# Pedagogical Strategies in Practical Report Writing and Teacher Perceptions of the IBDP Biology 2016 Internal Assessment: A Multiple Case Study

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# List of Abbreviations

ACARA Australian Curriculum and Assessment Reporting Authority

AR Assessment Research

ARB Annotated Research Bibliography

ATAR Australian Tertiary Admission Rank

CAS Creativity Action Service

CR Curriculum Research

EE Extended Essay

HL Higher Level

IA Internal Assessment

IBDP International Baccalaureate Diploma Programme

IBO International Baccalaureate Organisation

IERD International Educational Research Database

ISA International

ISES International Schools Examination Syndicate

JTRA Jeff Thomson Research Award

NOS Nature of Science

OCC Online Curriculum Community

OR Outcomes Research

PCT Pedagogical Challenge Type

PD Professional Development

PDR Programme Development Research

PIR Programme Impact Research

PLC Professional Learning Community

PLN Professional Learning Network

PSOW Practical Scheme of Work

QACI Queensland Academy of Creative Industries

QAHS Queensland Academy of Health Sciences

QAR Quality Assurance Research

QASMT Queensland Academy of Science, Maths and Technology

SACE South Australian Certificate of Education

SATAC South Australian Tertiary Admissions Centre

SL Standard Level

TGSM Teacher Guidance Support Materials

TOK Theory of Knowledge

VCE Victorian Certificate of Education

# Abstract

The internal assessment (IA) is an integral part of the International Baccalaureate Diploma Programme (IBDP) Biology curriculum, requiring students to design and execute an open-inquiry investigation and document results in a written practical report for summative assessment. The IA is internally assessed by teachers and then externally assessed by an International Baccalaureate Organisation (IBO) moderator. Many IBDP Biology teachers find the IA process is pedagogically challenging. This study explores practical assessment reform in the 2016 IBDP Biology curriculum from two perspectives: (1) teacher perceptions concerning introduction of the 2016 IA protocol; and (2) pedagogical strategies teachers utilise to develop student understanding of practical report writing.

A multiple case study was conducted involving three, highly qualified in-service IBDP Biology teachers, with varying degrees of teaching experience from three different International Baccalaureate (IB) schools in Australia. Participants undertook semi-structured interviews and provided various teacher-generated documents that were analysed using a grounded theory approach.

Key findings were broadly classified into two themes: (1) pedagogical strategies and (2) teacher perceptions of the reformed 2016 IA practical assessment. Key findings revealed teachers utilised a variety of mostly planned formative feedback strategies to develop students' practical report writing skills. Teachers primarily used a transmissive, teacher-centred pedagogy that focused on low-order cognitive skills during inquiry lessons. Overall, the teachers supported and appeared to prefer the 2016 IA compared to the previous 2009 IA due its broader mark-bands, which were perceived as enabling a more valid and fair assessment method.

Teachers reported having engaged in several different formal (IB and/or school-initiated) and informal (teacher-initiated) professional development experiences to develop their understanding of the 2016 IA, which were mainly beneficial. Low self-efficacy was generally experienced with planning, interpreting and implementing the 2016 IBDP Biology IA over both short- and long-term periods. Ten core pedagogical challenge types (PCTs) were identified in relation to the 2016 IA that appeared to significantly influence teacher self-efficacy at some stage. Most of the PCTs were successfully resolved, leading to significant enhancement of teacher self-efficacy in relation to future use of the 2016 IBDP Biology IA protocol.

**Key words**

assessment, curriculum reform, formative feedback, internal assessment, open-inquiry, pedagogy, teacher perceptions, practical report writing, professional development, self-efficacy.

## Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by any other person except where due reference is made.

Signature: ________________________

Date: ________________________

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*Don't let anyone rob you of your imagination, your creativity, or your curiosity*
-Mae Jemison, physicist and astronaut

# Chapter 1 Introduction

The International Baccalaureate Organisation (IBO) (2012) contends that all International Baccalaureate Diploma Program (IBDP) subjects are reviewed every seven years, in order to "ensure that each is fit for purpose in a changing world and incorporates the latest educational research and lessons learned from a thorough evaluation of the existing curriculum" (p. 1).

Prior to 2016, the IBDP Biology curriculum had remained unchanged since 2009 (IBO, 2017a). As well as the introduction of some new theoretical content, the new 2016 IBDP Biology curriculum also includes significant changes to the assessment of the summative practical investigation component, known as the 'internal assessment' (IA). Past studies (e.g. Fensham, 2009; Wallace, 2011; Ryder, 2015) have indicated that changes in practical work assessment may significantly influence teacher pedagogy – a factor which underpinned the first of my proposed research questions in the current study (i.e. *1. What pedagogical strