" and the "assessment verbs". There were misalignments between the planned and assessed curriculum in terms of the level of the difficulty of the exam questions, which means not most of the questions required demonstration of critical thinking.

In summary of the document analyses of the graduate attributes of the university, the course outlines for both first-year courses and the exam paper for CEM1880; there appears to be little evidence of alignment between how critical thinking is planned and assessed.

5.3 Lecturer Survey Responses

This section presents a concise summary of each individual lecturer's survey responses, focused on what their responses suggest about them in terms of the two research questions (See Appendix 13). The findings from the lecturers' survey help to answer research questions 1 and 2; what are university lecturers' perceptions of critical thinking? How is critical thinking being planned, enacted and assessed in the first-year chemistry courses at this university? A broader finding of the lecturers' survey is included in the case studies which are presented in Chapter 6. Findings from data analysis obtained through the University Lecturer Critical Thinking Strategy (ULCTS) questionnaires are presented. This data, as earlier described in Chapter 4, is derived from Qualtrics software used to conduct the survey. Out of nine first-year lecturers, six began the survey, and five voluntarily completed the survey. The lecturers who completed the survey were: Gavin, Patrick, Denise, Stella and Ben. Isaac started answering one question, Joan and Amanda did not participate in the survey. In the lecturers' survey, there were 27 items formulated to answer the research questions. The open-ended items sought to prompt lecturers' opinions about what they understood by the concept of critical thinking and to list what critical thinking skills were. These items were asked in order to address research question 1, and the responses were categorised into the importance of critical thinking. Items 4 and 5, and 11 to 13 mainly addressed research question 1. The rest of the items dug deeper into finding out the lecturers' perceptions relating to the planned, enacted and assessed curriculum, which is addressed by research question 2.

What were university lecturers' perceptions of critical thinking? The following survey items investigated lecturers' perception of critical thinking: questions 4, 5, and 11 to 13. Questions 1 to 3 were related to survey consent. Questions 4 and 5 of the survey instruments were open-ended. Lecturers were asked to describe their understanding of critical thinking. Lecturers' responses revealed that they could describe critical thinking and could identify by listing what were, in their opinion, critical thinking skills. Their responses can be found in individual cases. However, in the case studies, the lecturers did not report, nor were they observed to carry out the critical thinking definition given above. For questions 11 and 12, lecturers were invited to respond to the survey questions using a

Likert-type scale with the numeric designation of Extremely important (4 points), Very important (3 points), Moderately important (2 points), Slightly important (1 point), and Not at all important (0 points). The complete survey instrument and all the scales used are provided in Appendix 13, and the methods section in Chapter 4 provides details of the design of the survey. How the lecturers rate the importance of critical thinking to the teaching and learning of chemistry was "very important" or "extremely important" according to Gavin. For Patrick and Denise, it is very important while Stella believes it is extremely important, and Ben reported slightly important, as shown in Figure 10.

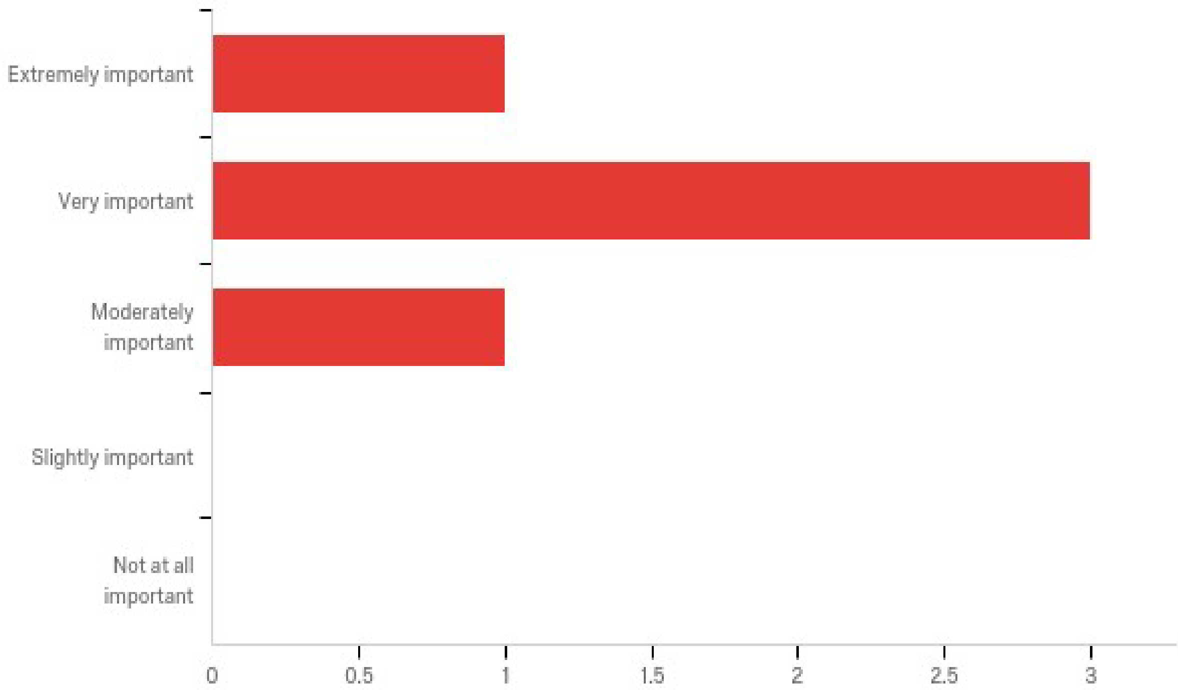

Figure 10. Importance of critical thinking

All lecturers were unanimous in rating the importance of critical thinking in tertiary education as "extremely important" or "very important" as shown in Figure 10. This finding aligns with the statements of all lecturers in the case studies (Chapter 6). Ben rated the importance of critical thinking to the teaching and learning of chemistry as "moderately important", yet he rated the importance to tertiary education as "extremely important" along with Stella and Gavin, while Patrick and Denise believe it is "very important".

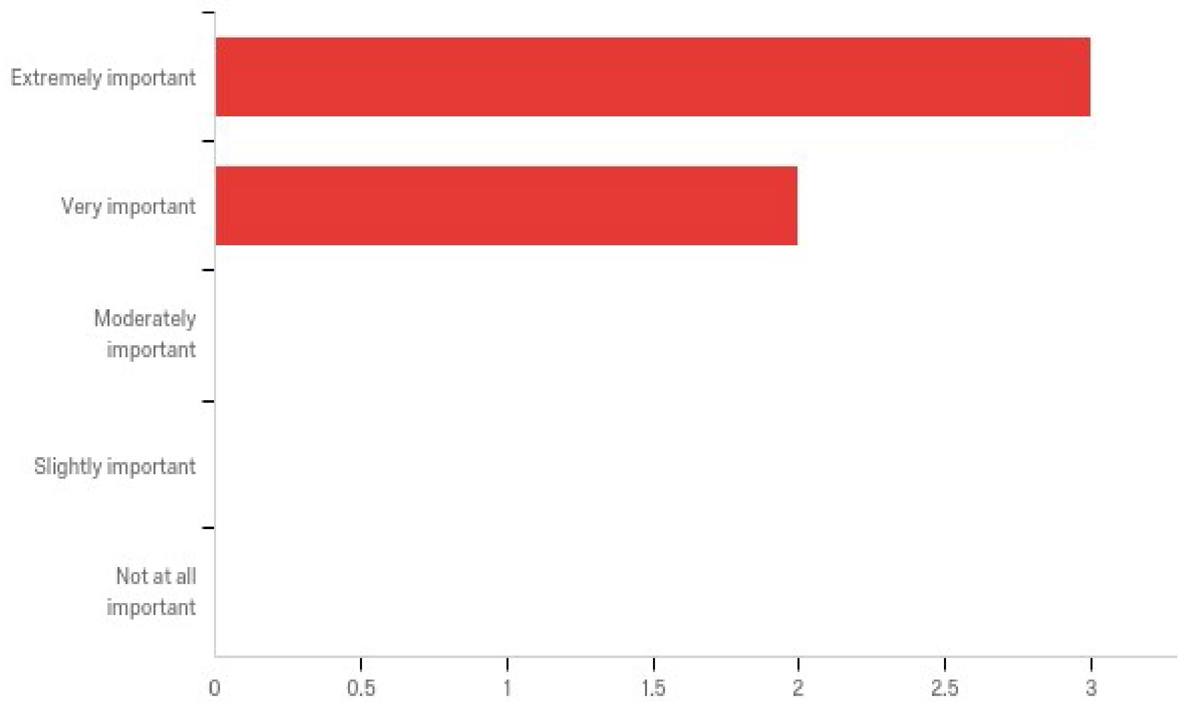

Figure 11. Tertiary education

From the Paul-Elder theory of thinking, when the element of thought was applied to intellectual standards, the result is intellectual traits. These traits (or attributes) are vital to a successful thought process (please see Section 2.7.2). Question 13 (has sub-section question from 1-18) sought to investigate what the insight and integrity of the lecturers' understanding, maybe, giving a deeper understanding of the lecturers' perceptions toward critical thinking. These questions were identified as conceptualisations and evaluations of critical thinking adapted from the intellectual trait inventory (Hawaii Community College, 2015; Paul & Elder, 2008b; The Foundation For Critical Thinking, 2017). Lecturers were invited to respond to the survey questions using a Likert-type scale with the numeric designation of Strongly agree (7 points), Agree (6 points), Somewhat agree (5 points), Neither agree nor disagree (4 points), Somewhat disagree (3 points), Disagree (2 points) and Strongly disagree (1 point). Questions were derived from the 8 intellectual traits.

Item 1 asked the lecturers to respond to the statement: "I admit that there is much to learn from others", Denise and Gavin agreed with this statement while Patrick, Stella and Ben strongly agreed. Responding to Item 2: "I analyse the beliefs I hold"; Gavin, Patrick and Denise agreed while Ben and Stella strongly agreed. For Item 3: "I question scientific evidence, and what method was used to come up with the evidence", Ben agreed while the others strongly agreed. In Item 4: "I accurately represent viewpoints I disagree with"; Gavin, Stella and Ben agreed to the statement, Denise strongly agreed while Patrick somewhat agreed. Patrick neither agreed nor disagreed with the statement "I behave in accordance with what I say I believe", while Stella and Ben agreed, and the others strongly agreed. Stella agreed that she changed her understanding when scientific evidence indicated a different position while the rest strongly agreed. Gavin somewhat agreed that he uses the term "I do not know" frequently. The other lecturers agreed and strongly agreed. Stella strongly agreed that she adhered to the principles of sound reasoning when persuading others of her position and did not distort matters to support her position and other lecturers agreed.

All the lecturers strongly agreed, except Ben who agreed, to understand the tentative nature of scientific knowledge and that it can change as new technologies enable scientists to discover new concepts and natural phenomena. Stella completely disagreed that her prejudices or biases influenced her thinking, the other lecturers agreed while Denise strongly agreed. The lecturers all strongly agreed that they recognised that evidence in science could come in different forms. Additionally, Denise and Gavin strongly agreed that they could think of a difficult intellectual problem in which they have demonstrated patience and determination in working through the difficulties, the other lecturers agreed. Patrick somewhat disagreed with the statement that he sees problems from the most reasonable perception and does not try to "win" at all costs. In other words, Patrick did not see problems from the most reasonable perception, and he tried to win at all cost. The other lecturers strongly agreed, but Ben and Stella only agreed.

Further analysis revealed that Gavin neither agreed nor disagreed that he used different strategies for dealing with complex problems in his teaching to keep large classes engaged. Patrick and Denise strongly agreed, and Stella and Ben agreed. Only Ben agreed when the other lecturers strongly agreed they recognised that it was important to engage their class in challenging intellectual work. Gavin disagreed, and Stella somewhat disagreed that they explored their “uncritical thinking” attitudes and realised that this could keep them from seeing things as they are, while others agreed. Gavin somewhat agreed that he encouraged others to come to their conclusions and tried not to force his views on them while Ben and Patrick agreed, and Stella and Denise strongly agreed. Gavin could presumably not encourage his students to come to their conclusions, and he might force his views on them. To the last item for question 13, Ben, Stella and Gavin somewhat agreed that they stood up for ideas and beliefs that were not necessarily their own. This suggested these lecturers might not believe the ideas of others. Denise strongly agreed, and Patrick agreed to the statement.

The above analysis of individual lecturer’s surveys was based on the Paul-Elder theory of applying intellectual traits to elements of thoughts, as discussed in Chapter 2. Table 4 summarises the items that align with each universal intellectual trait. In this research study, Table 4 is the summary analysis of survey question 13, created by the researcher.

Table 4. Summary analysis of survey question 13

Universal Trait	Items
Intellectual Trait	1
Intellectual Humility	1, 7, 10, 16
Intellectual Perseverance	12, 14, 15
Confidence in Reason	8, 13, 17
Intellectual Empathy	4, 18
Intellectual Autonomy	3, 6
Intellectual Courage	2
Intellectual Integrity	5, 9
Fair-mindedness	11

With regards questions related to intellectual humility, responses to the items had little variation, with Gavin and Stella indicating a fairly well-developed tendency toward the disposition of intellectual humility while others indicated a strong, well-developed disposition, based on the intellectual trait inventory scale (Appendix 15). However, in the case studies, some of the lecturers were either not interested in training for teaching critical thinking, or some were only willing to learn for particular reasons. The lack of interest would suggest a lack of intellectual humility. Therefore, the lecturer's survey responses for intellectual humility does not align with what they reported in the case studies.

The lecturer’s intellectual perseverance findings are similar to their intellectual humility, with Gavin tending towards fairly well-developed tendencies to the trait. This suggested that the lecturers recognised the importance for their students to engage in challenging intellectual work. Apart from Gavin, the other lecturers “strongly agreed” and “agreed” to the use of different teaching strategies for dealing with complex problems to keep large classes engaged. However, such different teaching strategies were not observed in the teaching practices of the lecturers.

Confidence in reason items showed the lecturers have a well-developed disposition towards the trait, but Gavin and Patrick's responses showed that confidence in reason was “fairly well-developed”. The findings for intellectual empathy were varied, with all the lecturers averagely on the tendency of fairly well-developed towards the trait. Patrick indicated more of a weak disposition but showed a tendency towards development.

All the lecturers had well-developed dispositions towards intellectual autonomy and intellectual courage. In terms of intellectual integrity, all the lecturers had strong dispositions to the trait, except for Patrick, who showed fairly well-developed tendencies. Presumably, Patrick might not always behave in accordance with what he says he believed. All the lecturers were found with a strong disposition towards fair-mindedness. Figure 12 is a summary of the findings reported for question 13 (items 1 to 18).

Figure 12. Lecturers conceptualisations and evaluations of critical thinking

Lecturers' conceptualisations and evaluations were demonstrated by the intellectual trait inventory (Figure 12). There was a little variation in their responses. This finding showed that the majority of the lecturers either "strongly agree" or "agree" with the items. This also showed their personality strength and fair-mindedness, which also demonstrated their critical thinking skills. Therefore, the lecturers had an area of strength as well as room for improvement. Although there were variations in how the lecturers answered some of the survey questions and what they reported and were observed in the case studies. These items were designed to measure the intellectual development of traits such as intellectual humility, intellectual courage, intellectual empathy, intellectual autonomy, intellectual integrity, intellectual perseverance, confidence in reasoning and fair-mindedness. As such, because the lecturers were not strongly developed in all the 8-intellectual traits, this possibly might have affected how they were developing critical thinking in their course. Therefore, further investigation would be required to ascertain this claim. In light of this development, interviews and lecture observations were carried out with each lecturer. The report of this investigation is provided in Chapter 6. The lecturers survey responses were analysed comparatively with the study's critical thinking definition.

5.4 Student Survey Responses

This section reports on the students' feedback using the Chemistry Student CT Skills Test (UCSCTST) questionnaire to obtain responses that would help to answer how critical thinking is being planned, enacted and assessed at the university? The two chemistry courses were CEM1880 and CEM1881. The findings from the students' survey help to answer research question 2; how is critical thinking being planned, enacted and assessed in the first-year chemistry courses at this university?

Table 5 shows the sample size of the findings from student surveys that are presented in this section, and the figure was developed by the researcher in this research study. The number of responses per survey question differed for both CEM1880 and CEM1881. As shown in Table 5, of the study population of 420 for CEM1880, 93 subjects started, and 54 completed the survey. From the 320 enrolled in CEM1881, there were 46 respondents, and 34 completed the survey.

In the students' survey, there were fourteen questions, with Question 14 having 19 sub-items. Altogether there were thirty-two items developed to provide more depth to how critical thinking is being planned, enacted and assessed at the university based on the student experience. Both CEM1880 and CEM1881 answered the same survey questions (i.e. the same instrument).

Table 5. Student Sample Size

First-year chemistry students' cohorts	CHEM1880 students	CHEM1881 students	CHEM1880 responses	CHEM1881 responses	CHEM1880 completed responses	CHEM1881 completed responses	Total completed responses
740	420	320	93	46	54	34	88

5.4.1 CEM1880 Student Survey Responses

When asked to describe what they understood by the term critical thinking, 65 out of the 93 students were able to give varied definitions with similar elements to the definition of this study (Chapter 1.2.1).

Here are some of the responses:

> "**Thinking** about something objectively, to form an accurate judgement of something''
>
> "Deny everything until someone shows you the **proof**''
>
> "**Approaching** a problem by following a **logical sequence**''
>
> "The **evaluation** of an issue to form a **judgemen**t''
>
> "**Analysing** a problem by deconstructing it and thinking about each part separately''.

The emerging themes from these definitions are; proof, approach, sequence, judgement, analysing, these themes are similar to the 1990 consensus definition by research experts with themes such as "purposeful, self-regulatory judgment which results in interpretation, **analysis**, **evaluation**, and **inference**, as well as explanation of the **evidential**, conceptual, **methodological**, criteriological, or contextual considerations upon which that judgment".

This definitions from students suggest that they are aware of what critical thinking means and how it should or could impact their learning in chemistry.

Table 6 shows more description of critical thinking by students.

Table 6. What is critical thinking?

Q5 - Please describe what you understand by the term "critical thinking".

Please describe what you understand by the term "critical thinking".
Having the ability to apply skills and knowledge in a practical way (i.e. not just regurgitating memorized information).
Thinking in an intelligent way
Understanding what is being asked and thinking about it in a wider context than just the question
Thinking deeper
Being able to think rationally to solve problems and make decisions, while minimising personal preferences and/or biases.
Looking at somebodies work and making your own decision about what you think of it
problem solving and being able to employ different strategies to solve problems
Application of knowledge to solve issues where the techniques aren't expressly taught
Being able to interpret information and apply it to a context in which you may not have done before.

Similarly, students were able to list what they thought critical thinking skills were. Their responses included the following as shown in Table 6, and ranged from "open-minded, curiosity, non-biases, listening, explanation, evaluation to observative and analytical, metacognition, patience, self-control, reasoning (ability to understand where different parties are coming from), perceptiveness, a healthy scepticism, visualisation, self-awareness, analysis/evaluation of information''.

Table 7. Critical thinking skills

Q6 - In your opinion, please list what 'critical thinking skills' are.

In your opinion, please list what 'critical thinking skills' are.
problem solving
application of prior knowledge to solve further issues
Interpreting, understanding and applying knowledge.
thinking criticaly
- Ability to be open minded about a new topic or idea - Challenging both new and existing ideas, exploring their strengths and weaknesses
problem solving, problem analysis, effective communication and, background knowledge
conceptualizing, analysing, evaluating
-questioning given information -applying taught information to other diverse areas
Ability to view things from multiple points of view. Able to challenge your own ideas. (Not rash nor self loathing) Forming ideas/opinions independently from other two skills.
identifying "problems", finding solutions from memory, finding patterns.

The last open-ended question in Table 7 asked students if they thought critical thinking was important for students to develop and to explain why. The students unanimously agreed that it was crucial for them to have critical thinking skills as part of their qualification, to understand the content, help them throughout their degree to undertake research and to gain future jobs.

Some of the reasons the student respondents thought critical thinking was important for them to have was:

> "It is important that students understand how to make decisions when faced with a question or problem"

> "Critical thinking skills allow us to apply the knowledge we learn in lectures"

> "If students can think critically, they can improve themselves by identifying what needs to be changed"

> "When critically thinking, students can also evaluate useful information and constructive criticism"

"Critical thinking is essential; otherwise one would accept ideas based only on authority: parents, teachers, lectures, and celebrities, or convenience''

"It is easier to accept ideas without question rather than think about them critically. Hence if we want to be a rational agent, we need good critical thinking skills ".

Table 8. Importance of critical thinking

Q7 - Do you think it is important for students to have good critical thinking skills? Please explain your answer.

Do you think it is important for students to have good critical thinking sk...
Yes, for improvement these skills are important. If you are unable to evaluate your own or others uni work then there is way or showing an understanding of what has been done and were improvements can be made.
Yes. When information is just memorized, you forget it straight after the test, so it's basically pointless. Being able to think critically means that you can actually use what you've learnt to solve problems and develop new ideas which will actially be useful.
yes, I often think it is good to try to actually understand what your lecturers tell you and think about it yourself rather than just accepting what they tell you, which is critical thinking in a way. It is also helpful for assignments.
Yes. If they can't relate theory to the real world or think deeper to go into ideas then it won't be as useful
Yes. As lots of exam questions seem to want the extra level of thinking
Yes, because critical thinking is important when making decision and understanding complex concepts.
Yes- critical thinking involves thinking for yourself, rather than having someone else do it for you. It builds good problem solving skills, and allows you to make decisions based on the quality of information that you are given.

It was important to know what the students thought about the level of development of their critical thinking skills. This is partly an indication of the impact of the teaching that the students received from the lecturers. Figure 13 shows the percentages of student responses. Of the student respondents, 54 out of 93 answered the question. Of these 54, 29 (54%) reported that their critical thinking skills were "moderately developed" and 21 (39%) answered "somewhat developed".

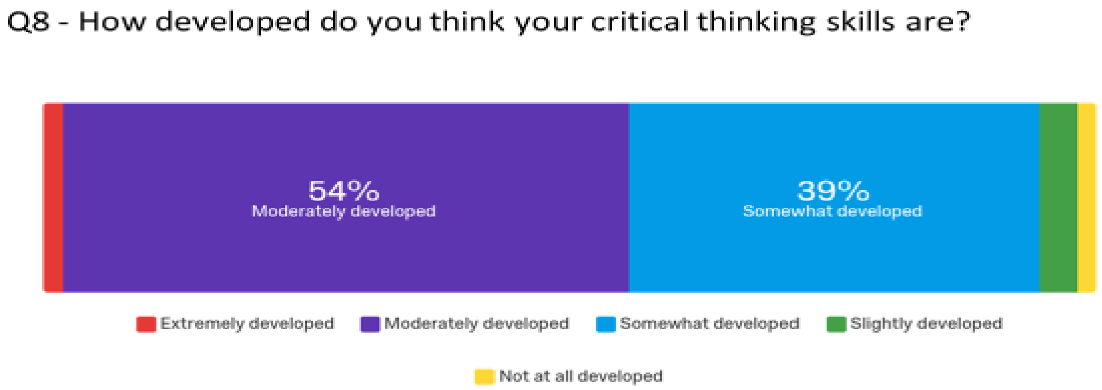

Figure 13. Critical thinking development

Students were asked how interested they were in developing their critical thinking. Figure 14 displays a broken-down bar showing the levels of students' interest in critical thinking.

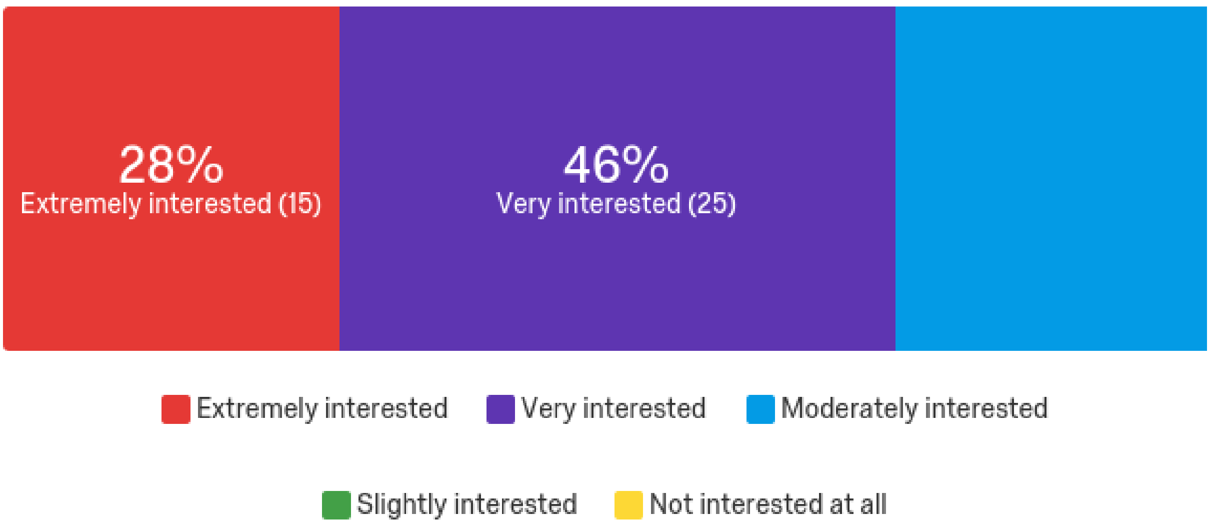

Figure 14. How interested are you in developing your critical thinking skills?

All the 45 students' responses unanimously reported that they are interested in developing their critical thinking skills. 15 out of 45 students reported they are "extremely interested", 25 reported "very interested", and 14 said "moderately interested".

Thirty per cent (i.e. 16 students out of 54) reported that they used critical thinking "most of the time" during their CEM1880 lecture. As shown in Figure 15, 44% reported "sometimes", and 20% said "not often".

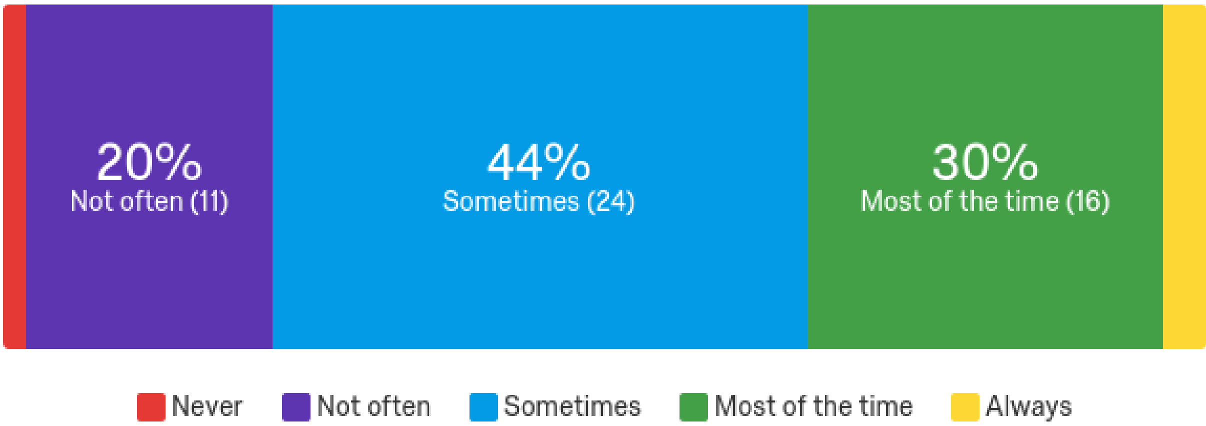

Figure 15. How often do you use critical thinking?

More than half of the student responses stated that they were "sometimes" distracted with other things during their CEM1880 lectures. Table 9 illustrates the simple descriptive statistics table for this item. Altogether, 53 out of 54 students reported a level of distraction with other things during lectures for CEM1880. This was also observed as influencing student engagement during the lecture observations on multiple occasions with different lecturers.

Table 9. How often are you distracted?

#	AWA.FIELD		SIMPLETABLEWIDGET.CHOICE_COUNT
1	Never	1.85%	1
2	Not often	22.22%	12
3	Sometimes	57.41%	31
4	Most of the time	9.26%	5
5	Always	9.26%	5
			54

SIMPLETABLEWIDGET.SHOWING_ROWS_OF

Students believed that their lecturers' knowledge and understanding of critical thinking was good. Table 8 shows that only 6% reported their lecturers had a poor understanding.

Table 10. Lecturers knowledge and understanding

Q12 - Please rate your lecturers knowledge and understanding of critical thinking.

#	Answer	%	Count
1	Very good	18.87%	10
2	Good	47.17%	25
3	Acceptable	28.30%	15
4	Poor	1.89%	1
5	Very poor	3.77%	2
	Total	100%	53

In further exploration of the data to determine students' views of how their lecturers were developing critical thinking in them, some students believed that their lecturers were not involved at all in developing their critical thinking skills, as can be seen from Table 10, out of 53 students, 22 reported that they received were "moderately involved" with developing critical thinking in CEM1880. Ten students stated, were "very involved", and 15 said were "slightly involved".

Table 11. Level of involvement

#	Answer	%	Count
1	Extremely involved	3.77%	2
2	Very involved	18.87%	10
3	Moderately involved	41.51%	22
4	Slightly involved	28.30%	15
5	Not involved at all	7.55%	4
	Total	100%	53

Out of 53 students as shown in Table 11, 22 of the students reported they received "good support" developing critical thinking in CEM1880.

Table 12. Level of support

#	Answer	%	Count
1	Very good support	5.66%	3
2	Good support	41.51%	22
3	Acceptable support	33.96%	18
4	Poor support	11.32%	6
5	Very poor support	7.55%	4
	Total	100%	53

When students were asked to compare by rating the quality of critical thinking experienced within the university outside CEM1880, 47% reported that it was "good". It can be seen from the data in Table 13 that the majority of students believed that they were receiving critical thinking within their university education.

Table 13. Quality of critical thinking

#	Answer	%	Count
1	Very good	7.55%	4
2	Good	47.17%	25
3	Acceptable	37.74%	20
4	Poor	5.66%	3
5	Very poor	1.89%	1
	Total	100%	53

Most students reported that they concentrated, listened and paid attention in their CEM1880 lectures. Table 14 shows the distribution of the level of concentration, both in the number of responses and the percentage. However, during lecture observation, most of the students did not pay attention, and were texting on the phone, having a chat and watching football on their laptops.

Table 14. Level of concentration

#	Answer	%	Count
1	Outstanding	5.66%	3
2	Better than expected	28.30%	15
3	Meets expectations	49.06%	26
4	Unremarkable	11.32%	6
5	Poor	5.66%	3
	Total	100%	53

In Table 15, it is apparent that more than half of the students who responded were interested in CEM1880. Additionally, all of the focus group reported their interest in CEM1880.

Table 15. Interest in CEM1880

#	Answer	%	Count
1	Very high	5.66%	3
2	High	39.62%	21
3	Moderate	35.85%	19
4	Low	15.09%	8
5	Not at all	3.77%	2
	Total	100%	53

Table 16 displays the levels of students' commitment to CEM1880, especially in terms of attendance, reading and completing practice questions more than 50%

of the respondents were "strongly committed''. The focus group reported that they were committed to CEM1880 and described how often they put in work at home with reading, use of library, and in online resources provided for the course. Some watched the lecture video available online again to listen to things missed or that needed clarity.

Table 16. Level of commitment

#	Answer	%	Count
1	Extremely committed	16.98%	9
2	Strongly committed	58.49%	31
3	Moderately committed	13.21%	7
4	Slightly committed	9.43%	5
5	Not committed	1.89%	1
	Total	100%	53

Figure 16 presents the breakdown of CEM1880 students' perceptions of critical thinking according to how they conceptualise and evaluate information in different circumstances. Figure 16 shows that the student conceptualisations and evaluations of critical thinking were not strong; the overall result shows more students choosing "sometimes agree" which is a "weak disposition but showing a tendency towards development" or "fairly well-developed tendency toward the disposition" as classified by the Intellectual Traits Inventory rating scale (Appendix 15).

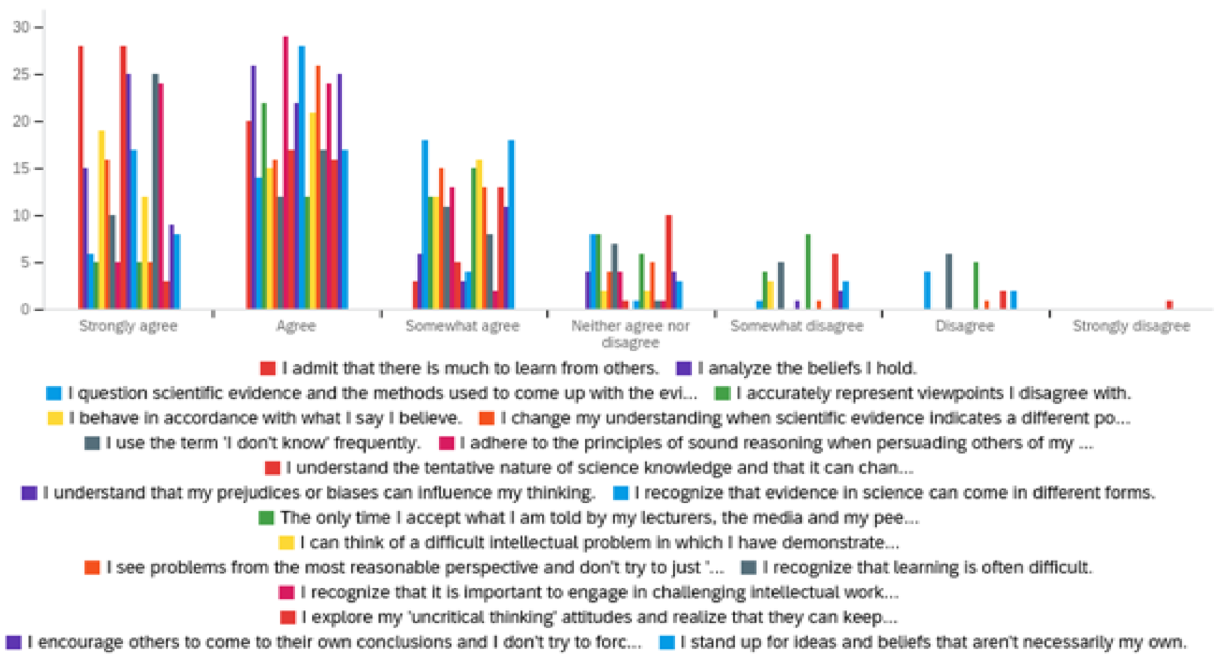

Figure 16. Students conceptualisation and evaluation of information

5.4.2 CEM1881 Student Survey Responses

Figure 16 presents the word cloud from 34 student descriptions of critical thinking. The higher the frequency with which words were mentioned, the larger the font size.

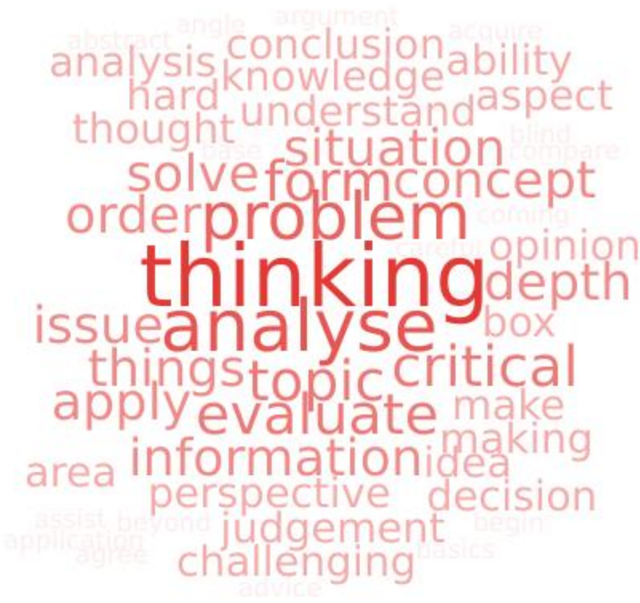

Figure 17. Student critical thinking descriptions word cloud

Some of the most frequently used descriptions were:

> "Thinking about something in-depth and a new challenging way/different perception''
>
> "Making decisions after comparing different arguments for a given topic''
>
> "Looking thoroughly and in-depth into problems and issues''
>
> "Looking from different angles and perceptions into solving problems or critiquing something''.

In their opinions of critical thinking skills, some of the students reported:

> "Curiosity''
>
> "Understanding the parts that are important and the parts that are not''
>
> "Thinking in a way that makes sense''
>
> "Ability to analyse, form an opinion, evaluate, make a judgment and summarise a subject''.

Other opinions included:

> “Listening, explanation, evaluation’’

> “Creativity, understanding the whole picture, awareness, knowledge referencing’’.

All 34 students reported that critical thinking is important, and some of their reasons were:

> “Students need to be able to understand the material and then be able to use and apply it’’

> “Critical thinking is a way of thinking that once learned, can be used for any topic’’

> “It introduces other skills that can be used whilst studying but also in real situations if needed’’

> “Especially in today's society with the media flooding us with information and opinions and 'facts', it is important to think critically of any bias behind informational and whether something is true or not’’

> “When solving problems, sometimes, the solution is not straight forward, and critical thinking is important’’.

From Table 17, we can see that 41% of the students that answered the item ‘How developed do you think your critical thinking skills are?’ believe that theirs are “somewhat developed”, while almost 18% are “slightly developed” or “not at all developed”.

Table 17. What is critical thinking?

Q8 - How developed do you think your critical thinking skills are?

#	Answer	%	Count
1	Extremely developed	5.88%	2
2	Moderately developed	35.29%	12
3	Somewhat developed	41.18%	14
4	Slightly developed	14.71%	5
5	Not at all developed	2.94%	1
	Total	100%	34

Table 18 shows that students are interested in developing their critical thinking skills. None of the student reported they were not interested. This result perhaps is an indicator that these set of students would rather not memorise content.

Table 18. Critical thinking skills

Q9 - How interested are you in developing your critical thinking skills?

#	Answer	%	Count
1	Extremely interested	26.47%	9
2	Very interested	41.18%	14
3	Moderately interested	20.59%	7
4	Slightly interested	11.76%	4
5	Not interested at all	0.00%	0
	Total	100%	34

Table 19 shows that more than 50% of students reported that they use critical thinking "sometimes" while taking CEM1881.

Table 19. How often do you use critical thinking?

#	Answer	%	Count
1	Never	0.00%	0
2	Not often	23.53%	8
3	Sometimes	58.82%	20
4	Most of the time	14.71%	5
5	Always	2.94%	1
	Total	100%	34

Table 20 shows that almost 60% of students reported that they were "sometimes" distracted during lectures for CEM1881, with different levels of distraction. As mentioned previously, when classes were observed, students were frequently distracted with other things such as talking on the phone and watching sports on their laptops.

Table 20. How often are you distracted?

#	Answer	%	Count
1	Never	0.00%	0
2	Not often	11.76%	4
3	Sometimes	58.82%	20
4	Most of the time	20.59%	7
5	Always	8.82%	3
	Total	100%	34

The overall response to the question "Please rate your lecturer's knowledge and understanding of critical thinking" was very positive. As shown in Table 21 students rated their lecturers' knowledge and understanding of critical thinking as "very good", "good" and "acceptable".

Table 21. Lecturers' knowledge and understanding

Q12 - Please rate your lecturers knowledge and understanding of critical thinking.

#	Answer	%	Count
1	Very good	20.59%	7
2	Good	50.00%	17
3	Acceptable	29.41%	10
4	Poor	0.00%	0
5	Very poor	0.00%	0
	Total	100%	34

Table 22 shows that over half of those surveyed reported that their lecturers were "extremely involved" and "very involved" in developing critical thinking in them. However, a few respondents reported that their lecturers were "slightly involved".

Table 22. Level of involvement

#	Answer	%	Count
1	Extremely involved	5.88%	2
2	Very involved	20.59%	7
3	Moderately involved	47.06%	16
4	Slightly involved	26.47%	9
5	Not involved at all	0.00%	0
	Total	100%	34

As shown in Table 23, the question "How well have your lecturers supported you to develop critical thinking skills in CEM1880 or CEM1881?" provoked a range of positive responses with "very good", "good" and "acceptable" support.

Table 23. Level of support

#	Answer	%	Count
1	Very good support	5.88%	2
2	Good support	29.41%	10
3	Acceptable support	52.94%	18
4	Poor support	11.76%	4
5	Very poor support	0.00%	0
	Total	100%	34

Figure 18 displays a summary of students' conceptualisation and evaluation as an indication of their critical thinking perception after answering different items. Figure 18 shows that the student conceptualisations and evaluations of critical thinking was average; the overall result shows it was "agree" which is a good disposition and "sometimes agree" which is a "weak disposition but showing a tendency towards development" or "fairly well-developed tendency toward the disposition" as classified by the Intellectual Traits Inventory rating scale (Appendix 15).

Figure 18. Conceptualisation and evaluation of information

Other items in the survey had the following results:

In response to the question 'How well have your lecturers supported you to develop critical thinking skills in CEM 1880 or CEM 1881?', a range of responses were positive, reporting as 'very good', 'good' and 'acceptable' support. The majority of those who responded to the item 'Please rate the quality of your own critical thinking experiences in university courses other than CEM 1880 or CEM 1881', felt that the experience was positive. There were two students out of the 34 responses to the question that reported negative. Respondents were asked to indicate how well they concentrated, listened and payed attention during lectures for CEM 1881. Over 70% of the responses were positive. About 85% of students reported that their commitment to CEM 1881 related to lectures, reading and completing practice questions.

5.4.3 Summary of Student Survey Responses

The student survey responses were analysed comparatively with the study's critical thinking definition. To sum up the students' survey results, over half of those surveyed interestingly reported that they were "always", "most of the time" or "sometimes" distracted by other things during lectures for CEM1880 and CEM1881. When asked to rate their lecturers' knowledge and understanding of critical thinking, 50 students (CEM1880) and 34 (CEM1881) reported that their lecturers were "capable", "good" or "very good".

It could be expected that, since the students perceived their lecturers to have a good knowledge and understanding of critical thinking, these lecturers would have a higher percentage of a report on being "extremely involved" in developing critical thinking in their students. However, there were 2 students out of 34 from CEM1881, and 2 out of 53 from CEM1880, who reported that their lecturers were "extremely involved". 7 students for CEM1881, 10 for CEM1880 responded "very involved" when asked about developing critical thinking as part of the learning and teaching in these courses. Ironically, 73 students for both courses reported their lecturers supported them in developing critical thinking in CEM 1880 and CEM 1881. When asked to rate their general critical thinking experience at the university courses other than CEM 1880 and CEM 1881, students reported that they were at the expected level. More findings will be discussed in detail in Chapter 6.

5.5 Student Focus Group

> "I don't think you can think critically when you're told how the equation works" (Student).

Student feedback was derived from the student survey responses and the focus group session. The first set of analyses examined the students' survey responses in previous sections, followed now by the focus group session. It was intended that the focus group would comprise of students from the two chemistry courses offered in the first year (CEM1880 and CEM1881). However, only three students from CHEM1880 participated. The findings from the focus group helped to answer research question 2; how is critical thinking being planned, enacted and assessed in the first-year chemistry courses at this university?

The students who participated in the focus group were asked if their lecturers had helped them to engage in critical thinking in CEM1880 and CEM1881. Some of the student comments were:

> I find in foundation chemistry a lot of what we're taught is like the foundation, so the laws and the equations that we need to use, and I don't think you can think critically when you're told how the equation works.
>
> I find that in CEM1880 lectures, a lot of it was less critical thinking because you're learning the foundations (content).

It became clear that student understanding of content knowledge during lectures were not strong when the students referred to their different lecturers:

> I find it harder to take in all the information that Patrick gives out. Like if I study it afterwards, I find it easier to remember. Like during the lecture I'm like, I don't know what's going on, this is insane. And then a few days later, if I'm studying for his section, random - it makes sense.

Another student stated:

> I find it difficult to engage at all. The lectures tend not to be for me, go up and listen for an hour, write down what they say and then go home and do it yourself. Doing the actual work is not an issue for me, more I don't learn very well in a lecture format.

Discussion with the focus group about the teaching strategies they are exposed to from their lecturers suggested critical thinking might not be taking place. For example, one student described it below.

> I think it was Gavin that did the thermodynamics; I couldn't pay attention to him at all. Like I found him very slow like he was the complete opposite of Ben. He was just very monotone slow, so I couldn't understand everything he was saying, but I also found him very boring, his slides were impossible.

Another student indicated:

> Ben goes quite fast and I think that might be on purpose, maybe because everyone taking notes rather than just listening to him talking, but maybe that just worked for me because I don’t take notes.

Students reported they would prefer a better structure for their assessment. They believed the online quiz was not helpful to their learning as there were many quizzes and not all were targeted to what they had learned each week. The students also stated that the quiz approach by Denise might be good but only at the end of the class. For example, one student commented:

> I think it might be more beneficial instead of having it in the middle of your lecture, have it at the end or the start. If I’m stuck, then I can refresh it. For what the last lecture was, or at the end, like you know exactly, not breaking people’s train of thought and maybe another problem of people being a bit embarrassed about it.

An area where students wanted to see a change was for the assessment. Students would like questions that were relevant to the learning objectives. In summary, the student focus group interview was an opportunity to find out the reflections of students on the teaching strategies they had experienced from various lecturers in their chemistry course. Students did not report on specific teaching strategies other than that they expected the university teaching model to be lecture-based. Students found lectures boring and found ways to understand the content after the lecture session. They reported a targeted assessment of learning objectives would be more beneficial, rather than having to answer questions that were not relevant to what they were learning at the time to obtain that 5% from the “best choice on-line problems”. Students unanimously agreed that critical thinking was important for their learning in chemistry; they were able to describe the concept and reported that there was not much application of critical thinking during their lecture sessions.

Students reported that the laboratory sessions were more engaging than the class sessions and described the laboratory sessions as having more interaction of students with lecturers and laboratory demonstrators. They reported that each session had a manual that clearly stated learning objectives and what was expected of students at the end of the experiment. Students noted that it was almost impossible not to know what they were doing because the result from the calculations gave insight as to whether they had to perform the experiment again. They reported that as they progressed with using the laboratory manual, they were able to ask questions and that help was readily available.

5.6 Chapter Summary

This chapter reported on the findings of the study drawn from the document analysis, the lecturer and student survey. A descriptive statistical analysis was reported for the lecturers and students. The lecturers unanimously rated the importance of critical thinking in tertiary education as "extremely important". The data analysis in this chapter revealed: students reported their lecturers are moderately involved in supporting them to develop critical thinking in CEM1880 and CEM1881, students reported that weekly assessment should be entirely targeted to their learning objectives and students reported that engaging them during lecture is more effective than having PowerPoint slides available to them. There was a misalignment between the planned curriculum and the assessed curriculum which this may impact on the achievement of the university's graduate attribute. The next chapter offers findings of the case studies.

CHAPTER 6.
FINDINGS OF THE CASE STUDIES

6.1 Introduction

Reporting findings in a case study is characterised by repetitive and consistent review of the collected information to identify answers to research questions (Szalma & Hancock, 2011). The researcher in the current study avoided a simplistic approach that could occur due to the repetitive nature of the case study research. In addressing the propositions, the findings remain focused on the research questions. The previous chapter provided insights and evidence about the context in which the study is situated and what background factors, including lecturers' perceptions, contributed to this learning context.

This chapter reports on the nested cases and provides evidence to answer the research questions. The findings are presented in individual cases for eight lecturers in the narrative form under themes aligned with the research questions. Findings are drawn together the data collected from each lecturer by way of individual interviews, observations of their teaching and from their individual surveys. In reporting the case study, the analysis was done comparatively with the study's critical thinking definition.

The chapter explores university lecturer perceptions of critical thinking (research question one), enacted and assessed curriculum concerning the development of student critical thinking (research question two) and perceived obstacles to fostering critical thinking in their courses (research question three). Data sources are triangulated to provide rich descriptions in response to the research questions in the chapter summary. The narrative of the themes is presented under the following headings for each case: defining and understanding critical thinking, perception and importance of critical thinking, teaching concepts, classroom interaction and teaching activities, and assessment.

6.2 Case Studies

The following cases are narrated from the synthesis of the context to the study and data collected from the eight lecturers at West University. The pseudo lecturer names are Denise, Aaron, Ben, Gavin, Stella, Isaac, Patrick and Joan, while pseudo courses identifiers are CEM1880 and CEM1881.

Table 24. Data accounting log

	Ben	Denise	Patrick	Gavin	Isaac	Stella	Joan	Aaron	Students
Lecture OBS. 1	04/04/2016	08/03/2016	29/02/2016	15/03/2016	23/05/2016	14/03/2016	21/03/2016	08/03/2016	
Lecture OBS. 2	05/04/2016	09/03/2016	29/02/2016	15/03/2016	25/08/2016	15/03/2016	23/03/2016	09/03/2016	
Lecture OBS. 3	06/04/2016	14/03/2016	N/A	N/A	26/08/2016	15/03/2016	04/04/2016	09/03/2016	
Lecture OBS. 4	17/05/2016	N/A	N/A	N/A	N/A	N/A	05/04/2016	N/A	
Lecture OBS. 5	N/A	N/A	N/A	N/A	N/A	N/A	06/04/2016	N/A	
Lecture OBS. 6	N/A	N/A	N/A	N/A	N/A	N/A	16/05/2016	N/A	
Lecturer interviews	07/08/2016	17/08/2018	26/08/2016	23/08/2016	25/08/2016	16/08/2016	30/08/2016	30/08/2016	
Online survey for lecturers	28/09/2016	28/09/2016	28/09/2016	28/09/2016	Incomplete	28/09/2016	N/A	N/A	
Online survey for students									21/10/2016
Focus group									03/11/2016

Table 24 contains details of the data collection for the case studies. The researcher created the table as a form of accounting for data.

6.3 Case Study 1: Denise

"You can either have a big bang, or you can have a good lecture" (Denise).

Denise is a 36-year-old female chemistry lecturer with six years of teaching experience. She holds a B.Sc and Ph.D qualification and is a lecturer for CEM1880. Throughout the interview, Denise's passion for supporting students to become successful scientists by providing meaningful learning opportunities was evident.

6.3.1 Defining and Understanding of Critical Thinking

From Denise's description of critical thinking, it was apparent that she had an understanding of the concept and how this skill can be applied when her definition is analysed against the expert's definition as seen in Chapters 1 and 2. Denise defined critical thinking as:

> Part of critical thinking, I would say, is the ability to assess information and see whether it makes sense, whether it fits into a logical way of viewing the world—I guess the ability to formulate a mathematical problem from a written statement or a written question, the ability to assess whether information makes sense. So, there are two examples of what critical thinking is or how you might apply critical thinking. Critical thinking, in general, it is about understanding and integrating information and being able to use it appropriately. I would also say critical thinking is about; I do a lot of teaching the mathematical skills that are required in chemistry because I am a theoretical chemist, and I think maths is so important. (Denise, Interview)

In the survey, she stated that critical thinking is "the ability to assess whether information makes sense and use concepts and information to solve problems appropriately". In her opinion, she listed critical thinking skills as "analysis - inference - problem-solving - decision making".

Denise understood her own use of critical thinking. That is, critical thinking is something that needs to be developed after students have conceptualised the theories and models used as the basis of science. To not do so means that students would not develop as scientists because it is true that chemistry students need to learn some principles, theories and laws. However, it is helpful to engage students in critical thinking while content is integrated (Section 2.9).

In further discussion with Denise about her understanding of critical thinking, she stated:

> It is totally possible to get a hundred per cent in the CEM1880 exam without actually applying any critical thinking. I do not think the students passing the exams or fulfilling the learning objectives is necessarily critical thinking. I think if they do pass the exam based on an understanding of what they are doing, then that is critical thinking. But if they pass the exam based on just memorising an approach and then just applying that multiple times then I think that is not critical thinking. (Denise)

It was apparent at the interview with Denise that she has a good understanding of critical thinking, but lecture observations indicated that there was less application in practice.

> I think that is very important, and I think being able to conceptualise what you are given and have theories and use models form the basis of science. And I think, if you cannot do that, you are not ever going to be a scientist, to be honest. I think that those things, they grow as you get older as a scientist. So, you think you understand something, and then you learn that you did not really understand it, and you understand it a bit deeper. I think that is all true, and I think that your critical thinking skills also grow as you get older. So, I can look at something in history and say, "You have done that wrong," and they go, "How do you know that?" And I'm like, "Magic." And no, it is critical thinking, and it is not magic, you know, just that ability to understand things on a mathematical level and a conceptual level. I think that is what makes you a good scientist. (Denise)

6.3.2 Perception and Importance of Critical Thinking

During a discussion with Denise about her opinion of critical thinking, she made the point that teaching chemistry with critical thinking strategies was essential but doubted if there were sufficient time and resources to make this a functional teaching practice. It was apparent during an interview with Denise that she does not think that critical thinking can have much impact on the type of chemist a student turns out to be. However, at the same time, she stated her support for the critical-thinking approach to learning and the importance of teaching and learning in tertiary chemistry. Denise said that she was not convinced that critical thinking by itself could enhance the quality of chemistry students' learning:

> I think it's totally possible that they are able to fulfil the learning objectives without any critical thinking at all. I wouldn't define critical thinking in terms of the learning objectives. The ability to assess the information that's given to you, to look at a problem and be able to answer it based on understanding, not just based on pattern recognition. (Denise)

Connected to the quote above, merely adding critical thinking as a separate learning objective would not work because, in Denise's view, students need to connect critical thinking with their assessment of information and a problem presented in a context. This perception of Denise supports the claim that teachers were seen to have a different understanding of what critical thinking means; hence, how they integrated or not integrated this concept into their teaching (see Section 2.5). Denise's response suggested that the course assessment practices did not explicitly require critical thinking from students. The above statement indicated that Denise was a bit confused about what would demonstrate whether students were using critical thinking or not.

Denise did not believe that there was a relationship between students' understanding concerning the learning objectives and the application of thinking critically: "I don't think that these things are related, though, so I don't think that students' abilities of learning objectives are necessarily giving them critical thinking".

Denise revealed during the interview that she had not received any formal training or professional development in teaching critical thinking. This was not necessarily her choice, nor did she not value integrating critical thinking into her teaching. She is yet to be presented with such an opportunity by the university. She added that she had made an effort to learn from colleagues, and she suggested that this approach to professional development might be more beneficial than critical thinking training.

She commented that professional development is not always focused on individual growth, but instead, more generalised strategies are suggested. As such, she thinks that what is learnt from colleagues is more practical, and she found this useful to apply based on individual teaching style and the type of class or students. It appeared that Denise was clear that she did not need more teaching strategies suggested to her through professional development training, as she has not always found these helpful in the past. She commented that professional development should be geared towards individual growth, while what is learnt from others depends on personal teaching style and the type of class or students being taught.

> It could be helpful to learn from other people's experiences. In the end, I think you do just have to do what works for you and what works for the class environment that you are in. I think I would probably be a bit hesitant about going to some sort of critical thinking teaching, training kind of course. I think, in real professional development, you need to spend the time trying out things yourself, ideally. I guess getting feedback from other people about what works and what does not work in a constructive kind of way, but that is a lot more. That takes a lot more effort, I think than a critical thinking teaching or course. It is a lot more individual, I guess, and I think that is how it has to be because everyone does teach differently. (Denise)

Denise believed that critical thinking for the teaching and learning of Chemistry and tertiary education is "very important". She mentioned that the key to helping students understand that knowledge is not magic, is to teach them to think critically, using theoretical knowledge:

> Conceptualising theories and using models is the basis of science. If you cannot do that, you are not ever going to be a scientist. You may think you understand something, and then you find that you do not understand it at all, so then you try to understand it a bit deeper. You can look at what you have done wrong and realise that it is not like magic. Critical thinking is the

> ability to understand things on a mathematical and conceptual level, and I think this what makes you a good scientist. (Denise)

While recognising its importance, Denise reported that critical thinking was not identified explicitly in the Course Learning Outcomes. This suggests that the Chemistry Department has not aligned the course outlines with the Graduate Attributes of the university and with the Learning Outcomes of a curriculum. (Section 2.10) Therefore, the Graduate Attributes are not met.

> I mean, it definitely happens, and I find it very frustrating when it happens because I think it is just really unfair on the students. I think that there are some lecturers that are also worse at it than others. Sure, if the alternative is memorisation and not understanding things, then definitely, critical thinking is important. I'm probably the strongest proponent of critical thinking. (Denise)

According to Denise, critical thinking is essential for scientists. However, she thinks what is debatable is the extent to which it contributes to academic success:

> Usually, what the students need to know is how to solve the problems at the end-of-term exam. Whether that requires critical thinking or not, that is a different question because it may be just that it requires the ability to apply a procedure, which is not necessarily critical thinking, although it does require the ability to work out what procedure to apply, which probably is critical thinking. (Denise)

Denise suggested that chemistry students could achieve academic success through memorisation without developing critical thinking skills. She stated:

> I think you could pass CEM1880 without having any critical thinking ability whatsoever and just memorising how to answer the test questions. (Denise)

She further stated, "Memorising is not the best way to learn in chemistry. I don't think that's the best way at all. But I do know that there are students that do that. If the alternative is memorisation and not understanding things, then definitely critical thinking is important".

6.3.3 Teaching Concepts

Denise held to two prevalent teaching concepts: to "convey understanding" and to "use concepts". During the interview, she disclosed that she would like her students to understand what she is teaching them, rather than just to know the facts. She was aware that there were more elements to teaching Chemistry than just relaying information:

> I would have to say that the key ideas that drive my teaching philosophy and behaviour are that it is most important for the students to understand what I am talking about, and to be able to use the concepts that I am teaching them, than it is for them just to know facts, or to know about things. Therefore, I would say that understanding is the key that I am always trying to convey to the students. (Denise)

At the interview, Denise mentioned that the core content and material that she teaches remains the same each year, with a little variation or emphasis on specific aspects. She has taught the Ideal Gas Law, Boyle's Law, Avogadro's Law, Charles's Law, Dalton's Law and the Kinetic Theory of Gases, with variations in Atmospheric Chemistry and Chemical Reactivity. She stated:

> I always teach the Kinetic Theory of Gases. Some semesters I will give a derivation of that; some semesters I will not, depending on what else I want to emphasise. (Denise)

At the interview, Denise described how she tried to develop critical thinking skills in her students by encouraging them to use critical thinking when asked a question during lectures. It seemed that Denise understood that applying critical thinking skills was important for students to grasp the content, recall knowledge and its application:

> There are definite strategies that I take. In my lectures, when I put up questions, I don't straight away give the answers. I say, "Try this first, and only after you've tried it will I give you the answer." I give them directions on how to get the answer. If not, you're not learning any critical thinking at

> all. I encourage the students to try to understand things. I give them the information that they need to do the problems. (Denise)

Even though Denise believed in and advocated for enabling her students' critical thinking and understanding for application, three observations of her lectures showed no critical thinking teaching approach other than the lecture method due to pressure to cover course content, lack of a laboratory assistant and large class size. Denise was convinced that in order to get through the course content, she has to stop the demonstration activity. She stated:

> This is a class of five hundred students without any extra money, TA support, or technical support. However, I found that it took so much of my effort to organise the demonstration that I was not teaching the material. (Denise)

Connecting to the statement above suggests that Denise was focused on the teaching aspect rather than students' learning outcomes. Perhaps this is why she said learning objectives could be achieved without critical thinking. Denise's department focussed primarily on content knowledge and expected individual lecturers to cover core content. As a result, Denise had to decide to stop the demonstration activity that she enjoyed doing.

> While I enjoyed doing that, because we do not have the technical support to do that all the time, I thought, no, I am not going to do that. I am going to focus on teaching. (Denise)

6.3.4 Classroom Interaction and Teaching Activities

Data from three lecture observations with Denise showed the contrast between when she delivered a lecture to when she used the quiz to interact with the whole class by asking everyone to stand up, and the last person standing got chocolate from her in each class. Denise indicated during the interview that it was vital for her to get the students thinking; hence, the way she interacts with them. It was apparent that Denise valued the application of what she has taught and wanted her students to get into the process of engaging their thinking to make logical scientific conclusions.

> For me, that is, I guess key to developing as a scientist, and I suppose it is also key to developing critical thinking, you have to have the opportunity to try something and to test out your ideas before you can make that step of actually understanding what you are doing. (Denise)

The lecture observations supported this view. For example, when Denise was observed using interactive teaching activities, she used quizzes to engage students. This teaching activity is an example of Denise's teaching practice implemented as a formative assessment for learning. Using quizzes enabled her to provide students with quick feedback about their developing understanding of the scientific concepts being discussed, and also provided her with an indication of students' developmental progress aligned with the learning objectives for specific lectures. She engaged students through a quiz during all observations of her teaching. This quiz used multiple-choice questions that required students to convey their understanding of the concepts she was teaching. This may provide an indication that Denise was aware of specific teaching activities to develop students' critical thinking skills.

Denise was also observed using transmission of information (lecture) as a mode of delivery during lectures because of her perceived need to cover the weekly course content. This demonstrated the extent to which Denise engaged in critical thinking. She reported:

> When I first started teaching this course, I didn't do any of the quizzes; I didn't do any of the interactive activities; I just stood up and lectured. I did some demonstration, but then I found that, actually, that took so much of my effort to actually organise the demonstration that I wasn't teaching the material, so it was like you can either have the "big bang," or you can have a good lecture, but you can't have both. (Denise)

According to Denise, she used demonstrations as a tool to impress the students, which she referred to as "big bang." For example, she had a presentation where she exploded balloons with hydrogen, helium and nitrogen and demonstrated the principles of reactivity to the students in the lecture. This strategy fitted into some part of the element of thoughts, the intellectual standard and intellectual traits (Section 2.8). However, there was tension between the delivery of the content to students and how the learning outcomes were achieved that relate to knowledge and understanding (pedagogy). Denise decided on what content she would focus on and hoped that the students would apply self-regulated learning to understand the content further. As earlier reported, she stated:

> …you can either have a "big bang", or you can have a good lecture, but you cannot have them both! (Denise)

With regard to Denise's comments above and below, she may have been aware of the specific teaching activities that are needed to develop the students' critical thinking skills. However, they were not related to any particular professional development that she had received. She mentioned how she had to find her way when it came to teaching strategies. It seems that Denise realised that it is not just about strategy, but rather, about the context in which they are employed. As established in the literature, teaching critical thinking requires a clear understanding of the process and an awareness of the conceptual components related to the teaching approaches that are effective in developing the critical thinking skills of students (Section 2.6).

> When I started, I was very young and impressionable, and people said, you have to do it this way! And I would try to do it that way, and it would be a complete failure. And somebody else would say, no, you have to do it this way, and I would try it that way, and it would be a complete failure. too, and it wasn't until I developed the confidence in myself and my ability to teach and my ideas about how to engage students that it all started to work. (Denise)

During her interview, Denise revealed that her mode of delivery and teaching strategies have evolved over her career from a lecture approach to a practical demonstration, self-guided learning, and now, quizzes. Denise found that she was not able to manage the quality of students' work with self-guided learning. She discovered quizzes were more efficient as they identified for her how many students could recall the information: "I just stood up and lectured. It was boring for me; it must have been very boring for the students." (Denise)

6.3.5 Assessment

Denise had a strong belief that there should be an alignment between the learning objectives and the assessment questions in an examination. This is similar to a scholarly understanding in which students should not be left wondering about the link between what they understood from the content taught and how they are being assessed (Section 2.11).

> I suspect what you will find with my section of the course is there is a very good match because I am very clear about what I expect them to do. I often criticise my colleagues for this. How could the students possibly know how to do this, because you haven't asked them to do so? There may be one or two cases of some multi-choice questions where there's not a good match. I always have it in my head that if I ask a student a question, it has to be something that they can answer from the learning objectives. (Denise)

Denise realised that emphasising efficiency when marking examination papers, meant that she has to design the assessment questions carefully. This could imply that asking students to choose the most appropriate item rather than using their own words might create a marking problem; hence, the discrepancies in having alignment between the learning objective and the examination items (verbs). This assessment approach would not foster students' critical thinking (Sections 2.10 and 4.2).

> That would be because of marking. If you say "describe" then, and you have five hundred papers to mark, then you're going to get five hundred different descriptions, and you have to read them all. If you say "circle" the one of this that best describes, one of the learning objectives might be like "Describe what makes a molecule a greenhouse gas" and then in the exam it might be "Which of the groups and why is CO2 a greenhouse gas" because it has a circle the right one. (Denise)

In all of Denise's lecture observations, she explicitly made the learning objective for that lecture clear on the PowerPoint at the beginning of her lectures. Denise also mentioned what was expected of her students, the likelihood of examination questions and gave enough information and evidence.

Then, she went further to mention that she always has a good match in her section of the examination questions and believes, based on statistics, her student assessment rating is lower than the other lecturers'.

According to Denise, the reason for low performance in her section is because students tend to do well in what they are familiar with and have memorised; there is also a lack of concentration and commitment during a lecture on the part of the students.

> They tend to do better on the ones that they have studied in high school. Largely, probably because they have already memorised how to do those types of questions. They can do well on the numerical calculation questions that they do at high school but not so much on the ones that they are actually required to understand why gas is a greenhouse gas and all of those kinds of things. So, it probably means the pass rate for my part of the course is lower. But again, that is just the people who are pissing around on Facebook, so I am not particularly concerned about that, quite frankly. (Denise)

6.3.6 Case Summary

Denise's classroom interaction approach was connected to her teaching concept, as mentioned earlier (Section 6.3). Denise was observed using quizzes, which increased the number of questions she asked and interactions with the students within five minutes. However, this did not increase the number of questions that students asked, nor did it sustain classroom interaction for the rest of the 50-minute lecture, given that the number of questions asked by students is an indication of their understanding or ability to clarify information (Martineau & Boisvert, 2011; Paul & Elder, 2012b).

Denise was very aware as to how interaction within lectures can change student's thinking and how they learn. Implementing critical thinking teaching activities in Denise's lectures lacked the element of consistency suggested by Paul and Elder (2012b).

Even though Denise did not create ways for giving feedback during or after the lecture, her overall engagement with the students was good, even if there was no explicit critical thinking development in the classroom. It was evident in Denise's LOG that she asked questions occasionally. Overall, as observed in her lectures, Denise might have exhibited some critical thinking indicators that were not planned for by using questioning technique, but she was not consistent in her approach.

Denise's opinion about her assessment process was that she had done a good job aligning her learning objectives with the examination questions to develop critical thinking in her students. Denise reported ways such as demonstration and allowing students to ask questions to develop critical thinking in her students. It became clear that Denise was able to identify a range of factors that could motivate students to develop critical thinking within the chemistry course.

During the interview, Denise agreed about the importance of critical thinking to teaching chemistry in higher education but doubted if there would be enough time and resources to make this a useful teaching practice. Her observation results showed that her lectures were somewhat engaging, which showed a little drift for a moment from the lecture approach that lights up the room and tends to promote the concept of critical thinking. Denise embraced the idea of encouraging her students to think critically. In all observed lectures, she engaged her students with quizzes and rewarded the last person standing with chocolate, which the students enjoyed. Most importantly, she promoted content knowledge, content recall and understanding; thus, she increased student interaction. Beyond the lecture approach, the quiz strategy seemed to be the only different element in her teaching technique.

The observation indicators depicting how Denise used critical thinking showed that she was very descriptive in how she provided a solid foundation of understanding the fundamental principles of chemistry in her related topics to her students. She also enhanced applied mathematical skills relevant to her topics and developed a working understanding of the atomic structure, periodicity, chemical bonding, material properties and gases with her class by demonstrating step-by-step calculations.

Denise was always very clear concerning the learning objectives at the beginning of her lecture, what is expected of her students, the likelihood of examination questions and providing enough information and evidence. Sometimes, Denise made students examine others' thinking in discussions, and somewhat communicated, listened and connected with her students. However, there were no planned activities other than the quiz, and she did not help students deal with conflicting sources if there were any (Appendix 9). Stimulating controversy, banishing putdowns and ensuring critical engagement in group activities never occurred. However, Denise allowed her students to talk to each other, which indirectly raised the level of discussion and ultimately created an atmosphere for critical thinking in the classroom. This was an indication of "Element of Thought" from the Paul and Elder critical thinking framework, though she did not enable students to progress to the second stage of "intellectual standard".

6.4 Case Study 2: Aaron

"It's just ridiculous, so students have no sense of formative rather than summative assessment". (Aaron)

Aaron has been teaching for over 30 years with a B.Sc, MA and Ph.D. Aaron teaches CEM1881, and he was part of the team that developed the course. The semester the study data were collected, Aaron was not teaching CEM1881, but covered some sessions for Stella.

6.4.1 Defining and Understanding of Critical Thinking

Aaron described critical thinking as analytical thinking, which he stated was the ability to develop the skills which allow a person to address a problem that could not otherwise be dealt with. He believed that critical thinking is the ability to work through a problem in a systematic, logical, analytical way. He added this process does not have to happen only in science as it could happen in humanities or other fields, which he mentioned have a lot to do with higher-level thinking. He stated:

> Critical thinking is strongly related to a combination of analytical thinking, rigorous thinking, slow, deliberative thinking, comparative thinking, all those kinds of things which are not as opposed to instinctive reactions. (Aaron)

Aaron believed that the most important thing was to drive students to be self-motivated learners, such that they are enabled to like the material, engage with the content, and then apply the knowledge and understanding. He said:

> So, the most important thing in the first place is to give motivation. (Aaron)

As the interview progressed, it was evident that Aaron believed in motivating and empowering students with the opportunities to achieve the desired learning outcome. He mentioned that the major problem in achieving that was in the way lecturers teach and in overcoming the idea that some students do not like the mathematical aspect of chemistry while some do. This was evidenced in the following statement:

> The big divide between the classes that we teach, is both pedagogically and whatever is the Maths divide. (Aaron)

6.4.2 Perception and Importance of Critical Thinking

As with other lecturers, Aaron perceived that there were limitations to integrating critical thinking into the teaching of chemistry, feeling that too much could overwhelm the students. He noted that it was hard to balance what was required regarding course content versus what was anticipated regarding engaging students with critical thinking. He stated:

> It's compromised you know, there's a limit to what you can aspire to in them because it is an introductory course. There is this tension between essentially formulaic buildings of skills as opposed to critical thinking and so it is hard to maintain. (Aaron)

He was convinced through his own experience from the early years of his career, that you could get a good job without a degree in chemistry and believed that no student wants to do chemistry. As a further example, he explained that he had a gifted student years ago who would not pay much attention in class nor apply himself to critical thinking, but who graduated with a first-class degree in chemistry.

Aaron had a divided opinion on the importance of critical thinking to tertiary chemistry teaching. According to Aaron, it was not necessary for a degree in chemistry. Therefore, he would not be looking at critical thinking for chemistry.

It was apparent during the interview that Aaron, like some other lecturers, was sceptical about training for including critical thinking into teaching. He referred to when he started teaching about 20 years ago, how there was no training compared to the present. He gave an example of how in the United Kingdom, the academics had to undergo a training course they regarded as a waste of time and expressed the danger in the idea of training:

> Regarding training then the main danger is that in Britain, for example, academics often have to do it, go on a teacher training course. Many even regarded it as a complete waste of time, because if they're not interested in it, and they don't think they're learning anything. Then it's not going to have much of an impact. The reality is that the people that are motivated choose to go on these courses and that's good. But, forcing people to sit through class, is ineffective. (Aaron)

Later in the discussion, Aaron indicated he considered critical thinking as the key to knowledge and understanding, and he believed (in similar fashion to Denise) that he learnt more from colleagues than any training could provide. He commented:

> One of the big challenges is you need to have breadth and depth of thinking. To develop higher-level critical and analytical thinking skills, you need to work in-depth, but you need to have a breadth about what you do. In my view, the most effective ones are ones which for in terms of engagement from my colleagues are ones which are very directly related to Chemistry. (Aaron)

Aaron strongly believed that there was power in engagement and a critical thinking approach to learning. He gave an example of what according to him, was the best activity he learnt in a conference, which he thought could not happen in chemistry. He described how a private university used literature to change the lives of the students and the school:

> I can remember, the best example I could ever come across, of an activity, it was in the United States, it was fantastic, and you could never have done it in chemistry. (Aaron)

However, given that critical thinking is course-specific, and there are discipline-specific activities that could promote students' critical thinking, then the above quote would not be accurate. Perhaps, Aaron might need awareness of different activities that could foster critical thinking in chemistry.

During the interview, Aaron revealed that some people have no business teaching chemistry, and according to him, these people make it worse for students to comprehend and have meaningful learning. He indicated that such people who come into the university should not all teach, but instead, the system should allow them to be experts in their area of strength. Aaron commented, "I'm a great believer in differentiated responsibilities." He gave an example of Professor Elliot (pseudonym) at the Southern University (pseudonym), who was offered a teaching position, and he refused to take the job because "he did not believe that he could lecture properly, and he did not believe he could properly engage with classes. He didn't think it was appropriate to be an academic".

According to Aaron, the Professor Elliot argument was that:

> In a functional university, you optimise the talents of the whole group of academics, based on their different predispositions and expertise. (Aaron)

In finding if Aaron was enacting the curriculum to develop students' critical thinking, at the interview, Aaron expressed his displeasure to the idea of training or professional development on how to integrate critical thinking to the teaching of chemistry. He stated:

> Are we doing a comedy show or what? Here's the deal, I think. There are some academics, actually quite a fair number of academics, probably more than you might imagine, who are really quite dedicated to their teaching. They really want to do a good job, and they seek input from the outside and they work on that, and we do have results from those people. Anybody who wants to upskill can. (Aaron)

Aaron mentioned that it was easier for him to learn from a chemist he had respect for. He gave an example of programmes in the United States, fostered by the American Chemical Society with an exclusive nature and problem-based learning approach. He commented:

> It is much easier to enact there than it is here because essentially, they have monolithic courses, and they can control everything about your course, and it's much harder here to provide. (Aaron)

Aaron reported that the workshops with visiting scholars were a good experience. He gave another example of an Erskine visitor whom he found to be a fantastic teacher and learnt the "concept test" he mentioned earlier from, Aaron reported that the Erskine visitor ran a series of lectures and interactive sessions. Aaron also mentioned that he had learnt a lot from Igor Finn (pseudonym) another chemist from the United Kingdom, commenting: '… "he's a fantastic teacher at the Northeast University (pseudonym) and one of the things he's done was to set up a good laboratory", and Aaron was involved with Igor Finn in the setup.

6.4.3 Teaching Concepts

Aaron strongly believed that the lecture as a way of transmitting content was an effective pedagogy. This suggested that Aaron was not enacting the curriculum to develop students' critical thinking because as established in Chapter 2, to develop students' critical thinking requires more than transmitting content. He stated:

> Yes, there's no point, so why, I mean why you would do a degree in chemistry? It was clear to me very early on that the reason that traditional disciplines had been so effective pedagogically is that these disciplines typically involve providing an environment in which you can own your critical thinking skills in a particular context. Once you've owned them in one context you can move many of those skills laterally. So, I fought a pitched battle with Luke (the gifted student) for three years to try and force him to apply himself and become a more (amongst other things), critical analytical thinker. (Aaron)

Further, into the interview, Aaron described his teaching as developing an excellent package, trying it out, and, if it worked, sustaining it over time. He believed that for a course like CEM1881 the teaching approach should stay the same:

> First-year courses for CEM1881, historically there was certainly a significant amount of evolution, to get a good package. But once you've got a package it worked reasonably well, then that's okay. But then it might be two or three years before you work through that material. Once you've might have gone through that pattern that should be in reasonable shape for a few years. (Aaron)

Aaron held two main conceptions about teaching CEM1881: he believed in making the course accessible, and relevant to everyday life. The interview revealed that these conceptions were formed as a result of him creating the course CEM1881. Aaron further explained that CEM1881 was designed for students with a non-continuing general interest in chemistry. He indicated that the aim of CEM1881 was to provide a course which would be accessible to a very diverse audience. Some students in this course had virtually no chemistry background and some had some chemistry background, none of whom were expecting to major in chemistry, but with the hope that they might be encouraged to understand key ideas.

In order "to make the course accessible", according to Aaron, the philosophy for teaching CEM1881 was to have examples both in the lectures and the labs that were related to real life and were not stereotypically traditional chemistry. The aim, essentially, was to build some foundational thinking and particularly teach students how to think about chemistry. In order to "make it relevant to everyday life", Aaron described that the fundamental problem in chemistry was the abstract nature of the subject, which he referred to as "dealing with very different time scales and very different distance scales". He added:

> Dealing with very different time scales and very different distance scales. You start by introducing that range of magnifications and then start to introduce the concepts of atoms and molecules and bonding. That way, with the intention that it was not threatening to the people who were not

confident in maths and people who hadn't done much background chemistry. (Aaron)

6.4.4 Classroom Interaction and Teaching Activities

As a way of interaction, Aaron mentioned his use of concept tests via clickers or by a show of hands to vote. He reported that he used this strategy to provide feedback and gain a good census of the understanding of the class and to determine if the teaching could move on. He believed that this enabled his students to engage with the material and to interact with other students. Aaron believed that the large class and the fundamental way in which the brain works was a major constraint to his teaching practice and classroom interaction. Aaron reported that he uses concept tests regularly. However, this was not demonstrated in the lectures (observation notes).

Furthermore, he had a very detailed description of what he believed about how the brain works from a book he read, *Think Fast and Slow* by Kahneman (2011). Aaron further explained that how the brain works determined the real model of what goes on in the classroom. He indicated that the brain was engaged in 24/7 activity, trying to make sense of the world. He mentioned that primarily the brain had been evolutionally programmed to make rapid decisions. To form decisions, the brain received sensory input then progressed to deliberate slow thoughts, which were arduous to work with. Aaron strongly believed that this is why some people are unable to master statistics and, thus, how it restricted him in classroom interaction.

In further discussion, he described how he perceived that classroom engagement had been inhibited. He indicated that the history and philosophy of science have changed over time. For example, he explained that 50 or 100 years ago, students arrived at the university with a great set of skills and were eager to experiment with chemicals. They thought about what they were doing and had their explosions and colour changes.

Aaron reported that now, things have changed with a generation that was too safeguarded and risk-averse to undertake practical work, and all the observation of practice was to go to Google or YouTube with no sense of any activity or practice. He lamented the fact that society now has not helped the development of chemistry. He mentioned that the culture does not give students room to explore as the students lived in a risk-averse society where anything dangerous cannot be performed as an experiment. Aaron commented:

> You end up with these very formulaic laboratory activities. I mean chemistry's a dying field in many ways. The core of traditional chemistry is on the decline. (Aaron)

Aaron's opinion of what classroom interaction should be like, "that lecturers should provide students with diverse learning opportunities, not be just lectures", was not supported by observation of his lectures.

Aaron indicated that with persistence, things could get better in the teaching and learning of tertiary chemistry:

> I think we should try harder, and it's a continuous struggle to try harder, but there are reasons why it's not straightforward. (Aaron)

Aaron was unhappy about his perception of a culture change in chemistry, in which students are told to know something without necessarily knowing why. If students are unable to connect reason and relevance, chemistry becomes abstract to them, which makes it difficult for them to think of new ideas. He stated:

> Just do the problems, and in three years, then you can start to think about something that interests you. Solve the following fifteen differential equations, five Taylor Series. Why did I do that? When you're doing NMR in the third year, it will be beneficial to you. I can remember doing Taylor Series in the first year, and I was told and in third year I couldn't remember what Taylor Series was all about. I couldn't remember anything about Taylor Series, it's just completely ridiculous you know.
>
> That problem has been with us, but there are reasons why it's hard to break that, and one of that is the content, this content problem, that students tend to get immersed in textbook knowledge and jumping through the hurdles as they go through, but they don't really have adventurous open-ended learning. (Aaron)

Data from lecture observations showed that there was no relationship with Aaron's teaching concepts and his actual teaching practices. There was very little variety in Aaron's teaching methods as conveying information predominantly characterised his lectures. Aaron reported that he used concept tests regularly. However, this was not demonstrated in the lecturers observed.

Aaron described his teaching strategy as getting an excellent package: "trying it out, and, if it works, sustain it over time". Further discussion with him revealed that he believed that for a course like CEM1881, the teaching strategy should stay the same. He said:

> No, no, not for a course like that, for higher level courses yes, but not for first-year courses. First-year courses for CEM1881, historically there was certainly a significant amount of evolution, to get to a good package. But once you have got a package it worked reasonably well, then that is okay. But then it might be two or three years before you work through that material. Once you have might have gone through that pattern, then you might go back and go so right, that should be in reasonable shape for a few years now, not a lot, but a few years. (Aaron)

6.4.5 Assessment

Aaron agreed with the assessment items mapping tightly with the learning objectives. He also believed that scaffolding assessment for the weak students was a good example and that he had carried this out in the past. He explained that with the problem-solving aspect of CEM1881, he set past examination questions as test papers with minimal credit. According to Aaron, in his experience he found that some students with A-level chemistry were better grounded. He noted that when put to the task of analyses, they had cues and immediately were able to latch onto the problem. He stated:

> I've found a lot of weak students who don't have that. You know, it's all a jumble to them. They don't understand what the word means when you say, "write a critical account". Well, what does that mean? (Aaron).

It became apparent at the interview that Aaron did not believe in the concept of grades. He considered grades as myopic, and according to him, successful learning should not be assessed based on grades, as they dilute the aim of learning in the first place. He explained that what is learnt through a process should have nothing to do with grades. This belief has aligned with numerous other scholars (Section 2.11).

> People have a myopic focus on grades. I hate grading, and it's incredibly overrated. It's really important to give feedback to students, that's one thing, but grading it's just ridiculous, so students have no sense of formative rather than summative assessment. None at all. (Aaron)

For logistics reasons, Aaron strongly believed that some questions could not be asked in the examination and like Stella, Denise and Patrick, he reported that he pushed for multiple-choice questioning to save time during marking because it was a large class:

> Traditional exams or whatever and there are real logistical issues in the exam. So, I have to say that I was one of the people who pushed for multiple-choice questioning for CEM1881, on purely logistical grounds. If you've got three hundred students when I was teaching CEM1881 we used to have about a hundred and thirty students, it's hard; it's just very inefficient.

> There's nothing intrinsically wrong with multiple-choice questions it's to write multiple choice questions which are good. You're going to spend a week marking first-year scripts you know, it's ridiculous to spend that time, so if we can put half of that on machine marking then the reality is that I've just saved you half a week's work, right, because you can do something else. (Aaron)

Aaron further expressed his disappointment with the university system. According to him, the system has been over commercialised, thereby losing the focus on improving the quality of teaching and instead tended to focus on marketing and research.

> Revenue gathering is a big issue because science is expensive, universities are expensive, and revenue gathering is primarily research-oriented. The vast majority of the revenue of this university comes from undergraduate

> student fees, in fact the majority, significant majority, two thirds, more than two-thirds comes from undergraduate teaching.
>
> But if we teach super well, or super poorly, actually it doesn't affect our enrolments very much. The discretionary money about dealing with enrolments doesn't, is not primarily focused on upskilling teachers. It's primarily focused on branding and marketing, selling the product. It's very hard to overcome the intrinsic biases in the system to overrepresentation of research. (Aaron)

6.4.6 Case Summary

Given that Aaron's teaching idea was "to make the course accessible" and "make it relevant to everyday life", it could be expected that he would use peer discussion, classroom discussion and inquiry-based teaching. During explicit instruction, there should be a high level of lecturer-student interactions, problem-based learning, a high number of questions asked by the lecturer and students as strong teaching strategies that promote critical thinking.

No such activity was observed during Aaron's teaching. In fact, Aaron was not observed to have any classroom interaction *at all*. He mentioned during his interview a time when he used clickers for anonymous student responses and suggested hand voting for gaining feedback from students.

Aaron used the transmission of knowledge as a mode of teaching. He did not think that he needed any training in integrating critical thinking into his teaching as much as some of his colleagues did. He was reluctant to undertake professional training in critical thinking from educators he did not know. He does not appreciate the idea of students being assessed in the form of an examination or test, such that a student's success is attached to grades. However, Aaron agreed that the learning objective should be reflected in the examination items if students are put through this form of assessment.

6.5 Case Study 3: Ben

"And the better people are educated, the better they're going to be.
It contributes to wellbeing". (Ben)

Ben is an experienced lecturer of 31 years and has held leadership roles within his department and the university. Ben is a CEM1880 lecturer and the course coordinator; he is 58-years-old with a BSc (Hons) and PhD qualifications.

6.5.1 Defining and Understanding Critical Thinking

Ben demonstrated that he could describe what he thinks critical thinking is. He defined critical thinking as:

> Critical thinking to me is to be able to think critically, to be able to bring the knowledge that you have, not just of that particular subject but common sense and precedents, and use those to analyse a particular situation, and come to some sort of view that you think is sensible. Critical thinking is actually to be able to recognise that you can't do it, and saying, no I can't make sense of this, and have to go and find out more about it. Bringing everything you know, and being honest with yourself to make sense of situations and information that you haven't been presented with before, even with stuff you're been taught, to be able to think critically about it and say, actually I don't agree with that, or I don't see why it's that way, and then go and talk to the lecturer or talk to somebody else, about why it's that way, and either change your own perceptions or change the perceptions of the person who's giving you that bit of information. (Ben)

The survey data indicated Ben's description of critical thinking as "being able to apply prior knowledge, experience and techniques to make sense of (criticise) new information or experiences". Ben could identify by listing critical thinking skills as "combination of knowledge, awareness, confidence and experience. Be able to experience/observe, conceptualise, contextualise knew things and associated them with prior knowledge and experiences".

Ben agreed that critical thinking is vital to teaching in tertiary chemistry:

> Absolutely, critical thinking is important to anything. It's important to tertiary education because one of the principles aims of tertiary education is not to inform people about, not to give them knowledge; it's to help them to think how to think, and to help them learn how to learn. And

actually, critical thinking is embedded in that. I mean it's intrinsic to it. Without critical thinking, you haven't learnt how to learn. And you haven't learnt how to think. Thinking without critical thinking, without the critical part is a waste of time, and can be antisocial, I think. (Ben)

In the survey data, Ben rated the importance of critical thinking to the teaching and learning of chemistry as "slightly important" and to tertiary education as "moderately important". At the interview, Ben described how he was able to recall how to solve a solubility problem after about six years of not engaging in that area of chemistry. He further explained that, even though you memorise in chemistry, one can still pick up the understanding when required:

> I think students do memorise things. After about six years, one of the first things I had to do was run a test in the laboratory, and the students were given a problem with solubility products. And I had no idea how to solve it. I could solve all sorts of quantum mechanical problems, but I could not solve a solubility equilibrium problem because I'd forgotten. But on the other hand, I got a textbook; it took me three and a half minutes to work out how to solve it because as soon as I sat down and looked at it, I thought, that makes sense. (Ben)

6.5.2 Perception and Importance of Critical Thinking

Ben mentioned during the interview that he had no formal teaching training or professional development on critical thinking. However, he believed that critical thinking skills could be developed implicitly, and he did not believe in teaching critical thinking. He believed that improving students' critical thinking can be a matter of implicit expectation.

> As an undergraduate, right through being a graduate student, it's implicit in everything I do. I haven't had any formal training saying, we're going to teach you about critical thinking. In a sense, I'm not convinced that teaching people about critical thinking helps. Well, it might make them more aware of it, but I think that critical thinking comes about because of your exposure, and Universities are where students take advantage of it. They are great places to learn about critical thinking. (Ben)

Ben was convinced that a lecturer evolves in the ability to develop students' critical thinking. This is not the finding of Raikou et al. (2017) who stated that it is unlikely that a lecturer will develop this ability without training. Ben went on further to explain his thinking:

> I don't think there's any one event. It's just something that grows with time. I think as you go on in your career you tend to get better at working out how to get students to think critically. (Ben)

6.5.3 Teaching Concepts

Ben reported that he held two dominant teaching concepts; he cares about teaching, and he wants to advance the teaching of chemistry. His interview revealed that these main conceptions drive everything related to Ben's beliefs about teaching, learning and the world at large. His caring and passion about teaching, according to Ben, was born out of the need for people to be educated for a better society:

> I care a lot about teaching. Education is really important to society. It's a major component to progress in society. And the better people are educated, the better they're going to be. It contributes to wellbeing. It contributes to the ability to make informed decisions, even if those decisions aren't in the right field because it helps you to think about problems. All of those things have an overarching effect on how I teach. (Ben)

In terms of advancing in chemistry, Ben believed that students should be able to progress in their understanding of chemistry:

> Chemistry is good for the wellbeing of society and individuals. The other key thing is, there are some things that students need to know about fundamental chemistry if they are going to advance in Chemistry and Engineering. (Ben)

6.5.4 Classroom Interaction and Teaching Activities

According to Ben, his approach to classroom interaction was the use of PowerPoint as a tool to building up their attention to the lecture, although he is yet to know if this interaction technique works or not. He said:

> My principle lecturing mechanism is PowerPoint. So, when I'm actually in a lecture, I use PowerPoint. I start the lecture by reminding them where we have come from and where we are going.

Ben further indicated that, he also used gestures and questioning as another form of interaction with his students during lectures:

> I try to get out in front of the lectern and walk in front of the lectern and wave my hands around, I try to question the students, and sometimes I find they're not terribly receptive to that. (Ben)

During the interview, Ben stated that due to limited time, his lecture lacked further interaction opportunities:

> And sometimes also, if we're pushed for time, I find that you don't have a lot of time to talk to the students. (Ben)

Ben reported his own lack of teaching activities in his CEM1880 lecture aside from the lecture approach. He mentioned that technology seemed to be dictating teaching approaches currently and he spoke about the restraint that comes with that constraint. For example, students may think all they need to know is in the PowerPoint, and as this is available on the eLearning website can lead to class absenteeism.

Ben's teaching strategies use technology and PowerPoint as a static series of images to explain concepts and processes, rather than a dynamic explanation of the flow of thought. This teaching practice does not suggest Ben is enacting the curriculum to develop students' critical thinking. Perhaps video could help by recording his annotations or the use of a tablet device or electronic blackboard. Ha said:

> So, I used to be chalk and talk, so I used to use blackboards, whiteboards, I liked doing it that way, I thought it was a good way, a better way than PowerPoint of engaging the students. PowerPoint tends to lock you in. But there's been a big push in the university to go to PowerPoint and to put everything on eLearn, and for the students to be presented the same stuff that they're given in note form.
>
> I change my notes pretty much every year a little bit; sometimes they're big changes, sometimes they're small changes. I intend to make some small changes in the second semester just from the feedback that I got from the exam. But I'd say that the way I present lectures has been pretty much fixed for a long time now. I tend to give the same lectures in the same order with the same material, at the same rate, tell the same jokes! (Ben)

The above statement indicates that he thinks about teaching as a process-driven rather than student-outcome driven. That is, he was focussed on what he did rather than what students were learning or the experiences he was providing for students to be able to learn. The interview revealed Ben's teaching concept and behaviour, which may provide insight into his professional journey and commitment. He was confident in the level of his course content knowledge and the way he taught it.

When observed, Ben used a transmission-of-knowledge approach to deliver his lectures. He spoke very fast, showed no signs of integration of critical thinking into his teaching practice and seemed to have no strategy of engaging his students. He said:

> I use animated PowerPoints, so they're not static, so they tend to build up, so they start with not very much, and they'll build up. I haven't got a lot of feedback from the students. Not that I've sought a lot of feedback from the students as to how it works. (Ben)

Connecting to the above statement, Ben made it clear during his interview that he is always open to hearing back from the students, when they were struggling and held tutorial once a week in which he is more focused on supporting the development of problem-solving skills and providing more detailed understanding. Aside from the tutorial session, Ben did not attempt to encourage student to examine their thinking or use props to simplify learning objectives. Rarely was the learning objective mentioned during lectures nor did Ben connect his content to student thinking by asking questions.

6.5.5 Assessment

Given that assessment provides information about student understanding and exposes how they have defined or interpreted the content knowledge, lecturers should draw upon an assessment type that is critical-thinking focused. However, according to Ben, the assessment type and items in CEM1880 had remained the same over the years, evolving gradually rather than rapidly because the department concluded that students would not do well with change. If CEM1880 assessment has remained the same for years, then, the course has not determined if assessment restructuring is needed, nor is it able to identify areas where learning expectations are not met. He said:

> The learning objectives change, they evolve rather than changing radically, so if we have a change in the learning objectives then we alter the questions. But if you look at the examination papers, as with most first-year courses, there's a fairly similar structure from year to year. If we were to drastically change the structure, the students would be horrified. (Ben)

In the literature, learning objectives can be achieved through planned student-centred learning strategies. It is interesting to note that during the interview, Ben revealed that learning objectives should drive how the lecturers teach. However, there are tendencies for lecturers to drift away from this and it is rare for students to look them. Ben said:

> The important thing about the learning objectives really is that it gives us coherence from year to year as lecturers, and it also allows the people who teach the second year. And that's why I emphasise to my colleagues, don't drift too far from the learning objectives because if we do that, then nobody knows, there's no record of what we've covered. So, the students in the second year might end up with gaps, and we don't want gaps, and we don't want redundancies. (Ben)

Ben believed strongly that the learning objective should align with the examination items almost all the time:

> We use the same verbs. I don't think it's a deliberate policy to try to be consistent; it's just that's the language we use in the course. I can always tie a question in an examination, back to a specific learning objective. There are some of my colleagues who tend to stray a little bit at times. (Ben)

As the interview went further, it was apparent that Ben had some concerns about the examination items and topics that lecturers covered do not necessarily come from the course learning objectives and the impact that this can have on students learning and understanding in chemistry. Ben referred to an ongoing situation he was handling in his position as the course coordinator:

> What I've noticed in recent years is that a couple of the people in our team, one in particular, tends to ask the same things (in the exam) over and over again. And so, there are things that are in the learning objectives that he is not asking about in the examination questions. And my concern is that he's not teaching those things. That would be a bigger concern. Because if he's not teaching them, that means that we are leaving a hole that's likely to cause problems later on. (Ben)

Looking at the past examination papers with Ben at his interview, he realised that there might be few mismatches with the assessment items and the course learning objective verbs. He acknowledged this as useful feedback for lecturers:

> This is good feedback. I would have thought we were using the same verbs because that's the sort of language we describe, but if we're not, maybe that's something we should think about. (Ben)

If this feedback is integrated, it can be reported as good practice to align the learning objective of the curriculum with assessment (Section 2.10).

Further into the interview, Ben reported that the lecturers teaching into CEM1880 meet, although, nothing much changes related to the learning objectives:

> We do change the learning objectives though, and we do change the content. In fact, we had a meeting just a couple of days ago about tweaking the content of the course. We do that collectively. We meet irregularly. We went through all the learning objectives and talked about what we are doing well, what we aren't doing well, what isn't there that should be, what is there that is, become archaic and redundant. To be honest we ended up not changing very much. (Ben)

The responsibility to develop student critical thinking and integrate learner-focused teaching activities in the enacting of the curriculum is left for individual lecturer:

> I think that every lecturer when they start the course, reflects on what the learning objectives are, and how they're going to achieve them: you've seen your learning objectives. I think they're probably rather more extensive and elaborate and specific than pretty much any other first course in the university. (Ben)

Upon reflection, on the departmental examination, Ben believed that the department could do more by carefully planning and checking the examination items given to assess students. Also, that lecturers need to purposefully teach and be learner-focused and not assume based on what they think. He reported:

> One of the things I think we find is when we get the exams, we do a bit of an analysis about which questions were done well, which questions weren't done well, and that's a really good feedback mechanism for how you're managing to get information across.
>
> For example, I had a question that was a multi-choice question, and not many people got it right. You will think, if they just had random choices you would expect them to know, thinking twenty-five percent of them would get it right. Somewhat less than five, ten per cent of them got it right. And actually, a lot of them got the same wrong answer. But even worse than that, when you looked at the statistics, the weaker students were more likely to get it right. Now when I look at that question, I still think it's a really good question. So what I've decided is I actually didn't

> teach it appropriately. And so I'm going to go back, and so I thought very hard about that.
>
> I've got to make explicit things, some things that were in the past implicit, and I thought they were self-evident, so I thought all the students would recognise that, but clearly that hasn't happened. (Ben)

6.5.6 Case Summary

Given Ben's concept for the teaching of "caring about teaching", one could expect a variety of critical thinking indicators (activities) to be apparent in his teaching. However, Ben was only observed teaching using lectures in which he conveyed information to students. If he included critical thinking, one would expect to observe class discussions, peer discussions and inquiry-based teaching to achieve his "advancing in chemistry" teaching view (concept). However, none of these was observed.

Ben discussed his way of interacting was through the use of PowerPoint. However, during observations, he used PowerPoint presentations without asking questions which were contrary to his stated teaching concept, "caring about teaching" (discussed in Section 6.5). Research has shown that using any form of technology as a tool can promote the development of critical thinking when it is used appropriately (June et al., 2014; Kogut, 1996). However, using PowerPoint on its own without incorporating it as a vehicle for interaction or thinking development, will not yield any critical thinking skills.

Ben also reported that he would consider helpful, professional development on critical thinking as opposed to time-wasting ones. This perception was potentially a hangover from previous professional development, where he had not found the training unprofitable.

Ben reported that his teaching could be better, and that that he had an excellent disposition to seek help, but that he did not want to waste time on developing critical thinking instructional strategies. He also shared the opinion that critical thinking is a possible approach in the teaching of chemistry. In Ben's view, there is room for improvement in involving teaching development activities that can result in increased student engagement and learning in the class.

6.6 Case Study 4: Gavin

"Do we do much to develop critical thinking in our students? probably not". (Gavin)

Gavin is a chemistry lecturer with 22 years of teaching experience, a 52-year-old male with a B.Sc. (Hons) and a Ph.D. qualification. He teaches CEM1880.

6.6.1 Defining and Understanding Critical Thinking

At the interview, Gavin described critical thinking as being able to put emotions to one side and look at the facts. He related his definition to how a group of chemists reacted with their feelings when he was Chair of the Polymer Division in IUPAC. No one turned up for the IUPAC conference that year when terrorists bombed Istanbul Airport:

> That worries me a lot that you know, scientists who are meant to be the people who are best equipped to using critical thinking, just in this situation, were incapable of it. (Gavin)

In the survey, Gavin defined critical thinking as: "being able to use the information to evaluate whether something is true, false or a mixture of both". In his opinion, he identified critical thinking skills as: "selecting the right information. Adapting the information for the purpose at hand. Applying the information. Doing so with logical principles. Making a conclusion".

Data from his survey showed that Gavin believed the importance of critical thinking to the teaching and learning of chemistry is "extremely important". Gavin explained it was possible to have an easier critical thinking integration in some topics in chemistry than others. As an example, he explained that "thermodynamics" was an easy topic to integrate critical thinking, but that it was not easy to integrate critical thinking into "aqueous solution":

> Thermodynamics is a very rigid discipline, so in some ways, it's easy because there's no choice. Like the section on aqueous chemistry which XYZ teaches, that's very descriptive. So, I don't know how much critical thinking there is in there. (Gavin, Survey)

Further, into the interview, Gavin expressed how he thought critical thinking was important and he believed that critical thinking is very vital for chemists:

> Critical thinking, I think a lot of the questions in chemistry do get at critical thinking, but equally a lot of them are probably around memory work. However, we all want to develop critical thinking because we all understand that that is probably the most crucial skill to have. (Gavin)

6.6.2 Perception and Importance of Critical Thinking

Gavin believed that lecturers were not developing critical thinking in their students. This finding seemingly demonstrated that the whole essence of university education was defeated (Section 1.0). However, Gavin strongly believed that the choice of teaching approach could help students develop critical thinking skills:

> To be honest, do we do much to develop critical thinking in our students, probably not? I think that if you present your lectures in a way that shows critical, logical thinking, I guess you hope that that rubs off on the students. But you know, honestly, when there’s one person and you may be, in principle we’re teaching four hundred and fifty, it’s just not possible. (Gavin)

He further mentioned how he believed critical thinking should be taught: true critical thinking almost has to be imparted on a one-to-one basis. Gavin indicated that the possibility of students gaining the one-on-one opportunity to develop critical thinking skills was most likely lost in transit during tertiary education. With this being said and connecting to the above quote, CEM1880 lecturers might not be enacting the curriculum to develop students’ critical thinking. He stated:

> This move in universities towards large classes and, it is by very definition a move away from imparting critical thinking, and yet if you read what universities say, they’ll always say, we’re teaching our students how to think critically. And then at the same time there’s nothing, underneath all that is like, we want to have larger classes because it’s cheaper. (Gavin)

Gavin reported he had not received any formal training within the university on critical thinking and the only training he received in twenty years was on general "teaching methods":

> There is nothing in particular on critical thinking. The only thing, when I started out, I did a course on teaching methods. This would be twenty years ago. (Gavin)

However, Gavin argued that he would not have gotten the job as a lecturer if he did not have critical thinking skills:

> But on the other hand, you know, I think you could argue that for most of us, we wouldn't be getting appointed as lecturers unless we had a reasonably well-developed ability to think critically. (Gavin)

6.6.3 Teaching Concepts

Observations indicated that Gavin might not be enacting the curriculum to develop students' critical thinking. This is because Gavin held particular views about teaching. The answer he gave on teaching approach was a comparison of teaching practices decades ago and those of the 21st century. He stated:

> There's a classic sort of question and answer method of teaching. I guess the Socratic Method. But it's not possible to use that anymore, because you know, you have to put up in advance these sets of lecture notes. So quite often I find myself asking the class a question, what do you think the answer to this is, and then I'll realise, it's pointless to ask them because they've got the notes in front of them already. In that sense, lecturing has changed a bit. (Gavin)

This statement indicates he had not considered other types of questioning, though this is inferential. He provided examples with voice and video recordings of lectures and use of PowerPoint and revealed how unhappy he was about these ideas as well as his struggles using technology to teach. Data from Gavin's lecture observation showed no use of PowerPoint, rather a PDF slide was shown on the projector:

> You couldn't even pay me to watch myself on videos. I also find the modern method is a bit constraining when I use PowerPoint, I like to just go through things one at a time. But it's hard to do that if you've got to constantly be changing the slides. (Gavin)

Later, at the interview, Gavin reported that he held two dominant conceptions about teaching: he believed students need to be able to take or have a good set of lecture notes, and that a lecturer should cover the course content. The interview revealed that these conceptions had been his teaching philosophy for over 20 years. Data from the lecture on "Introduction to Thermodynamics" showed that Gavin's approach to teaching was a "chalk and talk, get through the content" approach. In addressing his concept "students need to be able to take or have a good set of lecture notes", according to Gavin, good lecture notes will make up for a poor lecture. He also stated that lectures only have a short memory span in students:

> Even if you give a fantastic lecture it will only stay in your memory for a short period. On the other hand, you can be someone who gives a very boring lecture, but if the student has a good set of notes, then they can look back on that and learn from it. Maybe they even learn more than what they did during the lecture. So that would be you know, a methodology, I guess. And you know, it's probably just based on you know, experiences that I had and even more, so my peers had when I was a student. (Gavin, Interview)

In terms of "cover the course content", Gavin strongly believed that it was more necessary to cover course content than any other thing and that was what he gave priority to during his lectures. During Gavin's lectures, he presented learning objectives at the end of the lecture and referred students to look at them in their notes:

> My other philosophy is to make sure I cover the course content. I don't think that gives a large amount of wriggle room in our lecturing because we have such a detailed description of what should be covered. My sections of notes, I always pointed out at the end or the beginning, what was going

> to be covered. I just try to do things very logically to build up brick by brick. (Gavin)

Gavin mentioned that he did not think much about his conceptions of teaching. He thought that an excellent chemistry textbook was good enough for learning and anything outside the lecture method and getting through core knowledge was a waste of time:

> I don't think too deeply about teaching philosophies. It's not my job, and it doesn't mean that I don't care about them, I just think by and large there are well-developed methods for teaching chemistry. I mean you've only got to pick up a textbook, there's a whole row of first-year textbooks, I think that there is a well-trodden path regarding how to teach first-year Chemistry. (Gavin)

6.6.4 Classroom Interaction and Teaching Activities

Although Gavin emphasised his years of teaching experience, during lecture observations from the back of the class he did not seem to be successful in engaging students. Most of the students were observed to be using their phones, while others were working on laptop computers, engaging with Facebook; chatting and watching football. Gavin did not seem to be aware of things he could do, nor of his responsibility in enabling the commitment of his students.

Gavin believed that critical thinking was important to be a chemist:

> …critical thinking, I think a lot of the questions in chemistry do get at critical thinking, but equally a lot of them are probably around memory work. But we all want to develop critical thinking because we all understand that that's perhaps the most crucial skill to have. (Gavin)

At the interview, Gavin expressed how difficult it was to have much interaction in his lectures due to the restraints of the lecture recording system the university has adopted, as well as the use of PowerPoint. Gavin reported that more could be done and that he believed technology and large classes were partly to blame for lack of classroom interaction:

> There's a glass wall between the podium, the lecturer, and the rest of the lecture theatre. So, it's quite difficult with the glass ceiling. It's hard to do question and answer unless you leave blanks in your notes. But that sort of seems a bit cruel to do that, so I guess you just try and interact by asking questions and then explaining the answers even in they're there. Classes are also very large. (Gavin, Interview)

According to Gavin, the core content had stayed the same for some time without updates until a recent student failure on his part of the course:

> For CEM1880 they're all the same. Although we do look at updating them. But the updating is usually around things that you teach, but then you realise they're not covered, so like this came up for me with an exam question in Thermodynamics last semester. I taught this and put it on as multiple questions on the exam. And only four per cent of students got it right. And then I and the course coordinator had a look, and we realised, well although we both teach this, whenever we do that section of the course it wasn't written in the Learning Objectives. So, we updated the Learning Objectives to include that. (Gavin)

Further discussion in the interview revealed that updates were done when textbooks were changed, and this was not very often:

> In terms of large-scale changes, probably only really when we change textbooks. In twenty-two years here, we've changed once. We had a textbook by an American guy called Raymond Chang about six or seven years ago. We changed to the current one, which is called Chemistry Cubed. (Gavin)

Gavin also reported that his teaching approach had not changed over the years:

> Originally it was written on a whiteboard, then it became overhead transparencies, and then it became overhead transparencies with handouts and then it just sorts of became lecture notes made available online. So, you know the content hasn't changed that much, but I suppose you can see that transition in delivery. (Gavin)

Connecting to the quote above, Gavin did not seem aware of teaching strategies he could enact to foster students' critical thinking, which suggest he might not be enacting the curriculum to develop students' critical thinking.

Gavin stated that owing to limited lecture time, there were still elements of rote learning and lecture in his teaching as there were basic facts, reactions and principles that students have to learn. He further stated that students had to memorise or learn some things to be able to advance to the next step in their understanding of some topics, even though he does not see the need. At the same time, Gavin criticises making students memorise:

> About five or ten years ago I had a debate with most of my colleagues said that they felt it was important that students still had to memorise the periodic table. I don't why do you need to know the Periodic Table now? There's no justification. What you need to know is to understand the Periodic Table, and that's where our emphasis should be. (Gavin)

6.6.5 Assessment

During Gavin's interview, he expressed surprise that assessment items in the course did not align with the course learning objectives. He agreed that there should be a strong correspondence between the two because of the impact it might have on students. However, Gavin also thought it might not be a problem if the learning objective did not match the examination items depending on what sort of discrepancy occurred:

> Are they very different? I think there should be a very strong correspondence between learning objectives and exam. Especially in this course, so I look at first-year chemistry as being, you know a bit of a transition between school and university. (Gavin)

However, in further discussion with Gavin, he reported that to be a chemist, critical thinking is essential for assessment:

> A lot of the questions in chemistry do get at critical thinking, but equally a lot of them are probably around memory work. But we all want to develop critical thinking because we all understand that that's perhaps the most crucial skill to have. (Gavin)

6.6.6 Case Summary

Gavin was observed to give a lecture with a lot of chemistry content on poor slides and no interactions with the students. No questions were asked in the lecture.

Gavin's teaching practice was lecture transmission mode. Transmissive pedagogy, as discussed in Section 2.6.1, is when the material is taught systematically and additively Pratt (2002) by delivering factual and evidential information "for consumption". Transmissive-based techniques are usually "teacher"-centred. Gavin believed that all students needed was a good set of lecture notes. He was driven by the need to cover the course content. Gavin was not the only lecturer who believed that covering the course content was the most important aspect of his role as a lecturer: many had this view. Although topics for Gavin's lectures were mentioned at the beginning of each one, no specific learning objectives were stated.

Even though Gavin emphasised his many years of teaching experience, during lecture observations, he was not successful in engaging students, most of whom were on their phones, typing on laptops, checking Facebook, chatting or watching football. Perhaps not surprisingly, Gavin was not observed using critical thinking teaching strategies in his lectures.

Gavin did not recognise nor acknowledge that there are things he could do (teaching activities), nor did he take responsibility for enabling the commitment of his students. When asked about assessment, Gavin had no idea that there should be an alignment between the course learning objectives and the examination questions nor that there was a mismatch at the time.

Gavin's teaching concept indicated a lack of awareness of the potential of critical thinking when applied to chemistry and how he could enhance critical thinking through planning specific teaching activities.

Gavin clearly stated that he was more content-driven in his approach to teaching than focused on critical thinking. He might not be aware of critical thinking focused activities to offer his students related to his teaching practice. Gavin seemed not to see that there were measures he could take towards classroom interaction and that he was responsible for enabling the commitment of his students.

6.7 Case Study 5: Stella

"It would be helpful if critical thinking were occasionally explicit in teaching" (Stella)

Stella is a chemistry lecturer in CEM1881. She is 40-years-old, with 20 years teaching experience and a B.Sc. (Hons), PhD and Postgraduate certificate teaching qualifications. Stella teaches CEM1881 with an enrolment of 320 students on the course. Stella was the course coordinator for CEM1881 at the time of data collection. Her passion for CEM1881 and teaching was evident during the interview. She was driven by having a well laid-out content structure in a simplified form that she believed was suitable for meeting the needs of the diverse types of students taking CEM1881.

6.7.1 Defining and Understanding of Critical Thinking

At the interview, Stella described critical thinking as:

> …critical thinking, it's all about questioning the evidence that's put in front of you. So, rather than just sitting through a seminar or something and just blindly accepting what you're being told, asking yourself well okay, does that make sense? And this is a mantra that we actually have in Chemistry, full stop. Whenever we're doing our demonstrator training, whenever we're in labs, whenever we're doing anything, we always tell the students and the staff as well just to stop, and ask yourself, and does this make sense.

In the survey data, Stella described critical thinking as "critical thinking is taking the information learned in one setting and applying that knowledge to solve problems in another setting. For example, learning about moles in a chemistry context, and then answering a question about moles presented in a different format to that learned previously". Stella's opinion of critical thinking skills was "observation, analysis, evaluation, problem-solving, interpreting, discussion, and inferring".

Stella also believed that the importance of critical thinking to the teaching and learning of chemistry and tertiary education is "extremely important". According to Stella, critical thinking is considered important because:

> With what we do, because everything that we get, we get data and we have to interpret it. And that's pretty much the majority of what we're doing in this department is, we're making observations and then we're knitting things together, and we're thinking about well what does this mean? To do that, we have to have the toolbox behind us, and think out of the box, could it be that or could it be this? And just bringing everything together and saying, well, we've got this, but we can't make any definitive statements yet because we need more evidence, what can we get? It's hugely important. (Stella)

At the interview, when Stella was asked if she has had formal training in critical thinking, it became clear that she understood critical thinking to be a skill you picked up "on the go" through learning at the university implicitly:

> Only what I've read as inferred as part of my undergraduate and post-graduate training. You could say it would be informal training because that's for me, part of what a chemistry degree gives you are these skills. But it was never necessarily labelled directly as today you're learning critical thinking, it's just what you've picked up as you go through. So, it's indirect. (Stella)

Further, in the interview, Stella mentioned, it could be helpful sometimes if critical thinking were explicit:

> I think it would be helpful if it were occasionally labelled. I'm always a bit wary of putting labels on things, but, yeah if you could just reinforce to the students that we would want you to think critically about this and just use that type of language, rather than saying, today kids we're going to be doing critical thinking, you know, sit down, read this, think critically about it. That's not a constructive way of doing things but, just to keep reinforcing for them, so perhaps not directly, but perhaps more strongly indirectly would be a good way of going about it, I think. (Stella)

6.7.2 Perception and Importance of Critical Thinking

For Stella, it was evident that students' ability to think critically and to be impacted by the education they had received from CEM1881 was dependent on how much skill and learning students were prepared to receive. In other words, she believed students had a part to play in working hard to develop their critical thinking skills.

Stella believed in the importance of helping students to understand and interpret the content knowledge taught. This she considered enabling the student to respond appropriately to their individual and different learning needs. Conclusively, she stated that if this were accomplished, it would expand the student's overall involvement in the class and with the entire course.

6.7.3 Teaching Concepts

Stella believed in five concepts of teaching: the act of restructuring by a teacher, concept and use of the toolbox, laying a solid foundation, scaffolding learning and helping students better see the relevance of chemistry. She further explained that *laying the solid foundation,* for example, is a drive that has resulted in an explicit course content that was simplified by checking on students' content knowledge from previous classes and covering the content she believed they needed.

According to Stella, she restructured her teaching process to suit the set of students she was teaching:

> It's about structuring it for the particular year level that I'm teaching at, so one hundred levels is very much about firstly inspiring the students to want to continue on the subject. (Stella)

Regarding the toolbox, Stella believed that it is important for the students to be well equipped for them to achieve learning success with her:

> It's all about giving them the information, giving them the tools, talk about the toolbox. Getting them to draw on their own previous experience in relating that to a Chemistry environment. Getting them to think about what

> they're hearing, what they're learning and relating everything together. (Stella)

As regards scaffolding learning, in addition to giving the students the toolbox that they need, according to Stella it was intertwined with scaffolding the learning for the students:

> At 100 level I don't think you can do too much more than that. You're limited in what you can do. And then as you build up, realistically you're starting the course by saying, well you already know all this, we're just going to go into it in more detail. We're going to tell you more, and so building up, and so scaffolding the learning as you're going from 100 to 400. (Stella)

In addition to laying a solid foundation in chemistry, to "help students better see the relevance of chemistry", Stella believed that the most effective way to get the students hooked on chemistry. The way to do this was to provide them with a simplified concept to equip them for learning, which would make significant differences and contributions to their academic outcomes:

> We want them to carry on in Chemistry and show them that it's interesting and exciting. I think it's worth remembering that for CEM1881 we assume that students don't have any prior formal chemistry background. A lot of them do, but quite a few of them don't. (Stella)

6.7.4 Classroom Interaction and Teaching Activities

The concept Stella had about her teaching influenced her classroom interaction and what she did. Further analysis of her lecture observations data showed that Stella used questioning as a way of interacting with the students during lectures, but rarely waited for an answer. In two of Stella's lectures, she gave students about five minutes class discussion with the next person. She mentioned the idea of clickers as a good strategy during the interview, but the opportunity for their use was not observed. Stella did not seem to be enacting the curriculum to develop students' critical thinking because she used limited teaching strategies and classroom interaction:

> I interact with my students in lots of different ways. Whether they agree or not I don't know, but so it's all about being approachable. Because as a starting point, if you go in and frown at them, then you're going to be much less approachable. Use of examples, use of humour, asking them questions and just getting them to discuss it. Now there are various ways that you can measure that understanding. You can just get a general river around the room, or you could use the clickers or the cards. It's difficult with a very large class. (Stella)

The observations of her lectures about "symphony of science" showed that she often narrated information about famous chemists to the students, aiming to stimulate their interest by revealing they can become great chemists as well. In one of the lectures on "structure of the atom", Stella told the class to "examine each other's opinion by turning to the next person for about five minutes in a discussion". Summary information on these lectures was often included in the PowerPoint notes, while the entire lectures were available in video and audio recording for students.

None of the lectures observed demonstrated Stella's classroom interaction conception about teaching: that engaging students as much as possible helps students understand the chemical concept being taught. She indicated during the interview that a lack of time, large classes and the demands to cover the course content rendered this conception practically impossible to implement.

There was not much variation in Stella's teaching methods, even though one of the course overviews stated, "course aim is not to memorise information, the aim is to build understanding and apply it to real situations". Her lectures were mainly portrayed by delivery of information, according to her "It is difficult with a very large class" though she reported making eye contact with the students.

Stella would sometimes develop a detailed working understanding of the atomic structure, periodicity, chemical bonding, material properties, physical models and the properties of the gas in her topics by use of pictures, examples from nature and past chemists. In some of the lectures, she stated and explained the learning objective with the use of technology by playing an appropriate video and using PowerPoint and pictures. Stella sometimes created a climate for thinking by asking questions occasionally during the lectures.

In one of the classes observed, Stella helped her students deal with conflicting sources by allowing them an opportunity to clarify any issues. An example was when a student asked her that she read something different from what she told them last lecture about "dipole solvent". The student understood from the lecture that the boiling point of water is about 200°C higher than hydrogen sulphide and another source explained this apparent anomaly, saying strong intermolecular forces exist for H_2S and that it is not as polar as water.

6.7.5 Assessment

Stella was asked about the assessment and how she has used assessment as a tool to develop critical thinking in her students. When asked if the assessment was in alignment with the course learning objectives, Stella indicated that she thought the assessment verb matched the learning objectives. However, she mentioned that it might not be relevant to the students and explained why, but conclusively agreed there should be a match:

> Truthfully, I think you could probably count the number of students who read the course handout on the one hand. But you are right; they probably should match up a bit better. And so that is something that actually we can go back and look at for next year it would be a useful thing to do. In terms of the assessment that we put through this year, so there are two components to the assessment, there's the formal exam and test situation.
>
> The multi-choice which is new, that was introduced this year. And then there are the longer style answers as well, but maybe in the longer style answers, it might match a little better, whereas in the multi-choice it might not match as well. When we were setting the examination items, we didn't have the learning outcomes sitting in front of us, and so the language match-up wouldn't be as good. But that's a really good point, and that's something that we could work on, going forward. (Stella)

This statement indicates that lecturers did not use the learning outcomes when designing assessment items. According to Stella's quote, CEM1881 lecturers did not appear to have planned the curriculum to develop students' critical thinking. It may have been more related to keeping with what had been done previously and making assessments easy to mark.

6.7.6 Case Summary

Stella expressed her passion for making CEM1881 better each year for quality learning, and she is also making noticeable efforts towards gaining students interest in chemistry. It is striking to note that although critical thinking was not explicitly taught during Stella's lectures, nevertheless, there were critical thinking indicators in her teaching strategies.

Stella was an engaging lecturer who had simplified the content knowledge using what her students can relate to from their environment. Concerning Stella's LOG (Appendix 9), she developed a very great descriptive working understanding of the atomic structure, periodicity, chemical bonding, material properties, physical models and the properties of the gas in her topic area.

Stella consistently explained learning objectives and planned activity to demonstrate the learning objective with the use of technology by playing an appropriate video. She persistently created a climate of thinking, making her students examine others' thinking in the discussion. Stella sometimes used props and helped her students deal with conflicting sources.

Stella's overall level of engagement was above average. Stella embraced her role as a teacher and was to be able to integrate critical thinking into her lectures and to engage her students in critical thinking teaching activities. She also supports the notion that all content in chemistry is amenable to critical thinking.

Stella was observed using peer discussions as a result of the application of her teaching concept of "laying a solid foundation", "restructuring", "scaffolding learning" and "helping students better see the relevance of chemistry". In the lecture on "structure of the atom", Stella told the class to examine each other's opinion with a 5-minute discussion.

Even so, explicit instruction, problem-based learning and the number of questions asked would have helped to achieve and strengthen her teaching practices. For example, observation of Stella's "symphony of science" lecture showed how she narrated information about famous chemists to the students, aiming to stimulate their interest by revealing the possibility of them becoming great chemists as well.

There was not much variation in Stella's teaching strategies, even though one of the course overviews stated that the "course aim is not to memorise information, the aim is to build understanding and apply it to real situations". Her lectures did not explicitly align with the course aim. It is striking to note that although critical thinking was not explicitly taught during Stella's lectures, there were critical thinking indicators in her teaching strategies, based on earlier research findings discussed in Chapter 2.

Critical thinking indicators are regarded as teaching practices which could be in the form of different activities or strategies observed in the lecture, which are the characteristics and behaviour of active learning approaches to teaching. Indicators could be class discussion, purposeful questioning or problem-based learning.

It was clear that Stella recognised how instrumental that lecturer interaction with students during lectures could be in fostering active learning. Stella evidenced her dedication to teaching and her students' learning when she gave an account of the multiple occurrences of her professional training and development experiences within the university and for her department.

Stella embraced her role as a lecturer as being able to integrate critical thinking into her lectures and engage her students in critical thinking, probably because she valued critical thinking as a disposition and acknowledged the immense importance of critical thinking to the teaching and learning of chemistry as discussed in the literature.

In reviewing the assessment, Stella realised that some of her students struggled and some were high achievers, which gave her indications about their need for support. Given that she was also the course coordinator, her reflections on the range of students' needs, enabled her to support the resources for the whole course. She maintained that appropriate tools had been provided to ensure ongoing engagement of the students throughout the course via different means such as a multiple-choice assessment, online learning, tutorials and laboratory activities. She was of the opinion that with planning, practice and the desire to learn, students could do well with high academic achievement.

Stella had not received any formal training in critical thinking nor how to integrate critical thinking into her teaching either from the university or anywhere else.

6.8 Case Study 6: Isaac

"The Tertiary Education Commission Act says the teaching at tertiary level must be underpinned by research based on the element of critical thinking". (Isaac)

Isaac is a lecturer liked by many students for his dramatic approach in the classroom. Isaac is 67 years old, teaches CEM1881 and he has over 35 years teaching experience with a B.Sc. and Ph.D. in chemistry. Isaac won the "2016 staff of the year award" and the "lecturer of the year" for the college of science in the university.

6.8.1 Defining and Understanding Critical Thinking

In the survey, Isaac defined critical thinking as considering data and deciding whether it is correct, meaningful and/or relevant. According to Isaac, it was easier to integrate critical thinking in some aspects of chemistry than others, and he strongly believed that the topics he taught were very relatable and simplified. However, given that critical thinking has been established as course-specific in the literature, there are approaches for chemistry lecturers to adopt which support students' understanding and promote their critical thinking development in every chemistry topic. Perhaps chemistry lecturers could benefit from the critical thinking indicators earlier highlighted in this present study (Section 2.9).

Isaac described his experience with the student as "lovely" because they understood the content and could tap into their environment for relevance:

> I'm quite lucky actually in CEM1880 because my subject is water, acids and bases. And that's so environmentally based. That I can turn that round to

> the environment, and I like gin and tonic, and at the beginning, we talked about carbon dioxide dissolving in water, and you can see their faces glazing over, and I say but why is this so important. And then I showed a picture of a gin and tonic you see, and then we, throughout, we talk about then when you add acid to carbon dioxide in water it fizzes. Why does it fizz? And then I have a picture of my gin and tonic, putting a squeeze of lemon in it, putting the acid and it fizzes, and I've got little videos I showed. (Isaac)

It was apparent at the interview that Isaac was a strong believer in how important critical thinking was to teaching, learning and research in tertiary education:

> I come to work every day because I love teaching. And I love my research. My research is critical thinking. The Tertiary Education Commission in the Act says the teaching at tertiary level must be underpinned by research. And the reason it must is that there is the element of critical thinking that's got to go into tertiary kids. (Isaac)

Isaac mentioned that he had given much thought to what critical thinking is, and he described critical thinking as an interpretation at a higher level of being critical, being able to foster students to see science in the context of a global or more significant situation. According to him, he made his students find understanding using different scenarios during his teaching.

An example was when he taught pH, he took the students through understanding the nature of pH, the importance of pH to chemistry, what it means, the definition, how it is measured. He then put up a coral on the screen for the students to relate their understanding of pH. He had this to say:

> Then I put a newspaper heading on the screen of coral disappearing from oceans. And I said to them, why do you think this is? And they all look at me and I say, you don't think this is of any relevance to what you've done. And I say, what's coral made out of? And they all looked, and this is you know a big class, it's not a tutorial, it's a big class, then I put up the chemical formula for coral which is calcium carbonate, and one or two of

them began to see, I see where he's going. And then I put $CaCO_3 + HCl =$ and it's solved. (Isaac, Interview)

6.8.2 Perception and Importance of Critical Thinking

Isaac believed that scientist have to be critical. Isaac reported that science students tended to take the facts on board, and to take the thinking on board, they have to accept it. He perceived that if students are not able to ask question after being taught, ''they are less able chemists''. Isaac encouraged his students to question what he taught them for them to develop critical thinking. He stated:

> I said I made the whole lot up, it was complete crap. You know, you've got to think more, you've got to think about what things mean. You've got to be critical. I might get it wrong. (Isaac)

Isaac further stated with excitement the importance of critical thinking to tertiary chemistry teaching and learning. He reported:

> Oh, good God yes! I come to work every day, because I love teaching. And I love my research. My research is critical thinking. The Tertiary Education Commission in the Act it actually says the teaching at tertiary level must be underpinned by research. And the reason it must is because that is the element of critical thinking that's got to go into tertiary kids. So yes, yes, yes. (Isaac)

Isaac reported that he had refused to be taught or participate in some teaching training or professional development. However, according to him, he said he was more open to what made sense and what he believed:

> I want to be taught to teach by teachers who've got a lot of experience, and I respect them. Not by someone that's never taught in a university but knows the theory. (Isaac)

Further, into the interview, Isaac mentioned he would be open to critical thinking training because he felt that involved different teaching techniques, and he would want to know more about the concept. As a further example, he mentioned a 400-level course that he jointly taught with another psychology professor at the same time and how much freedom he had to teach and freedom for the students as well. He compared how different this is to what those who teach from theory do and make rules of what you cannot and should do:

> Totally different, and I'd like that. I'd certainly go to that. And I'd want to be part of it, and I'd yell out and scream and shout and if that's something, quite interesting you say that. (Isaac)

6.8.3 Teaching Concepts

Isaac revealed during the interview that he did not believe in the term "pedagogy", and he would rather say "technique". Isaac stated he would describe his teaching strategies as techniques rather than pedagogy. He explained that he does not like the word "pedagogy" because it suggests that teaching is a theoretical thing, and he did not see teaching that way. Isaac described that his teaching techniques changed with different levels of students and varying class size.

In further discussion with Isaac, he reported that he has one main teaching concept was to get students to understand rather than memorise facts: "getting kids to understand; I'm not interested in facts". The interview revealed that this concept had been formed over the years of his teaching, and he seemed passionate about the concept. He used it to work his way through teaching with students. Isaac strongly encouraged students to participate in his lectures.

6.8.4 Classroom Interaction and Teaching Activities

Isaac used a more dramatic approach to create a funny classroom interaction with the students. Isaac jumped across all the benches, ran to the back of the lecture theatre, sat with students and asked them questions.

For example, when he taught the Henderson-Hasselbalch equation, he ran to the back of the class and asked the students at the back how to derive the equation. He got these students to participate and say something. Isaac believed if he did not do that, some of those students would never have said anything nor learnt anything. He believed he disarmed the barrier that some of these students might have that they are not good enough and better not say anything not to embarrass themselves in class.

Isaac explained that his priority was to make students understand that it is okay not to understand and then learn and get it right. Isaac indicated that when he ran around the class, students watched and laughed, and he believed that made the difference for them to ease any form of the tension of not understanding what he was teaching them. Isaac spent a considerable amount of time cracking jokes and over time he said students looked forward to the fun part.

Isaac’s interview revealed that his classroom interaction was formed during his early teaching career when he went to observe a senior lecturer teach:

> When I started as an academic in 1981 Professor Sturt Robin (pseudo name) who’s one of the world’s top toxicologists and he said we don’t teach University teachers to teach, and that’s really bad news. Come to some of my lectures and just see what I do. Pick out the good stuff, discard the crap. And I went to his first lecture, and he’s sitting there, and he was sitting on the front bench with his legs dangling and he said, do you know, I’m going to talk to you lot about toxicology, they were medical students. But you know, I don’t think I understand it. And I could see the students just relieved. (Isaac)

Isaac believed that learning together with his students was a great teaching strategy that he believed has worked with the students over time. During his lecture on Henderson-Hasselbalch equation, he derived the equation with the students on the board and he purposefully got it wrong and was able to get the students yell “that’s not right”. He further mentioned that he got the equation wrong because he doesn’t understand it, not because I made the mistake on purpose. By the end of the session, he was able to take the students to a level of understanding for a boring equation to teach. Isaac believed talking to his students in a certain way could help them learn more effectively.

As a further example, he explained that how you approach the students with your words can either put them off or they can find it endearing:

> Whereas if I say, “hey you up there, derive the Henderson-Hasselbalch equation”, it would destroy them. But if you run across the benches and sit down and say, have you got a clue about this because I’m not sure I understand the last bit, you know, let’s see if we can do this? (Isaac)

According to Isaac, he also uses eye contact as a strategy with his students, and he believed it had worked well. He asserted that he constantly targeted students with eye contact and he maintained it throughout the lecture because he had seen that when he did that, it was easier for those students to ask questions.

6.8.5 Assessment

Isaac indicated that his students did well in the assessments for the topics he taught, and he referred to how he felt pleasantly surprised. Isaac further explained his dissatisfaction on how learning objectives were being perceived within the university and the department. An example according to Isaac was each time he had a learning objective that stated, "students should understand water" he criticised that students cannot understand the whole concept of water. He described what he meant as trying to teach them an understanding of water. He commented:

> If a learning objective was to understand water, then we could ask them any question about water. But of course, in CEM1880 we've taught them a specific aspect of water. So that's why I think, I don't necessarily agree with it, because we need to just use the English language a bit better and accept that we're not trying to say, they've got to understand everything, but we are just saying, we are teaching about water, you need to understand it. Then we can ask you questions about understanding water in the context of what we taught you. (Isaac)

Isaac was convinced that the learning objective and examination items should align to have a meaningful learning outcome for the student. Based on this conviction, he expressed how he felt examination questions should reflect and try to capture the understanding of students. Isaac's understanding of the important link between learning objectives and examination items might be an indication of his practices in assessing the curriculum to develop students' critical thinking. He stated:

> I think the learning objective and examination verbs should match, and that's why I get so mad, because it's again, it's about the specificity. You know, I love writing exam questions, what do you understand? Why in your

> understanding, why is water so important? You know, I'd love to write a question like that. (Isaac)

Additionally, Isaac, in his own way, was enacting the curriculum to develop students' critical thinking with his teaching strategy. Isaac believed that learning together with his students was a great teaching strategy. He believed it has worked with the students over time.

6.8.6 Case Summary

As enthusiastic as Isaac was during the interview about the importance of critical thinking and with his reported statement that his research is critical thinking (Section 6.8.2) not many varied critical thinking indicators were observed in his teaching practice. Isaac was only observed using dramatising in his lectures.

Isaac's teaching idea was to "get kids to understand; I'm not interested in facts".

Isaac dramatised concepts in his class, which might have encouraged the students to listen and sustain their attention for as long as he did it. This teaching approach might not translate or lead to students' understanding or learning and whether it developed critical thinking was debatable.

During the interview, Isaac stated that he believed it led to student engagement, and this was this why he took this strategy. He was of the opinion that this approach was linked to developing critical thinking and understanding because as he did this, he was equally asking questions that promoted students' critical thinking, working out equations together, deliberately making mistakes, so that the students could correct him, giving them prompts and expanding their imaginations. With this action, Isaac believed there was a conceptual link between developing understanding and critical thinking.

According to literature, Jones and Dale state that dramatisation is a "type of strategy that relies upon dialogue and it differs from role-playing which requires a longer period and a holistic, well-developed plot" (1994, p. 12). Similarly, dramatising is not the same as role-playing as seen by some scholars (Haruyama, 2010; F. N. L. Thomas, Seifert, Pascarella, Mayhew, & Blaich, 2014). However, Paul, Binker and Weil believe that "solid critical thinking always requires fundamental insights, and intuitions to guide it" (1990, p. 44). If this is accurate, then teachers committed to fostering critical thinking in their students must interest themselves in the dramatic, the concrete, and the highly visual and imaginative, such that foster critical thinking.

If dramatising by Isaac was not holistic and purposefully tailored to enhance critical thinking, his strategy may not have progressed beyond fun for the students. This thesis argues that only dramatising, which is used to evoke questioning or evaluation, is effective.

Isaac did think that dramatisation led to critical thinking, demonstrating a strong indication that his beliefs drove his teaching approach. Whether this led to understanding, as the literature argues, is a different question. Isaac believed that his approach led to better student understanding and was supported by the fact that his students thought he was a good teacher, and he also had won several teaching awards. There was no doubt (as stated in Section 7.3.4) that Isaac is a good teacher who was adored by his students, but the question remained whether his teaching strategies supported critical thinking skills in his students.

Isaac strongly encouraged students to participate in his lectures. Data from three lecture observations showed that Isaac's classroom interaction was different from the other lecturers in this study. He used dramatic gesture to intrigue and capture the students' imagination. Isaac was a firm believer that little things that a lecturer does can make a whole difference with the content itself.

Data from lecture observations with Isaac showed that there was a relationship between what he believed and his teaching strategies. He took every lecture with the same dramatic style and got the attention of the students and their participation.

6.9 Case Study 7: Patrick

"This isn't even in the learning objectives, but I taught it. You shouldn't be teaching it if it's not in the learning objectives" (Patrick)

Patrick teaches CEM1880; he has over 20 years of teaching experience, a BSc and PhD.

6.9.1 Defining and Understanding Critical Thinking

At the interview, Patrick described critical thinking stated:

> It's looking at what information you've been given and just trying to critically pull it apart. It's all self-consistent and not just being accepting but wanting to be analytical of a statement that may have been made. (Patrick)

In his survey, Patrick stated that critical thinking is "the ability to dissect and analyse data/information to enable one to arrive at a judgement or conclusion based upon the evidence". Additionally, Patrick identified critical thinking skills in his opinion as numeracy, literacy, comprehension. Patrick rated the importance of critical thinking to the teaching and learning of chemistry and tertiary education as "very important".

Observations of Patrick's lectures did not reflect his descriptions of critical thinking. He did not help his students critically to "pull apart the content", as he did not ask questions, or give students enough time to analyse or evaluate the content. The reason he gave for this disparity was that the department seemed more concerned about getting through the content and covering the learning objectives.

6.9.2 Perception and Importance of Critical Thinking

Patrick had a fascinating perception of critical thinking, and he believed scientist could create things from imagination. Patrick encouraged his students to be critical thinkers. He stated:

> Scientists tend to be creative and I use the old Willy Wonker analogy you know, do you know Roald Dahl and his children's books, you know, Charlie and the Chocolate Factory and I say scientists are like Willy Wonker, they're creative, they dream, and they make beautiful things from just their imagination. That's what we do at work. (Patrick)

Patrick believed teaching university first-years might be different to when he taught 2nd, 3rd or 4th year. He reported:

> So, with First Year, you've got a big class, which, I enjoy the big class teaching, it's a bit of a performance. (Patrick)

Patrick believed critical thinking is important to chemistry tertiary education, he reported: ''Yes of course, it's got to be yes, of course yeah''.

Patrick believed that there were aspects of chemistry that critical thinking can easily be integrated into more than others. He gave an example of an introduction to the nature of the atom and the understanding of the atom, where he taught his students the historical context of the discovery of the atom. According to him, it was easier to show his students that understanding the unknown, for example, in the discovery of fundamental particles and sub-atomic particles. Patrick argued that understanding was embedded first, in the way the scientist used the information available. And second, they use their brains in new experiments to understand what the unknown was phenomenon. He related these discoveries to a brand-new world before quantum mechanics.

Another example he gave was an introduction to gas laws, using the concept of ski fields and temperature. He attempted to create an understanding for students to relate to, develop their concepts and be able to use them to solve a real-world problem:

> Take an abstract concept from your lectures, apply it to the real world, and suddenly now you can critically think about it as opposed to, that's just a relationship that I have to remember. (Patrick)

Further, into the interview, Patrick yet again expressed his concern that his students be able to understand rather than memorise, as he indicated again that it might be hard to say if critical thinking can be integrated into all topics that needed to be taught to students to become a good scientist. He stated:

> We are conscious of the fact that we need them to know, have them as critical thinkers, and have them approach doing things, not just memorising but doing, and understanding. (Patrick)

Patrick revealed during interview that training to integrate critical thinking into teaching should be optional for lecturers who need it. He also mentioned those who need it will be the ones who will not show up. Patrick referred to his lack of interest in professional training is as a result of his experience working in the university:

> It should be optional. The problem is with that, is that those people who need help won't realise they do, and there will be those who don't need help will be the ones who are going. What can happen at other institutions is suddenly all the academic staff need to get teaching qualifications. Obviously, I reckon I'm doing better than most. The university should encourage people to renew and refresh and all that, but you know, I don't know if I need to be renewed and refreshed. I'm not putting my hand up to volunteer to go to be taught how to be a teacher. I can see it might be valuable, but you can see I don't want to do it. (Patrick)

Connecting to the above quote, he mentioned that even though he has not received any formal training on integrating critical thinking into teaching, he would not go for such training. Although he indicated that he participated in a National Science Foundation-funded seminar, he believed he was more interested in what the speaker had to say about student participation (those who are part of an interactive community are more likely to be successful) than learning about critical thinking. He said:

> I've not received any formal training. I have read, as I mentioned earlier, I read outside my area in chemical education, I wouldn't say that I'm up to date with the current trends in the best practices. (Patrick)

6.9.3 Teaching Concepts

Patrick revealed that he held two main concepts about teaching. Like Denise, Stella and Isaac, he believed in engaging students rather than not engaging them and that the responsibility of the lecturer was to convey information as an invitation to understand.

During his interview, he revealed that these concepts had been established while he was a student himself. In terms of "engaging rather than not engaging", it was apparent during the interview that Patrick valued experiential knowledge when teaching his students. However, he reported that there were some parts of chemistry that you just have to "knuckle down and know" and know that some "students just memorise stuff". He indicated many times that he would want to convey information by way of invitation to understand because he valued the understanding students gained to apply to real-life when he used real-life examples.

However, according to him, due to the large class size, what he could do was limited. He then mentioned that teaching must be targeted:

> It's all about, what do you need the students to know? First Year, you've got a big class, which, I enjoy the large class teaching, it's a bit of a performance.

6.9.4 Classroom Interaction and Teaching Activities

As part of Patrick's perception that chemistry should be made more relatable, he reported there was a year when he used a reward system to engage and interact with the students. He asked them questions and gave a free seventy-dollar resale value textbook as a reward to a student who got the right answer when the class decided who won by a popular round of applause. Other times, he described how he used a softball, which he called "the ball of destiny". He throws the ball and anyone who catches it has the option to answer or ask a question or nominate someone to pass the ball along to.

Data from lecture observations with Patrick showed that he believed in engaging the students and he understood the positive impact classroom interaction potentially has on students' learning. In one lecture, Patrick mentioned that he went to class with a spoon; he explained the spoon was symbolic and meant "spoon-feeding your education". Patrick was convinced that to help his students understand what they were being taught, a good understanding of what is expected of them must be established. Based on this conviction, he went further and explained to the class that he will not be spoon-feeding them but inviting them to engage in learning:

> Where you went to school and you memorised, and you didn't learn. I'd throw the spoon across the room, and it would hit the wall, and I'd say, we're no longer using the spoon, now it's about you engaging and your learning. And that often makes a difference, and I saw that in the comments from the students saying, I loved the spoon as a sort of symbolic throwing and cutting off the spoon type approach to learning. (Patrick)

Patrick teaches his first-year class different from other year level, because he believes there is more for the higher-level students to grasp. Patrick stated some students memorise, but he tries to engage the student, not overload them with information and teach at a pace comfortable with the students. He reported:

> With the First Year I have taught, so the 111 is mainly Physical Chemistry or the introductory stuff about Chemistry which is a little bit different, my passion in research then informs the teaching I do related to my research, so at the higher levels you do that, and I would embellish my lectures at the second, third and fourth year with research straight from the laboratory. You know that there are going to be some students who just memorise the stuff. (Patrick)

It was apparent at the interview that Patrick valued engaging his students and was passionate about extending an invitation to them to participate. However, the ideas Patrick had were one-off forms of interaction that occurred at the beginning of the course. He asked random questions from his lectures but hardly waited for an answer from the students:

> That type of things quite engaging to invite the audience to engage in that way and after the first lecture often a lot of students will come down and ask questions privately around the front desk, and I encourage, and if I hear a good question, then I'll ask that question out loud. (Patrick)

Data from three lecture observations with Patrick showed that there was no relationship between what he believed and his teaching practice. He also reported that the content varied slightly from year to year, but essentially did not change. Similar to Denise, Ben, Stella, Gavin, and Isaac, Patrick was focused on content delivery due to restrictions to get through learning objectives.

> I would say the delivery is probably pretty similar, and the content doesn't change. It changes slightly from year to year, when we see that students need to understand this a little bit better. And we're kind of restricted in some ways to those if we don't get through all the learning objectives. Those that teach into the CEM1880 we all had a meeting with the coordinator, we looked, and we went through point by point. Are these still relevant? Are these still here? Should we put more in and all that? Unless you do a total overhaul and revision, maybe you change the textbook that we're using and that would require a revision of what we do. It gives you an opportunity to look at what the learning objectives. (Patrick)

Patrick used to fill in the gap in his notes on the smartboard to get the students focused. He seemed to have most of his interaction with students as a one-off, rather than a consistent engagement. In finding if Patrick is enacting the curriculum to develop students' critical thinking, Patrick asked students questions as an indicator of critical thinking in his lectures. His lectures were easy to listen to and follow if the students already had some level of critical thinking skills.

According to Patrick, his students had better grades because he believed what he taught them they already knew from secondary school as an introductory part to chemistry. He thought this was because he was a good teacher, related to how he asked questions in the examination:

> Because mine's the introductory stuff and a lot of them have done it before, they tend to perform well, above the average. I'm a fantastic teacher, or they like the way I teach, or I ask questions in a slightly different way in the exam. I mark differently to; I'm not black and white, that's wrong. I can see where you're going it's not right, but your thought processes are getting there. (Patrick)

6.9.5 Assessment

Patrick valued the idea of consistent use of language regarding learning objectives and examination items verbs matching. However, as Patrick reported, he was corrected by the course coordinator for teaching outside the learning objectives as outlined in the CEM1880 document (course outline). Like Stella, he made an effort to cover the learning objectives (after an incident with the topic coordinator) through the multiple-choice style in the assessment process rather than an essay or elaborate types of questions. He recalled the conversation with the course coordinator:

> This isn't even in the learning objectives (co-ordinator).
>
> Oh, but I taught it (Patrick).
>
> Well, you shouldn't be teaching it, if it's not in the learning objectives (coordinator).

He followed on by saying:

> We are writing new multiple-choice questions, and so you can test right across. If I've given six lectures, and sometimes I need to come with fifteen marks and make it concentrated on a certain aspect of the course, but you don't get (to assess) every learning objective. When you ask multiple-choice questions that are worth one mark, you can survey the whole course. And you're hitting all your learning objectives. I look at the learning objectives to make sure that the questions I'm asking are relevant to what I did teach. (Patrick)

6.9.6 Case Summary

Although Patrick stated during the interview that he encouraged his students to be critical thinkers (Section 6.9.2), in his lecture observation, he did not model to his students how they can develop their critical thinking (i.e. no explicit teaching).

Patrick's teaching concept was "engaging rather than not engaging" and "conveying information with an invitation to understand". For example, he asked a few questions in his lectures, and when he did, they were intermittent, and sometimes he proceeded without waiting for an answer.

It was observed that students approached him after class to ask individual questions. He attempted to answer, but for reasons like others requiring the immediate use of the lecture theatre, that he had another class straight afterwards the lecture, or that students themselves were running for their next class, this approach was not very useful. Overall, Patrick's teaching lacked variety.

Patrick was a firm believer in the importance of critical thinking to tertiary chemistry education. Patrick was sceptical about the value in participating in a critical thinking instructional session and was not sure how critical thinking could be explicit in the teaching of a chemical concept. Patrick reported that his teaching style and engagement was through question and answer, for example, last year, he had some extra textbooks, and he offered the students for free for whoever asks or answers a question, will win a textbook. Patrick also engaged in the use of communication via the posting on eLearn (university website) electronically and email, communication in the classroom, trying to involve them as a class. Patrick's teaching strategies or activities have not changed, he reported that the content and the delivery does not change and if it does, it is only slightly.

6.10 Case Study 8: Joan

"Personally, I don't just lecture. I don't like it; I won't use PowerPoint for the first year, I think it's a presentation medium, not a teaching medium". (Joan)

Joan, with her BSc and MSc, has taught for over 35 years. Joan teaches CEM1881, she was the course coordinator for some years when the course was developed, and she was part of the team that developed the course.

6.10.1 Defining and Understanding Critical Thinking

When asked about how critical thinking is, she commented on other aspects of the interview at length (outside the scope of the interview) and eventually described critical thinking as:

> Looking at some information and using your knowledge or doing some research to see whether it's actually true or not. And not just taking it at face value. (Joan)

Joan agreed with the importance of critical thinking for learning chemistry at tertiary level. She added that when students are respected, it goes a long way to influence how they feel about the course and their disposition to learning:

> Absolutely critical thinking will help student learning in chemistry, but it's very hard to get the students to think critically about the material. Our philosophy as a department is that these students must be treated with respect. Lecturers must get to know their names if you can, must learn to pronounce their names, and if you can't pronounce them, then you go back and ask again and again because students must feel that they are being respected. You must be proactive. (Joan, Interview)

6.10.2 Perception and Importance of Critical Thinking

Joan strongly believed in the importance of critical thinking and as a result she reported that she does not lecturer, she asks questions. Joan does not also use PowerPoint though she believed that the clicker system could be extremely helpful both for the lecturer to know if the student understood and for the students who might be shy to ask questions. Joan reported:

> I don't like it, I won't use PowerPoint at first year, I think it's a presentation medium, not a teaching medium, maybe further up it's okay. Kids, they don't pay attention, they slope off. (Joan)

In common with the other lecturers, Joan believed that there were some aspects of the CEM1881 course learning objectives that were easier taught with critical thinking integrated than others:

> Absolutely some topics in chemistry are easier to integrate critical thinking than others. But in CEM1881, I don't think we do a huge amount of it at all. I think we do a bit more in CEM1880 because they've got slightly more accomplished students, whereas a great chunk of CEM1881 have done no chemistry before, so they don't have enough knowledge yet to really, to question anything. But having said that, we try to get them to think about it. (Joan)

Joan reported that she had no training in how to teach critical thinking. She was also open to any training in critical thinking only if she had the time. She stated:

> No, I haven't had any formal training. But I've probably been offered an opportunity that I haven't taken, from being too busy. But I don't think I have. (Joan)

Joan was open to any training in critical thinking though only if she had the time:

> Yeah, I would embrace any opportunity for critical thinking training. If it happened at the time when I have some time. (Joan)

6.10.3 Teaching Concepts

When asked about her teaching concept, Joan generalised it to the department's philosophy. This could also mean that she lives by this same philosophy ("our philosophy as a department is that these students must be treated with respect"). Joan had a lot to comment about the development of CEM1881, especially why the course was developed, and about the training she provided for the laboratory demonstrators. Joan believed she was born to teach, and her love for teaching drove her teaching philosophy. She went on to talk about her passion and commitment to the department and the part she had played over the years:

> I just like students. I love teaching, and I love being able to see someone who's come in, frightened of the subject, feeling that something that's beyond them, go out with confidence. I've come to think over the years, that some people are born teachers, and you can improve the bad ones, but you can never turn them into good teachers. (Joan, Interview)

Like the rest of the lecturers, Joan reported that the content of the course had not changed. Therefore, there was a tendency to teach the same topic most of the time, in the same way. However, different students each year made it different by way of asking them questions as she taught to help their understanding.

She said:

> The content of this course has stayed reasonably static. For people that are too shy to ask, I try, I ask a lot of questions. Personally, I don't just lecture. I don't like it; I won't use PowerPoint for the first year. I think it's a presentation medium, not a teaching medium, maybe further up it's okay. Kids, they don't pay attention, they slope off, talk to me, take notes, aren't capable of taking good notes. I try to ask as many questions as possible, and I try to get them to chat with me. (Joan)

6.10.4 Classroom Interaction and Teaching Activities

As a way of interaction, Joan mentioned how she had used her understanding of how there were various type of students in a class. She had trained herself to identify different types of learning behaviour. These learning behaviours ultimately determined how she interacted with students in her classes. She cited examples of how in CEM1881, the majority were mature students, those for whom the course was designed. She had noticed that most students did not ask questions and she believed this might hinder their learning:

> I try to make it interactive, which is difficult in that big lecture theatre, and I have used the clicker technology, but I really would like to use it again if I can find a way. I don't know why they don't issue everybody with a clicker. You know when they enrol. You know, they're not that there anymore. (Joan)

Joan, though passionate about teaching did not have much to say about critical thinking practices within the classroom in relation to how she practised. This could demonstrate a lack of understanding of the concept, which could suggest that Joan might not be enacting the curriculum to develop students' critical thinking.

Joan reported using chemistry cartoons and past chemists as tools to diversify her teaching:

> This year I've taken to starting every lecture with a cartoon at the beginning of the lecture. I've been collecting them. And I will say to them, do you get the joke, in case someone doesn't and then talk about the

> chemistry behind it. They're chemistry cartoons. I just found another one last night, two H buffalos and one O buffalo gives a water buffalo. Something just to get going with a giggle. I also try to tell them, like when we talk about a particular aspect of chemistry about the people that were involved in maybe finding out something personal about them. You've heard of Rutherford. Did you know he failed every major exam he sat when he sat them for the first time? You know, if someone had told me that when I was at school, I wouldn't have felt so terrible. You know, just things that make them feel that other people have struggled and therefore you can get there. (Joan)

Additionally, Joan reported on her delight with the use of clickers but said that it was time-consuming to set it up for a single lecture:

> I try to use clicker technology, and I would like to use that more. And I think that's an excellent thing in those big lecture theatres. (Joan)

Though Joan reported the use of clickers, she was not observed to use this form of technology.

6.10.5 Assessment

During the interviews, Joan expressed her belief in her students' excellent academic performance. It was intriguing to note that she had never looked at the learning objectives against which the students were being assessed. She was open to looking at the course learning objective and how the course could promote critical thinking in the students by how the assessment questions were asked:

> Well, actually this lot did really well this year. I've never looked at it like that, the learning objective matching up with what we ask the students in the exams. No, but we should sit down and look at this. (Joan)

Connecting to the above quote, Joan might not be assessing the curriculum to develop student critical thinking.

6.10.6 Case Summary

Joan has a love for teaching and practises some helpful teaching strategies with students. It seemed that because these strategies were not explicitly aligned with any critical thinking framework, they were not as effective as they could have been. Joan still thought that critical thinking would develop more naturally as the students go higher in their degree rather than in their first year.

Additionally, it seemed the students were already limited before they had the opportunity to learn, as the way the course CEM1881 was designed (for non-chemistry majors) contained the perception that these students cannot learn as well as those students enrolled for CEM1880.

Joan pointed out that perhaps students not developing their critical thinking was more about a lack of understanding of the content taught. Like Stella and Ben, she also reported that critical thinking might be more of an implicit concept than explicit, and therefore was not emphasised.

Joan believe she was born to teach. It could be expected that this would drive her to approach teaching slightly differently, with a variety of critical thinking teaching activities other than questioning. However, during lecture observations, Joan did not explicitly teach critical thinking even when she used questioning techniques.

Lecture observations showed that Joan used questioning during most lectures, but often did not wait long enough for a response. As much as Joan loved teaching, it seemed that because her approaches were not explicitly aligned with any critical thinking framework, they were not as effective as they could have been.

Joan expressed the opinion that students in CEM1881 could not learn as well as those students enrolled in CEM1880, going as far as to note that the course was designed with this in mind. Such a perception could have an effect on her teaching students in this course.

In terms of classroom interaction, Joan was observed to come down from the podium and walk around close to where the students were and sometimes personalised her communication with students. She did not mention this approach during her interview; instead, she discussed her approach as one she had trained herself in which identified the different learning behaviours of her students. Joan also mentioned that she had realised that mature students were not afraid to ask or answer questions, so she capitalised on that to get the class engaged and help students who were shy or afraid to talk in class.

6.11 Summary of the Case Studies

As stated in West University Graduate Attribute (Section 5.2.1) that the university's tool for developing learning outcomes is the use of Bloom's Taxonomy. Lecture observations did not reflect the explicit use of the three domains of learning (Section 5.2.1) and the understanding level of Bloom's Taxonomy. None of the lecturers reported on Bloom's Taxonomy at any point during the interviews as practice for planning, enacting and assessing the curriculum.

These case studies have been synthesised from the key findings. The main findings relating to teaching strategies used by university chemistry lecturers, and their perceptions towards teaching critical thinking are highlighted in the summary of the case studies in Table 25.

There were some alternative teaching strategies employed by some of the lecturers, such as questioning and scaffolding. However, the mode of teaching remained as the lecture, where content transfer was the aim and what was to be assessed. There was a growing quest in some lecturers for purposeful teaching, done through a reflection of teaching practices. This can result in active learning and quality teaching with the use of critical thinking activities.

All the lecturers had a definition of critical thinking close to the study's adopted definition: "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment" (P. A. Facione, 1990, p. 3).

The lecturers in this study reported that the barriers preventing them from adopting the active learning approach to teaching through the use of critical thinking was mainly because of:

- Pressure to cover course content
- Lack of time
- Lack of assistance
- Student immaturity
- Lecturers perceive lack of seriousness in the students.

Table 25. Summary of case studies

Name	Denise	Isaac	Patrick	Gavin	Ben	Aaron	Stella
Characteristics: Teaching concepts/practices							
Teaching activities	lecture, quizzes	lecture, humour	lecture, occasional questioning	lecture	lecture	lecture	lecture, scaffolding, questioning
Classroom interaction	somewhat	dramatising	minimal	minimal	minimal	minimal	somewhat
Assessment practices	match	never thought of it	mismatch	mismatch	assumption	disagree	assumption
Critical thinking perception	hesitant to training	no to training	no to training	no to training	will not go	not interested	yes
Lecture observation	somewhat descriptive	engaging via humour	somewhat descriptive	not descriptive	not descriptive	not descriptive	Somewhat descriptive

The researcher in this study research created table 25. Table 25 outlines the summary of the lecturers teaching practices, classroom interactions, assessment practices, critical thinking perception and lecture observation analysis.

6.12 Chapter Summary

This chapter presented the findings of the case studies. It sheds light on the research questions (see Section 1.6), especially a major aim of this study: to investigate how lecturers are developing student critical thinking in a first-year university chemistry course. The cases provided rich descriptions of the lived experiences of the participants as reported by them.

There seemed to be a division amongst the lecturers regarding promoting and developing critical thinking in the first-year university chemistry courses. There was a growing quest in some lecturers for purposeful teaching for effective learning, although some of the lecturers were not open to changing their teaching or to integrate critical thinking, and they did not see the need for ongoing teaching training, they felt strongly, and they were confident in their own performance.

The main activities that were identified from the lecturers' accounts of their teaching were: lectures, questions, quizzes, dramatising lecture components, PowerPoints, and class discussions. These activities will be picked up in the discussion chapter and related to the literature.

In this chapter, some comparison was made of the case studies by identifying the similarities and differences. These ideas will be elaborated upon more fully in the next chapter, discusses the findings.

CHAPTER 7.
DISCUSSION

7.1 Introduction

The following sections address responses to the study research questions. The investigation in this study sought to address the gap in research on how critical thinking is integrated by lecturers into a first-year chemistry course in a New Zealand University. The previous two chapters presented the context of the study and the case studies.

This chapter discusses the findings arising from this study. It takes a critical look at the results of the research and compares them to the findings in the literature.

The findings are then discussed as big ideas to capture each research question:

- What are university lecturers' perceptions of critical thinking?
- How is critical thinking being planned, enacted and assessed in the first-year chemistry courses at the university?

  Included is a discussion of student descriptions of the teaching activities they experienced in the courses that were the subject of this study.

  This is followed by a discussion of professional training lecturers received and its usefulness.

- What factors, if any, do lecturers perceive as obstacles to fostering critical thinking in their course?

The chapter ends with a summary.

7.2 Reflection on the Literature

As evidenced by the New Zealand Government's requirement for the inclusion of critical thinking skills, the demand for such skills means lecturers are expected to support students towards the development of these skills. Numerous findings in the literature support this argument. For example, according to Bao et al.

(2009, p. 1), the art of developing critical thinking skills is "critical to enable students of science, technology, engineering, and mathematics (STEM) to successfully handle open-ended, real-world tasks in future careers". Additionally, Chang (2011); Fung (2014); June et al. (2014); Heijltjes et al. (2014); Morlino (2012); Vieira et al. (2011) confirmed that critical thinking had been found to contribute towards a better understanding of science (as discussed in Chapter 1). Doing so requires the explicit teaching of critical thinking through teaching strategies accepted as best practices from the literature (Chapter 2). In other words, the literature suggests that critical thinking is better developed when teaching it is explicit. For example, Abrami et al. (2008) made clear the positive effects of explicit critical thinking instruction. In the same vein, Grussendorf and Rogol (2018) established that critical thinking in the classroom must be explicit for it to be developed in students and that this instruction should be combined with interactive learning (Section 2.6.1).

Zielinski (2004) posits that one way to help students develop higher-order cognitive skills involves creating learning environments in which students can grow in their ability to reason and think and doing so within the context of the content and processes of science in a way that leads to solving real problems. The purpose of this study is to explore the teaching practices used by university chemistry lecturers in developing students' critical thinking.

Further, this study investigated the perception of both lecturers and students related to critical thinking. This is important in chemistry as critical thinking has been found to contribute towards a better understanding of scientific information, enabling learners to solve problems creatively and informing them how to inquire using evidence-based models (as discussed in Section 2.6). The goal of science is to produce new knowledge about the natural world (Osborne, 2014). To achieve this, Osborne (2014) noted that central to the practice of science is critique and questioning and that without argument and evaluation, the construction of reliable knowledge would be impossible.

The contribution of this study to knowledge is to describe how chemistry lecturers valued critical thinking in the teaching of chemistry and to report on how they incorporated teaching strategies to develop students' critical thinking skills into their first-year chemistry classes. The study has identified some of the reasons given by lecturers as to why they did not act on what they believed was important.

The rationale behind choosing New Zealand for this study was embedded in the idea that students at the high school level in New Zealand are required to develop and demonstrate critical thinking (Section 1.7). However, this study identified that these lecturers had little knowledge about the skills that some students already had from their previous schooling (high school). This is despite that fact that critical thinking had been incorporated as a graduate attribute at the West University.

This study argues, as evidenced from the interviews and lecture observations, that there was huge resistance to incorporating critical thinking into the way lecturers planned, implemented and assessed students and there was an embedded culture to retain the status quo.

7.3 Lecturer Perceptions of Critical Thinking

Even though there seems to be wide discussion that university graduates must have the ability to think critically in a rapidly developing world, there remains a gap between the teaching practices of many lecturers and the desire to achieve expected graduate attributes (Hammer & Green, 2011). This is perhaps due to how the lecturers conceived critical thinking.

The first research question covered lecturer teaching practices, their descriptions, understanding and importance of critical thinking to higher education chemistry. In order to answer this question, this section discusses the results from the lecturer perceptions of critical thinking and how these perceptions translated into teaching practices.

7.3.1 Defining and Understanding Critical Thinking

From the literature, it is evident that the pedagogical viewpoint of teaching for critical thinking has been a movement for reform for decades and that dissent exists in the manner that critical thinking is understood and defined (Almatrodi, 2007; Brandenburg & Wilson, 2013; Kanbay & Okanlı, 2017). However, the lack of agreement should not deter lecturers from being keenly involved in classroom reform.

All eight lecturers in this study were able to define critical thinking as the ability to problem-solve and question information, although their understandings differ. For example, even though Denise was familiar with the classroom use of critical thinking by acknowledging the need for her students to have a deeper and conceptual understanding of the content they are taught, she was observed incorporating only limited student engagement. This definition is similar to the themes found in Danczak et al. (2017), the themes were generated from an open-ended questionnaire where respondents identified themes such as 'analysis', 'critique', 'objectivity', 'problem-solving', 'evaluate' and 'identification of opportunities and problems'. On the contrary to this current study, Danczak et al. (2017) did establish that 45% of students identified an activity relating to a practical environment as where they believed they developed their critical thinking while studying chemistry. This current study's main focus was on developing critical thinking within classroom teaching sessions.

As Grussendorf and Rogol (2018) argue, that critical thinking in the classroom must be explicit for it to be developed in students and that instruction should be combined with interactive learning (Section 2.5). Denise stated that students could pass examinations without the use of critical thinking by using memorisation and rote-learning, This notion is supported by Stowe and Cooper (2017) who argue that students can answer a range of questions that give them academic success without having an understanding or deep meaning of the information and about what is learned. On the contrary, some scholars established that memorising facts instead of understanding them can have a negative effect on student CGPA results or other academic success (Burton & Nelson, 2006; Hasnor, Ahmad, & Nordin, 2013). A number of researchers (Biggs, 1988; Entwistle, 1982; Gow & Kember, 1990) claim that it is the teaching approach that influences students to memorise (Chapter 2).

7.3.2 Importance of Critical Thinking

All eight lecturers reported that critical thinking is important to the understanding of chemical concepts in higher education. However, believing in the importance of integrating critical thinking into the teaching of chemistry does not necessarily mean they incorporate critical thinking into their teaching.

Paul and Elder (2012c), have indicated the lack of effectiveness of a number of modern educational practices. They argue against an educational approach that encourages the habit of memorisation which they define as "the unending dominance of unimaginative didactic teaching" that sustains an "anti-intellectual culture" (2012c, p. 10). Henk et al. (2015); White et al. (2016) suggest that didactic teaching approaches (also referred to as teacher-directed approaches) are not as effective in developing tertiary students' critical thinking. Similarly, teachers have to intentionally support learners to develop their own understanding instead of telling them things that they are required to memorise, as this is no longer considered to be teaching that leads to deep learning (Biggs, 2003a, 2003b).

7.3.3 Perceptions of Critical Thinking

There are mixed views among the lecturers on their willingness to participate in critical thinking professional training. Research shows undoubtedly that the willingness to want to learn how to teach critical thinking is required for effective teaching of critical thinking skills (McBride et al., 2002) (as discussed in Section 2.4). In the same vein, a knowledgeable teacher engenders high-level academic attainment in their students (Aydin & Aslan, 2016).

Studies have recognised teacher training and professional development as being crucial for strengthening teachers' content knowledge and broadening their teaching practices to be able to teach to a high standard (Richter, Kunter, Klusmann, Ludtke, & Baumert, 2011). Consequently, there is demand for lecturers to receive professional development to meet those high expectations (Pehmer, Gröschner, & Seidel, 2015).

Gavin's perception of critical thinking seemed to include the belief that because he was a university lecturer, he might not need professional support in order to foster critical thinking in his students. This perception is in error, as Elder and Paul (2010a) made clear that developing students' critical thinking is dependent on the degree to which lecturers think critically themselves. Gavin's statement might become evidence of what (Paul, 2005, p. 27) stated: "most faculty don't realise they lack a substantive concept and instead believe they understand critical thinking sufficiently and are already successfully teaching it within their discipline". Similarly, Alhamad (2016) encouraged a demonstration of the skill from lecturers (Sections 2.4, 2.5). Perhaps Gavin thought that because he can think critically this automatically makes his students able to do so, as mentioned in his earlier statement: "I guess you hope that that rubs off on the students".

7.3.4 Critical Thinking and Teaching Practice

As suggested in Section 2.8, for critical thinking to be present in teaching practice, there must be one or more critical thinking indicators, such as inquiry-based teaching (Osborne, 2014), classroom discussion, or purposeful questioning (Paul & Elder, 2008a). Other indicators of critical thinking include the evaluation of case studies, explicit instruction, and problem-based learning.

Sadly, none of these indicators were observed as being used by the lecturers, either in lecturer interviews, or in observations of classes. While the examples from each lecturer were important, the overall culture of the way teaching was done in this department, led to the prevailing (traditional) practices being retained.

For example, Denise's concept of teaching came across strongly on how interested she was in her students' learning when she taught. She indicated the importance of teaching chemistry with critical thinking strategies but doubted if there would be enough time and resources to make this a functional teaching practice. While recognising the importance of critical thinking, Denise acknowledged that the current culture was for students to memorise information rather than to process it.

When asked to describe critical thinking, Ben's first reaction was that he had no clue, but as he delved into thinking about the concept and what it might mean to him, he was able to give a detailed description. Ben believed that talking to colleagues was his way of learning. In his opinion, there was room for improvement in involving teaching development activities that can result in increased student engagement and learning in the course. He also shared the opinion that developing critical thinking was possible in the teaching of chemistry. Ben believed critical thinking was important. However, he was not doing more to develop critical thinking because he was used to teaching the same way and had retained these practices for years.

Stella expressed her passion for making quality learning better each year for CEM1881 and she was also making outstanding efforts towards gaining students' interest in chemistry. Stella's description of critical thinking was specifically a relevant judgement into how she interpreted the importance of critical thinking and her disposition to the concept (Section 6.7). She also supported the notion that all content in chemistry is amenable to critical thinking.

Isaac saw himself as an excellent teacher with many years of teaching experience and teaching awards and therefore, did not think anyone could teach him to teach critical thinking. Ironically, one could wonder what happened to the value and importance placed on critical thinking by the lecturers when, for example, Isaac reported that he believed critical thinking already occurred in his teaching practices and he could only learn from specific scholars. Patrick shared Isaac's view that he himself was a good teacher. Aaron did not think he needed training in integrating critical thinking into his teaching as much as some of his colleagues did. He was reluctant to undertake professional training in critical thinking from educators he did not know. The researcher is not reporting that these lecturers are not good teachers and experienced as they have reported nor condemning their years of commitment to educating students, the focus is on whether they were integrating critical thinking into their teaching practices or not.

7.4 Critical Thinking Planned, Enacted and Assessed

The second research question considered the teaching activities practised by lecturers. Data collected and analysed were used as a mirror to check whether the findings agree with the Paul and Elder critical thinking framework.

The results indicate that lecture mode was the means for direct instruction and communication. This result is consistent with previous research that found university education mainly employed traditional teaching methods (Whiley et al., 2017). This thesis, therefore, argues that lecturers must create experiences through which students are guided to explore real data to develop the desired knowledge-based and a thinking process that demonstrates excellence (Zielinski, 2004).

In order to examine how critical thinking was being planned, enacted and assessed in the first-year chemistry courses at West University, lecturers were asked what their teaching concepts were, if the assessment items were in alignment with the learning objectives, and to comment on their classroom interaction with the students.

Data from interviews, document analysis, survey, focus group and observations were used to answer the research question. The discussion answering this research question is presented in three parts. This section will first discuss the results derived from the case studies, lecture observations and document analyses that describe the teaching activities used by lecturers to provide a comprehensive understanding based on themes that emerged from the data analysis. The second part of this section discusses the survey findings that are directly tied to answering research question 2, while the last part discusses the focus group.

7.4.1 Teaching Concepts

This section discusses the teaching concepts and practices of the lecturers as seen in the findings from the interviews and lecture observations and the reports from the case studies. Teaching concepts relate to the research question enacted curriculum.

A teacher's primary duty is to promote student understanding instead of rendering content knowledge (Killen, 2014). Also, the important key around teachers' concepts of teaching has been identified by Kirkebæk, Du, and Jensen (2013) who stated that teaching and learning are impacted by various elements both within and outside the classroom which eventually determine the learning outcome. Similarly, Killen (2014) asserted that varied effects shape teaching and learning, many of which are easily managed by the teacher. Thus, the notion that improving student critical thinking can be a matter of implicit expectation as Ben and Gavin implied, is a false premise, according to the study by Abrami et al. (2008).

Teachers can make a difference and Gavin and Ben believed that the ability to develop critical thinking would occur in students over time. Ben's opinion is a demonstration that lecturers need professional training to infuse critical thinking into the course design. In the same vein, Zhang et al. (2015) argued that lecturers need professional development and that improvement can occur over time. There is the need for lecturers to understand how a critical thinking framework can be integrated into their teaching practice, as it is unlikely that lecturers will develop this of their own accord. This can be linked to numerous research findings discussed in Chapter 2 of this study. These studies showed evidence that without a well-informed lecturer who can use appropriate specific teaching approaches, the mission of developing critical thinking skills is problematic, if not impossible, to accomplish.

7.4.2 Teaching Activities

Teaching activities are the strategies or tools used by the lecturers as a result of their teaching concept (views). If the lecturers believe in the importance of embedding critical thinking into their teaching practices, then this should be evident in the teaching activities that they expose their students to experience.

It was evident in this study that all the lecturers engaged in lectures as the method of teaching. This finding aligned with findings from a range of other studies (Biggs, 2003b; Chen & Hu, 2013; Eagan et al., 2014; Espey, 2018; Krusemark, 2017; Whiley et al., 2017; P. Williams et al., 2014). These scholars strongly believe that the primary teaching approach at the university over decades has been predominantly lecture (as discussed in Chapter 2).

However, several reports, such as Killen (2014) and Paul and Elder (2012c) have shown that the traditional lecture model of teaching does not promote critical thinking. Therefore, different teaching strategies, tools or activities are required for learning of critical thinking to become effective.

Dean and Hinchey (1996); and Greatorex and Malacova (2006) explained that teachers are expected to be able to employ a range of teaching strategies appropriate to the age, ability and attainment of pupils and different learning purposes. Dean and Hinchey (1996) also stated that it is anticipated that teachers will engage students in different teaching activities suitable for learning. Pienta (2014) believes the mode of teaching instruction needs to catch up with the way in which students learn and therefore, recommends a change in approaches.

In addition, it has been conclusively shown that, despite the fact that teachers more often than not embrace the idea of high teaching and learning standards, many teachers are not inclined to apply these standard teaching practices (Creemers, Kyriakides, & Antoniou, 2012). This was confirmed in this study.

Teaching activities are important as they are strategic approaches for learning that promote skill development and understanding required for effective use of critical thinking and eventually desired learning outcomes (Hancock & Leaver, 2006; Szalma & Hancock, 2011). J. Y. Chan and Bauer (2016) maintained that first-year university students undergo stressful learning experiences, not as a result of lacking inability, but rather due to a lack of realisation of learning strategies. It could, therefore, be argued that student learning strategies are partly dependent on lecturers and their choice of teaching activities in order to enable students to think critically while engaging with the course content.

The lecturers in this study had a limited range of teaching activities incorporated within the lecture approach that they adopted. For example, Denise integrated quizzes into her lectures. While Paul and Elder (2012c) support provoking questioning (non-thought stopping) as an indicator that critical thinking occurred in a lecture session, Stowe and Cooper (2017) equally claim that memorisation is promoted when quizzes are composed of items that can be answered using recall rather than understanding the constructs. Joan reported the use of cartoons as a teaching activity, although she was not observed using them. According to the literature, if a chemistry cartoon is planned and tailored to foster students' critical thinking, then it could be categorised as a type of humour, and that would promote active learning (Rule & Auge, 2005) (Section 2.8.1).

7.4.3 Planned and Enacted Curriculum

This subsection presents a further discussion of the previous two subsections. This subsection includes the following topics:

- Summary of the lecturer teaching practices
- Student perceptions of lecturer teaching practices

Summary of lecturer teaching practices

There was variation in the teaching practices of these lecturers. Even lecturers who had a broader view of their role in enabling learning did not make links to what they could implement as appropriate critical thinking teaching activities.

All had a limited understanding of how their teaching could enhance critical thinking. Despite their claims that critical thinking was important, the lecturers' understandings and concepts about how people learn was a reflection of why they teach the way they do. It may be that some of the lecturers had not thought much about their teaching practices related to developing students' critical thinking. They had relatively underdeveloped teaching repertoires because they had never really reflected on or sought advice of external input about what this might be.

In this study, when asked how often they changed teaching strategies, the lecturers' indicated 'sometimes' as measured by the overall percentage score, from four out of the five respondents. Three out of the five lecturers admitted that they sometimes developed critical thinking in their students during lectures. Joan, Gavin, Denise and Isaac respectively believed that the use of clickers, PowerPoint slides, quizzes, and dramatisation were evidence that suggested that they did develop critical thinking in their students. Patrick, Denise, Gavin and Stella reported that they were either "very confident" or "confident" in teaching critical thinking to their students. They were not observed teaching critical thinking.

The results of this study are consistent with the findings of Grussendorf and Rogol (2018), who reported that today's universities do not teach critical thinking and argue that it appears that the state of higher education is far from strong in emphasising the importance of critical thinking. A second study, conducted by Nicole and Adams (2012), had similar findings; they reported that lecturers' knowledge and perceptions of the concept of critical thinking was severely lacking after they administered and analysed an online questionnaire via Qualtrics of 61 self-selected lecturers with teaching appointments in a college. In addition, a college chemistry teacher found that his students were unable to make reasonable predictions about the reactivity of elements and simple inorganic compounds. He, therefore, suggested that to make valid judgments about chemical reactions or reasonable predictions, critical thinking exercises would advance the students' critical thinking skills (DeWit, 2006).

Only Ben reported as being "slightly confident" about teaching critical thinking to students. Gavin, Denise, Patrick and Stella were able to describe critical thinking, identify critical thinking skills, and self-reported to be knowledgeable and very confident in teaching critical thinking, and so it might be assumed to be that these lecturers were developing critical thinking in their students.

Observations indicated otherwise. Again, this is consistent with the literature such as (Walker, 2017); (Grussendorf & Rogol, 2018); (Paul & Elder, 2012c), who noted that it takes more than being able to describe critical thinking: it must be explicitly taught after being planned.

As discussed in Section 2.8, with some suggested approaches for including critical thinking could be after class activities such as project-based learning and written assignments. Table 25, as earlier discussed, shows the strategies used by lecturers when they were observed. Most lecturers used lecture mode and questioning.

Students perceptions of lecturer teaching practices

Based on the student focus group responses, most students confirmed the lecture model as a means for conveying content knowledge to be the usual approach to teaching they have experienced. These findings indicate that the university chemistry lecturers teaching the first-year course in this study, mainly taught through lectures, without explicitly teaching critical thinking to students. This finding concurs with other studies (Toledo & Dubas, 2016). The student focus group further suggested that there was a need to redesign the chemistry first-semester course to help students develop critical thinking. In addition, Živkovil· (2016) suggests explicit teacher modelling of essential skills of thinking for students.

According to Liu, St. John, and Courtier (2017), engaging students in class plays a vital role in undergraduates' further pursuit in the STEM subjects. Additional literature established that when critical thinking teaching was included, it fostered students' understanding of the course content and helped them develop into independent critical thinkers as the university graduate attributes aspire them to become (Cargas et al., 2017; Martineau & Boisvert, 2011).

During the interview with the student focus group, it became apparent that the students had heard of the concept critical thinking and were able to describe what the concept of critical thinking meant and could identify skills that demonstrated critical thinking with them understanding what critical thinking involved and the skills required to help them succeed through their university courses. This is potentially due to the exposure some of the students had in their secondary school education from the New Zealand Curriculum (The New Zealand Curriculum, 2007). As a result, they were able to comment on how their lecturers were helping to develop critical thinking in them through their chemistry course.

Survey data findings indicate that 51% of the students reported that they used "sometimes" critical thinking while in CEM1880 and CEM1881. This result could imply that the students had only been challenged "sometimes" into enhancing their critical thinking skills in the chemistry courses. 58% of the students reported they were also "sometimes" distracted by other things or were not paying attention during lectures for CEM1880 and CEM1881. This distraction could be because the students found the transmissive lecture model boring and difficult to gain content understanding at that point of the lecture, as the students reported in the focus group interview. Interestingly, 48% of students believed that the lecturers had "good" knowledge and understanding of critical thinking. This result might be because the students believed without questioning that their lecturers knew everything and were experts in their field.

There is a research claim that sometimes students tend to believe sources of knowledge as correct when they should question everything as critical thinkers (Martineau & Boisvert, 2011). Although 47% of students surveyed reported that their lecturers supported them to develop critical thinking, lecturers did not give specific examples that would support this claim. A study by Martineau and Boisvert (2011) revealed that students, after being taught how to analyse, understand and write a contribution to Wikipedia, reported that in the future they would further verify with at least another reference what they believed to be true from Wikipedia. The Martineau and Boisvert's findings are similar to this study, showing that 48% of students believed that their lecturers were knowledgeable in critical thinking, which could imply the students believed everything that their lecturers taught them without questioning or verifying from other sources (Martineau & Boisvert, 2011). In other results from this study, 41% of the students ranked the quality of the critical thinking experience in the university courses other than CEM1880 and CEM1881 as "good".

The discussion for the students' description of the teaching activities they experienced revealed that students tended to understand the content taught by themselves (on their own) since they found the lectures either boring or unsuitable to support their understanding at the time in the lecture.

Interestingly almost 60% of those surveyed reported that their lecturers were "moderately involved" and "very involved" in developing critical thinking in them. This is a high percentage of students. The question is if the students reported that their lecturers were "very involved" how is it that the same students reported in the focus group that they find lectures boring. Again, if the level of involvement of lecturers was indeed high, it should have been evident during the lecture observations.

7.4.4 Assessed Curriculum

In course design, there is an expectation of alignment between course outline and learning outcome (Chen & Hu, 2013). Biggs argues that for critical thinking to be valued by both students and lecturers, there is a need to align and integrate curriculum and assessment (Biggs, 2003a, 2003b). Bers (2005) contends that this relationship between the curriculum and the assessment has a direct impact on students' learning because students align what they choose to remember with what is assessed.

Curricular alignment is a dynamic and multifaceted process. In the literature, alignment of curriculum, instruction, and assessment was proposed (Kurz et al., 2010). As such, lecturers need to observe and implement practice that ensures constructive curriculum alignment. Ziebell and Clarke (2018) concur with Kurz et al. (2010), and they indicate that in an aligned curriculum, what students should know (standards) is consistent with what they are taught (instruction) and that this corresponds with how they are assessed to determine their levels of achievement (assessment). Therefore, overall awareness of the link between learning outcomes and assessment tasks is important to succeed in developing critical thinking skills in a first-year university chemistry course.

Chapter 2 of this study argues that there is a global recognition of the need for students to develop a broader set of skills, one of which is critical thinking (Grussendorf & Rogol, 2018). How to assess critical thinking has become increasingly problematic. Literature has established that given that a primary justification for assessment is to improve student educational outcomes, the assessment must align with the purposes to which it is being applied (Care, Griffin, & Wilson, 2018). What is known regarding the importance of curriculum design and assessment in the literature established that any approach to curriculum assessment must ensure that the skills highlighted in the course outline align with the objective of the curriculum (Renshaw, 2014). In other words, when designing the curriculum, the assessment must be framed along with the learning objectives or desired learning outcomes.

To check this alignment and lecturers' awareness of its importance, lecturers were asked about the verbs in the examination questions. Gavin was unaware that the verbs used in examination questions were not a match with the verbs stated in the learning objectives of the course.

Ben seemed to be aware of the implication of the learning objective in relation to the examination questions. Similarly, Stella was aware of the need to have a match with the learning objectives when asking students questions in the examination. Stella was quite confident that her questions were based on the learning objectives. Denise equally reported that her questions always matched the learning objectives.

Isaac responded with displeasure related to lecturers who ask questions that were not related to the learning objectives. He indicated that his students consistently performed well in his section of the examination, with the implication that there was not an issue with the design of the assessment for him. However, he did not comment as to whether his questions matched the learning objectives or not.

Patrick stated that he had been reminded by the course coordinator previously about the need to avoid teaching outside the learning objectives. However, he valued purposeful examination questions. Aaron had not used assessment as a tool to develop students' critical thinking. He mentioned how tedious marking could be for a large class if specific elaborate questions were asked.

Joan reported that she had not looked at the language used in the examination and the potential of writing the learning objective as a tool to develop students' critical thinking. This was identified as a future possibility.

Despite the awareness of learning outcomes by the lecturers (or perhaps because of the lack of awareness), the assessments for CEM1880 were misaligned with the learning objectives for the course. Conclusively, there was no planning for the assessment of CEM1880 and CEM1881 to include critical thinking.

7.5 Obstacles to Critical Thinking

This section discusses the factors that lecturers perceive as obstacles to fostering critical thinking in their courses to answer research question three: What factors if any, do lecturers perceive as obstacles to fostering critical thinking in their course? The discussion in this section is based on what the lecturers reported, and these reports are linked to findings from studies in the literature.

Lecturers reported that the large numbers of students in classes made it, in the words of Denise, "this is a class of five hundred students without any extra money, TA support, or technical support, it's almost impossible" to integrate critical thinking activities.

Lack of time was another obstacle that the lecturers said was an impediment. Not enough staff support was also reported to be an obstacle. Denise reported that it took time to set up demonstrations in her class, and she was of the opinion that she would have continued using demonstrations if she had an assistant. She saw using demonstrations as a way to ask questions. In an extended discussion with Denise, her impression was that not all of her students were committed to learning, and she would not take responsibility for that. She revealed that some of the students were expecting everything to be handed to them, without doing much in the hope that they will pass.

Related to assessment, Denise highlighted some constraints in being able to ask students an appropriate question in the examination and also identified her colleagues as not being as effective as they should be. Denise's constraints were due to the rigour of marking as she was able to set the examination questions related to the topics she taught in the course. Like some of the other lecturers (such as Aaron), she recognised that marking written answers from students took more time than assessing multiple-choice questions (Wan & Cheng, 2018). In the words of Aaron, "traditional exams or whatever and there are real logistical issues in the exam. So, I have to say that I was one of the people who pushed for multiple-choice questioning for CEM1881, on purely logistical grounds" (Grussendorf & Rogol, 2018).

Technology was identified as another obstacle. Denise mentioned how frustrating it was for her to practice some teaching activities that she believed would foster students' critical thinking. Denise was able to conclude that the electronic provision of resources, giving students recorded lectures via the university's electronic learning, along with lecture notes and lecture slides, and concluded that the electronic provision was not helpful for the development of critical thinking.

Gavin explained that his perception of the lecture theatre setting was that it was not conducive for interaction because there was a glass wall (a safety screen in place for chemistry demonstrations) between the podium and the students. Gavin expressed that this was the reason for his lack of classroom interaction (Biggs, 1999; Mathews & Lowe, 2011). Joan, Patrick, Stella and Aaron mentioned that the clicker would be a good way to find out if the students were following and understanding the content. However, this was not available because it was expensive and somewhat superseded by phone technology (June et al., 2014; Kogut, 1996).

In Stella's case, she admitted that the course learning outcome was not consulted when designing the students' multiple-choice examination items. Lecturers and the university employ multiple-choice assessment due to barriers or limitations such as large classes caused by increased enrolments in classes (Stowe & Cooper, 2017). Students who view learning as receiving information mainly to pass the examination, graduate and might have a degree that lacks the adequate development of critical thinking skills to be experts in their chosen field.

As mentioned by Aaron, another barrier to quality and effective higher education teaching and learning that could develop students' critical thinking is the issue of over-commercialising university education. This might be accurate based on the literature as some studies have identified the low level of critical thinking skills in university students due to various reasons such as those mentioned above (Berube, 2012; Espey, 2018).

According to Broucker, De Wit, and Leisyte (2015), universities are driven by profit. This perhaps could result in quantity over quality, a reason for university lecturer's' workload dissatisfaction as presented in Section 2.5.3 (Mamiseishvili et al., 2016).

Joan still had some barriers in her mind that critical thinking would be easier for students as they progressed higher in their degree, rather than in their first year. There is nowhere in the literature where it is suggested that critical thinking is better integrated into learning at a particular level of university education. Adopting an engaging learning approach to teaching is encouraged throughout the literature (Abrami et al., 2015; Almeida & Franco, 2011; Espey, 2018).

The literature closely mirrors the findings reported by the lecturers about the obstacles to fostering critical thinking in the courses. Scholars like Snyder and Snyder (2008); Ebiendele Ebosele (2012) and White et al. (2016), believe some common barriers and obstacles prevent instructional transformation that is expected within the university teaching. Snyder and Snyder list 'four barriers that often impede the integration of critical thinking in education: lack of training, lack of information, preconceptions, and time' (2008, p. 92). White et al. identify 'lack of training, time and incentives' (2016, p. 620). This study suggests that lecturers should find a way to overcome the present obstacles in order to achieve a learner-centred approach to teaching.

7.6 Chapter Summary

This study had an overarching goal of examining the teaching practices of university lecturers in first-year chemistry courses, looking for the use of critical thinking. There was no report on the specific planned critical thinking teaching strategies and activities used by the university chemistry lecturers as these were generally lacking. This study has nonetheless revealed important insights into the lack of knowledge of how to teach critical thinking.

Based on the finding of this study, any assumption that critical thinking teaching strategies and activities were practised in chemistry classes at West University was false.

To encourage critical thinking, the 'conveying-of-information' approach to teaching must change. Lecturers need to question and modify their belief that students learn only when a lecturer covers the content material (Choy & Cheah, 2009). To this end, this study argues that critical thinking teaching activities should be integrated into the teaching of first-year university chemistry courses, because critical thinking clarifies the purposes of thinking and evaluating, assists with identifying its relevance, and enables deeper learning and retention (Stowe & Cooper, 2017; Walker, 2017). Duron et al. (2006) found that most teachers conveyed information through lectures and the authors concluded that this popular approach by *itself* does not encourage critical thinking in the students.

Some of the lecturers were observed asking questions occasionally during lectures, but these questions were not *purposeful*, as described by (Paul & Elder, 1998; Rashid & Qaisar, 2016).

A statement by Ben may sum it all up:

> I would say that the way I present lectures has been pretty much fixed for a long time now. I tend to give the same lectures in the same order with the same material, at the same rate, tell the same jokes. (Ben)

Bao et al. (2009) found that there is a relationship between instructional methods and the development of scientific reasoning. Further, they noted that because students need both the content knowledge and critical thinking skills simultaneously, lecturers need to find ways to integrate both agendas.

Consequently, rich and rigorous STEM education, without the inclusion of critical thinking, has little impact on the development of students' scientific reasoning (critical thinking) abilities. They concluded that it is not the content knowledge, but rather how it is taught, that makes a difference in student learning of higher-order abilities in science reasoning. Lecturers need to use clever questioning techniques or pose issues and problems as part of the lectures to model (critical) thinking processes.

There was also a strong culture of 'telling' students what the lecturers thought they needed to know. This has implications for teaching chemistry, for the professional learning of staff, and for curriculum design, wherein alignment exists between the assessments and the learning objectives. Consideration must be given into how critical thinking can be modelled within lectures, and how it can be a future focus for this team of lecturers. The prevailing norms and expectations from both staff about their roles and their students need to be challenged more, and lecturers need to assume the role of fostering students' critical thinking.

Since these lecturers were able to describe critical thinking, some expressively so, one would expect that their understanding of the concept of critical thinking would align with their underlying perceptions, such as those concerning their teaching practices or attitudes to professional training for implementing critical thinking. This finding is in line with Toledo and Dubas (2016), in that they reported that after a few years of teaching university chemistry, lecturers assumed that they had a solid grip on what constituted higher-order thinking (critical thinking) skills. Such reconsiderations led the lecturers to realise that they lacked a rigorous operational framework for teaching actions. Again, this finding seemed accurate for the lecturers in this study. For example, Gavin seemed to believe that critical thinking was almost impossible to integrate into some chemistry topics.

None of the eight lecturers interviewed had any formal training directly related to critical thinking as a teaching approach. In fact, there was widespread antipathy to the notion of being trained in teaching, let alone in teaching how to engender critical thinking, again reflecting on Toledo and Dubas (2016). Denise believed a chemistry student could get by, just by memorising and that students should be held responsible for their learning, the latter is in agreement with Stella's statement. There is, therefore, little incentive in the perception of the lecturers to adopt new teaching approaches. Whilst not rejecting the notion of possible deficiencies in student commitment and responsibility, this thesis does argue that there are moments when lecturers must foster the development of students' critical thinking using foundations other than rote learning.

Similarly, Aaron's opinion was that critical thinking was not necessarily important to the development of the understanding in chemistry, especially not at first-year chemistry. Aaron believed that the students did not have what it took at this stage of their academic pursuits, regarding content knowledge to be taught using a critical thinking approach. Obviously, the lecturers were unaware of what is expected at school level from the *New Zealand Curriculum*, which expects schools to teach and develop critical thinking to students prior to reaching university (Bell, 2014; Benade, 2009; Donnelly & Education, 2007; Gallagher et al., 2012; Lace, 2012; The New Zealand Curriculum, 2007).

The discussion on research question 1, "What is the perception of lecturers towards critical thinking?", revealed that all the lecturers except for Stella and Joan, were not interested in obtaining critical thinking teaching training. Denise was partly interested as she felt it was possible for students to have academic success without critical thinking. What Denise viewed as "success" was a misalignment with integrating critical thinking. This study argues that the result from developing students' critical thinking cannot be compared with the academic success achieved through rote learning. The process of developing students' critical thinking in a first-year university chemistry course must take a more holistic approach for a more effective and demonstrably long-lasting learning outcome.

Findings in this thesis echo the conclusions of six previous studies. First, they support Whiley et al. (2017), finding that university education mainly employed traditional teaching methods (the lecture). Grussendorf and Rogol (2018) argue that today's universities do not teach critical thinking well, also supported by the findings of this thesis. Their study found that an interactive and scaffolded critical thinking curriculum yielded statistically significant critical thinking in students. They discussed how not doing so retains the cultural status quo.

Grussendorf and Rogol (2018) propose that to break this cultural expectation, an early start and a long-term approach is required. This suggests a need to create a greater awareness of the prevailing culture for teaching and learning in universities and what it takes to change it. It will require leaders of curriculum development and teaching teams to understand the link between designing for learning and achieving the desired student learning outcomes.

Third, they confirm that Nicole and Adams (2012), finding that lecturers' knowledge and perceptions of the concept of critical thinking was severely lacking. Fourth, they argue that lecturers must create experiences through which students are an active participant in the learning process (Zielinski, 2004). Fifth, they reflect Abrami et al. (2008)'s meta-analysis study, which found that developing students' critical thinking cannot be effective through an implicit approach. And lastly, they support Kennedy et al. (2013), who state that university science education needs to be transformed by improving learning during lectures.

This thesis has not been able to fully report on a specific approach that is developing critical thinking in a first-year university chemistry course in West University because it did not occur within the context of this study. However, it did provide valuable understandings into the lecturers' perceptions, skill sets and views on professional learning, and it has prompted important points for future research into critical thinking.

CHAPTER 8.
CONCLUSION

8.1 Introduction

This study offers a unique contribution to our understanding of the needs of university lecturers to integrate engaging learning approaches to teaching through critical thinking and suggests that lecturers can look beyond the assumption that students develop critical thinking skills as they progress in their degree courses. It also contributes to the ongoing discussion on implementing critical thinking in higher education and the understanding of how lecturers in first-year chemistry courses in West University, New Zealand understand and have adopted the construct.

This study provides insights into the notion that integrating critical thinking activities into the course outline, learning objectives and teaching practices of first-year university chemistry lecturers is an effective pedagogical strategy aimed at developing students' critical thinking in learning chemistry.

In Chapter 5, 6 and 7, findings were presented, analysed and interpreted. This chapter summarises the contributions to knowledge that have been made through undertaking the research, identified pedagogical considerations and proposes recommendations for educators providing education to first-year university chemistry students and the university.

8.2 Summary of Thesis

Universities have a responsibility to develop teaching models of best practice to enable students starting from their first year of university to develop critical thinking skills (Section 2.5). In West University, there were nine university lecturers and about 740 first-year chemistry students from a New Zealand university in an urban centre. The students were enrolled in 2015/2016 academic sessions for both CEM1880 and CEM1881, while nine lecturers were involved in teaching these students. Findings were derived from student surveys, interviews with lecturers, lecture observations, focus group interviews with students, lecturer surveys and document analyses. Eight out of the nine lecturers participated in all the data collection. Eight case studies were formed from data analysis of lecturer interviews, their surveys and observations of their teaching, with additional data generated from student surveys and focus groups.

The data revealed that most students identified the extent of their lecturers' involvement in developing critical thinking as moderate or slight during teaching. Similarly, lecturers commented that they developed students' critical thinking skills "sometimes". Lecture observations indicated that there was minimal inclusion of direct or explicit use of critical thinking, especially in relation to chemical concepts. However, there was a promise that reflection by lecturers about their use of critical thinking can act as a tool for growth to produce well-grounded chemists with innovative minds able to discover new theories, rather than repeat what has been taught for centuries in the field of chemistry. All the eight lecturers thought critical thinking was important.

The literature positively links critical thinking with a better understanding of science, particularly chemistry (DeWit, 2006; Osborne, 2014; Pinto & Prolongo, 2013; Vieira et al., 2011), and link use of critical thinking with better academic achievement (Uzuntiryaki-Kondakci & Capa-Aydin, 2013). Although the lecturers in this study acknowledged the importance of critical thinking, they had not realised (in terms of their planning and enacting the curriculum), how they could use activities and model critical thinking. They had not made the link between students' use of critical thinking and their potential to improved learning outcomes.

While previous research reiterates the importance of embedding critical thinking as a graduate attribute more work needs to be done towards the practicality of students experiencing and growing in their critical thinking skills as developing future chemists during their learning of chemistry at universities. This is not to argue that the university system in West University never attempted to develop first-year students' critical thinking in CEM1880 and CEM1881. Lecturers recognised the importance of critical thinking, have some understanding of the concept and are making potential efforts towards critical thinking teaching activities that can engage students within a lecture.

Chapter 1 provides an overview of the statement of the problem for this study. It summarises the current understanding and background information about critical thinking and university graduate attribute were established. The justification for the study is established, and insight to the study provided.

Chapter 2 establishes the problem of the lecture approach to teaching in the field of science and chemistry discipline. A broad outline is presented, and recent specific trends are discussed. Chapter 2 provides the critical evaluation of scholarly views through books, journal articles, and other sources relevant to developing critical thinking in chemistry were investigated. This demonstrates how this study fits into a larger body of research. The gap in the literature was identified. The theoretical framework for the current study was established. The theoretical framework is based on the principles of Paul and Elder's critical thinking framework (Paul & Elder, 2008b). A general overview of existing thinking about critical thinking and university teaching is provided.

Chapter 3 highlights the propositions and conceptual framework. This chapter establishes the conceptual framework of the study as a tool for launching an inquiry and producing a strong narrative that is a theory-based and data-driven argument for the importance of the research questions, the rigor of the method, and makes inferences for further advancement of theory and improvement of practice.

In Chapter 4, the research methods used to answer the research questions are identified, and the rationale for the application is discussed. The methodology matters because it provides the guidelines to make the current study manageable, reliable and valid in order to make an informed judgement. Data collection and data analysis are explained. The methodology anticipated problems and steps taken to minimise the impact of the problem described. Sufficient information is provided for the replication of methodology in another context.

In Chapter 5, the context to the study is provided. The contribution of documents, the graduate attributes, course outlines, examination paper, surveys from both lecturers and students, and the focus groups are established. Based on document analysis and surveys that were applied to collected data, the results are presented. These show that:

- Lecturers are moderately involved in supporting students to develop critical thinking in CEM1880 and CEM1881, they do not plan to include critical thinking specifically.
- There was a misalignment between the planned curriculum and the assessed curriculum and critical thinking was not explicitly assessed.
- The contribution of the first-year chemistry course to the achievement of the university's graduate attribute of critical thinking is minimal at best.

In Chapter 6, the findings from interviews, observations and focus group are presented without bias. Only data that answer the research questions are presented in chapter 6 and chapter 5 as well. The findings answer the research questions by providing in-depth accounts of lecturers' perceptions about critical thinking and how they are developing students' critical thinking.

Chapter 7 discusses the data collected and its analysis in relation to the research questions. The purpose of this chapter is to interpret the findings from the data and discuss the significance of the study. The findings of the research questions are also aligned with reference to the literature reviewed. This chapter explains how this thesis advances the understanding of the research questions.

The student survey and focus group did not go quite as well as was hoped. The student survey respondents were low; 88 students out of about 740 completed the survey. Similarly, the number of participants in the focus group was low. In future research under these conditions, it would be beneficial to provide incentives for students' time to gain more willing participants.

The scope and limitations of this study are outlined in Section 8.6.2. However, it is worth noting that this study was not an intervention. Therefore, this thesis does not provide evidence related to a specific teaching approach for developing critical thinking in university chemistry students in their first year. The implication of this is that this study does not support a particular intervention program because the study investigated what lecturers were currently doing, rather than evaluating the effectiveness of an intervention. Of the effective approaches mentioned in the literature, some were not necessarily from first-year university chemistry experiences, and some were from experiences in other disciplines. This study describes the teaching practices of lecturers in a specific context, time and location. The implication of this is that this thesis is able to examine and report on lecturers' perceptions of critical thinking, the planned, enacted and assessed curriculum, and factors (if there were any) that lecturers perceived as obstacles to fostering critical thinking in their courses. The outcomes of this study relate to the perceptions of the lecturers and the rich differences in their interpretations of critical thinking and teaching more generally. Another implication relates to providing lecturers with professional learning to ensure alignment between the graduate attributes, curriculum design, teaching practice, and student learning outcomes.

8.3 Impact

A major benefit of this thesis is that teaching chemistry at this university can be reflected on by this team of staff to consider how their teaching aligned with the aims and objectives of the course and especially in relation to the graduate attributes. A more considered and informed approach by the lecturers may enable the development of critical thinking skills within chemistry, so that those graduating chemists go on to serve their communities, develop new chemical theories and be willing contribute to a career in the field of chemistry by applying these critical thinking skills.

This thesis has identified through the literature and the lecturer and student perceptions, the benefits of using critical thinking to inform further research. Full implementation will require lecturers to undergo professional learning and collaboration to understand and apply teaching practices which develop student critical thinking more effectively.

Longer-term gains in developing students' critical thinking skills through changes to teaching could be evaluated through assessment that incorporates the requirements for students to demonstrate critical thinking. The immediate impact would be changes to teaching approaches by lecturers and the department as a whole. The future impact would be seeing more knowledgeable and willing chemists and chemistry teacher graduate.

8.3.1 Pedagogical Impact

The original contribution to knowledge is the provision of insights related to the practice of integrating critical thinking into the university chemistry curriculum at the first-year level. This thesis has added to the body of research that argues for an active (i.e. engaging) learning approach to teaching specifically in West University. It has contributed to scholarly discussion on quality university teaching and eventually the achievement of the graduate attributes to which universities aspire.

One of the purposes of university education is to prepare students for the career challenges in the 21st century (Stone et al., 2017). Therefore, we would expect that this same expectation occurs in specific subjects such as chemistry and that this would be reflected in the approaches to teaching. Such was not the case in the course that was the focus of this study.

This study has identified an opportunity in tertiary chemistry education for lecturers to move away from lectures as a single delivery method and to include approaches that inherently promote critical thinking. In this case, there was a need to integrate critical thinking into the teaching of chemical concepts to help students' retention and recall of key ideas through approaches like one-on-one questioning, group discussions and group activities while in class. The need for lecturers to reconsider their perceptions and be more intentional when teaching critical thinking explicitly is emphasised in (Heinrich et al., 2015; Walker, 2017).

The findings of this study align with those of Abrami et al. (2008) in that lecturers assumed that critical thinking would be developed by students implicitly. Even when lecturers mentioned teaching strategies and activities that could have helped with developing critical thinking, they did not understand the importance of modelling thinking or problem posing in relation to the tentative nature of chemistry content. Including critical thinking in tertiary chemistry will require challenging the prevailing expectations about how students learn, including lecturer perceptions (Kennedy et al. (2013), clearer understandings about what critical thinking is, and clearer discipline-specific strategies for integrating critical thinking explicitly into teaching.

Similarly, lecturers could use clever questioning techniques or pose problems as part of the lectures to model thinking processes. For example, according to Lang (2016), the last five minutes of class can be used to make small changes such as purposeful questioning like "What was the most important thing you learned today? And what question still remains in your mind?".

The assumption that critical thinking teaching activities occurred in chemistry classes in the university where this study was undertaken was false. For the lecturers involved, there was a need to go back to the principles of good learning design, where learning objectives drive teaching approaches, and critical thinking is specifically emphasised as part of the design of teaching. In addition, when a stronger alignment with an assessment on critical thinking is emphasised, it is much more likely that critical thinking will be more highly valued within the discipline. To develop more informed decision-makers as scientists, universities need to challenge assumptions and practices within chemistry education that limit students' development of critical thinking capabilities and restrict their ability to meet the desired graduate attributes.

Another significant finding is the relationship between critical thinking and the types of teaching activities. Students in this study reported that they found lectures boring, and there was little or no use or development of critical thinking during their CEM1880 classes. This was confirmed through class observations. This study provides insights to better understand how lecturers perceive critical thinking and how they enacted this with the curriculum in CEM 1880 and CEM1881. Data revealed a lack of active learning approaches to teaching and embedded critical thinking in the enacted and written curriculum, and that critical thinking was not explicitly assessed.

A significant contribution to the West University chemistry department by this research was an awareness related to assessment practices. There was a promise from the lecturers to give attention in the future to assessment items. Ben and Stella made promises to make provision for alignment of the learning objectives with the assessment items the following year (Chapter 6). Ben and Stella are the course coordinators for CEM1880 and CEM1881 respectively. When the misalignment of the use of verbs in the examination paper and the learning objective (CEM1880) and learning intent (CEM1881) was discussed during the interview, Stella stated:

> It's an interesting observation actually, that's something that we can go back and work on, and develop that for next year, for sure. (Stella)

Ben stated:

> This is good feedback. I would have thought we were using the same verbs because that's the sort of language we describe, but if we're not, maybe that's something we should think about. Now there's circle obviously, and same with the sketch, yeah, rather than be able to describe. Maybe this will be a useful thing will come out of your thesis that you can point us to. So that's good. (Ben)

As a result of the discussions with them, they became more aware of the need to use higher-level verbs as indicated in Bloom's Taxonomy in assessments, rather than lower-level verbs such as "describe".

8.3.2 Discipline-Specific Impact

The discipline-specific impact can be viewed from a range of perspectives. First, findings from this thesis reveal that developing a higher order skill such as critical thinking is necessary from the first year of university education. Second, though not the primary focus of this study, this research identifies how critical thinking strategies and activities can be embedded into teaching and can be used as critical thinking indicators. Third, an achievable critical thinking framework for planning, enacting and assessing the curriculum are discussed. For example, an explanation is given for the rationale of the effectiveness of the Paul-Elder critical thinking framework. Bloom's Taxonomy was identified as another thinking framework that can promote students' critical thinking. Lastly, this study created an awareness of the importance of aligning critical thinking with the assessment.

This study's contribution to chemical education is such that university policy could provide a means of minimising the barriers reported by the study's participants. To begin with, the university can review policies around workload allocations and training for staff.

With regards to trans-localism, the location that enabled this study was an urban city in New Zealand. This location at the time of data collection enabled the researcher to write this thesis and make a significant contribution to New Zealand chemistry education. Therefore, the context of this small study is more beneficial to university education in New Zealand. However, some elements of this thesis could also be relevant to any university which may be interested in the specific application of embedding critical thinking into a first-year university chemistry course.

8.4 Relevance

Critical thinking is a higher-order thinking skill enables chemistry students to evaluate what they are learning, the evidence provided and how it fits with developing new and augmented concepts in chemistry. Developing critical thinking would help students to navigate the world beyond chemistry and transfer this skill to other disciplinary learning and everyday life to equip a small quota of the citizens of the world to reflect on why the quality of evidence matters and the importance of research protocols and thinking. Within the university setting, critical thinking skills definitely allow students to organise their learning, positively affecting their overall academic success (Paul, 2005).

8.5 Consequences

The results of this study led the researcher to conclude that university lecturers in West University would benefit from comprehensive professional development on critical thinking, such as that described in Mgijima (2014); and White et al. (2016), to help students make an authentic connection with chemical concepts and theories. This thesis has suggested that education should be a process involving analysis, evaluation and freedom to grow cognitively rather than a repetitive process, which a lecture model of teaching tends to promote, especially when critical thinking is not embedded into lectures. Without the application of critical thinking into learning in chemistry, students tend only to value memorisation. This thesis has established through the literature that memorisation does not support critical thinking (Fullan & Langworthy, 2014; Whiley et al., 2017). It has been established that critical thinking would develop the ability for chemistry students to argue based on information and query sources of evidence (Osborne, 2014).

Further, employers require graduates to have developed transferable skills such as critical thinking (Stowe & Cooper, 2017), specifically in chemistry graduates (Rayner & Papakonstantinou, 2015; Sarkar, Overton, Thompson, & Rayner, 2016).

8.6 Recommendations

This thesis has established that lecturers in this first-year university chemistry course have not embedded critical thinking into their teaching practices and therefore are not intentionally developing critical thinking in their students.

As such, arising from this study, there may be consequent implications for lecturers, chemistry departments and university policymakers related to the professional learning of staff. This research argues for a more engaging learner approach for teaching in higher education. Since accessible and quality education is a fundamental human right, this thesis makes the following recommendations:

- University Involvement
- Professional Training
- Policymaking
- Critical Thinking Indicators

Details of the recommendations are contained in the following subsections.

8.6.1 Recommendation 1: University Involvement

The main aim of university education is to graduate students who can succeed after graduation and are employable. The university should work with the chemistry department to make the graduate attributes attainable. This could include providing a system where course preparation among lecturers, including a redesign of the course to emphasise the integration of critical thinking into the course content, delivery and assessment, values the development of critical thinking in first-year university chemistry students.

8.6.2 Recommendation 2: Professional Training

Based on the data in this research, chemistry lecturers at this university did not teach critical thinking explicitly and have a poor understanding of how to integrate critical thinking. If this approach is not changed, it means that students may have difficulty questioning assumptions, evaluating claims or engaging in effective decision-making (Grussendorf & Rogol, 2018). As such, professional learning or training should be provided to lecturers about specific activities that would develop students' critical thinking. These changes could be evaluated through further research on their impact on students' skill development.

Adapting the university's professional teaching program to support collaborative planning with academic development should be considered. First-year chemistry courses should be dynamic and innovative in design by being aimed at delivering learning and teaching experiences that explore and apply critical thinking strategies. Such professional learning would enable lecturers to be aware of the multiple teaching approaches that might support students to develop critical thinking, select those strategies that are most appropriate for the content context and use them in practice.

8.6.3 Recommendation 3: Critical Thinking Indicators

Future studies should examine how the critical thinking indicators outlined in this research, can support lecturers to develop critical thinking in first-year university chemistry.

8.7 Extendibility

The following areas are emerging from the scholarship conducted in this thesis.

Given that several studies have established that transmission of knowledge and information through lectures predominates in many universities (Eagan et al., 2014), and that thinking skills, particularly critical thinking, need development in students (Elder & Paul, 2010a; Espey, 2018), much more needs to be done to change teaching practices. Research evidence in this study makes it clear that lecturers need to use explicit teaching strategies that promote the development of students' critical thinking.

One possible approach for further research could be to use two cohorts of students: one exposed to the transmissive lecture model, and the other to critical thinking designed interactive curriculum including assessment and teaching strategies specifically designed to enhance critical thinking. Relative outcomes of both cohorts could be compared in terms of growth in critical thinking with their baseline of skills.

In future studies, the use of a quasi-experimental design could enable a comparison of the effectiveness of particular critical thinking teaching strategies, especially questioning protocols. This research suggests investigating some specific teaching strategies described in the literature (Chapter 2), which can enhance the development of critical thinking with first-year chemistry students. Further research may inquire into which teaching strategies are best for developing critical thinking in a first-year university chemistry course and apply those strategies to students to verify the results.

Another area for potential study could be an investigation into whether critical thinking could be integrated to all areas of chemistry, or if the notion that critical thinking cannot be embedded in some topics in chemistry (as seen in literature and as reported in this thesis) is accurate. Other studies could examine and describe the lecturer's views about whether critical thinking occurs in laboratory classes.

There are likely to be some content areas that are more amenable to integrating critical thinking than others. However, because of the evidential basis that chemistry is premised on, questioning how we know, how reliable and valid the evidence is, and how theories explain or are limited in explaining phenomena, would go a long way to advancing critical thinking as applied to chemistry.

8.8 Assumptions, Limitations and Delimitations

It was a humbling experience to know that within research in education, one is censoriously constrained in various ways when engaged in academic research. The following sub-sections present identified boundaries concerning this study.

8.8.1 Assumptions

This study began with an assumption that critical thinking was already being developed during a first-year university chemistry class. From document analysis, interviews and lecture observations, it was quickly apparent that there was a huge variation in the lecturers' understanding of critical thinking and their perceptions towards it.

This challenged one assumption and by extension threatens other assumptions concerning teaching practices within tertiary chemistry education, especially that existing practices may limit students' capacities and the development of their critical thinking capabilities.

8.8.2 Limitations

The limitations of this study include, but are not limited to:

- Lecturer survey participants responses were reflections and captures of what the lecturers were thinking at a point in time. They might have come up with alternative suggestions had they been allowed more time. Despite this, no lecturer chose to change the written summaries of his or her interview, even after being invited to change or add content. Again, the decision not to make changes may have been due to a lack of time, although this explanation is less likely given that no lecturer made changes.

- This study was only conducted with one cohort of students. Different cohorts may have experienced the course slightly differently. The number of students contributing to online surveys, although low compared to the overall students enrolled, was more than sufficient to draw trends and substantive indications of their thinking. It is unknown how seriously students considered their answers. In addition, the results are limited to what their perceptions were on the day they answered the survey.

- The context was the first-year chemistry course in one university. It was important to contain the data gathering so that the context was the same for the purposes of background and academic oversight and development. However, there are implications for other universities globally, and what might need to be considered for interventions, better alignment of university drivers, policies and practices to enable students to develop critical thinking more directly.
- There was a limitation in analysis of the findings of this study, as a lack of evidence precluded the use of three areas ("elements of reasoning", "intellectual standards" and "intellectual traits") from Paul and Elder critical thinking framework.

8.8.3 Delimitations

This thesis did not:

- Identify teaching strategies that lecturers were using that could potentially develop critical thinking in a first-year university chemistry course, other than the practices observed in this study and identified by the literature.
- Attempt to replicate this study in the general field of critical thinking.

8.9 Personal Reflections

My doctoral time has given me the gift of exploring my orientation as an early-career researcher and my stance as a person. This meant continuing reflection, as I have sought to articulate aspects of chemistry education. As I conclude this thesis, I trust that there will be opportunities to continue to examine educational problems, proffer solutions, establish theories and make scholarly contributions. I recognise that I am still learning. After interactions with the research participants, I strive to cautiously and authentically convey their voice in the discussions we had and various issues which have arisen, as well as present my own understanding of what I experienced. There has also been a moment for me to consider what might yet be if critical thinking is embedded into the teaching of chemistry in a first-year university course and what the reaction of students and comprehension of chemical content would be and the possibility of gaining more chemists.

8.10 Concluding Statement

This project, which uses a qualitative case-study design using multiple data sources, explores the development of student critical thinking skills through its integration into the lecturers' teaching practices. More specifically, the study focusses on the planned curriculum that influenced the lecturers enacted and assessed curriculum.

Lecturers teaching first-year chemistry were recruited for this study. In addition, students from the first-year enrolled in chemistry courses were involved. In total, 8 lecturers, and 88 students participated in the survey. Data were collected through key participants (lecturers mainly, and students) and key documents (curricular material). Lecturers in the first-year setting were asked to participate in an individual semi-structured interview while students were involved in a focus group conducted by the researcher. Students were asked to complete an online survey, which served as a stimulus for the focus group. Data were also collected from curricular materials provided by West University, Chemistry Department.

Results of this study indicate that lecturers engaged students in a lecture approach to teaching. Results also show that the lecturers displayed limited critical thinking focus and engaging teaching activities with the students. Students described their use of critical thinking more in individual study time rather than in the lecture sessions.

Although there is provision for developing students' critical thinking skills in the university's graduate attributes, the assessments provided to students did not require critical thinking at the departmental level, and therefore, lecturers did not have a mandate to develop critical thinking skills. Rather, what was assessed was content knowledge and interpretation. So, this is what the lecturers focussed on in their lectures.

This study confirms that there was a disconnection between the perceptions of academic staff (lecturers) and students (Lloyd & Bahr, 2010). For example, Gavin reported that if he did not have critical thinking skills, the university would not have employed him. He also believed that he has a good set of lecture notes, which would make up for the lack of active learning activities and guarantee students' understanding of the content taught. However, the students reported that they could not pay attention to Gavin because he was very slow, and they found the lecture boring. This is one of the examples where the perceptions of lecturers about what students needed were not the same as what students thought.

One of the important pedagogical considerations this thesis has highlighted is that there is the need for lecturers to make greater use of active student-centred learning activities and provide less use of direct instruction which has also been found previously (Watts & Becker, 2008). Given that several reports (Almatrodi, 2007; J. Y. Chan & Bauer, 2016; Greatorex & Malacova, 2006; Paul & Elder, 2008b) have shown that traditional lectures do not necessarily promote critical thinking, it is important to include a range of different teaching strategies for critical thinking to become effective.

There are many factors to take into consideration with lecturer development, including what they think about what they need to do in their teaching in relation to their perceptions about teaching and learning. Potentially this could include increasing their awareness of teaching approaches (strategies), inspiring them to be willing to change from the status quo and participate in professional learning as well as challenging inherent and persistent cultural perceptions about what students need to know, may assist implementation and inclusion of explicit teaching of critical thinking.

It is time for students to be given more meaningful experiences which enable them to connect content and the processes of learning. This thesis, therefore, lobbies not only for students to experience engaging approaches but for lecturers to undertake critical thinking professional training that includes activities that provide indicators that students are using critical thinking skills. Otherwise, how will lecturers know whether students are developing this graduate attribute? Given that through effective application of active learning, vital competencies such as critical thinking are developed (Blair, 2012), the infusion of critical thinking into the planning, teaching and assessment of the chemistry curriculum in first-year university students requires a change of perception from lecturers (Roehl et al., 2013).

All lecturers should be given time and tools to infuse an authentic critical thinking approach into teaching practices and actively assess critical thinking. Based on this study and the review of literature, this thesis calls to contemporary university chemistry education lecturers to integrate critical thinking explicitly into their teaching practices more widely.

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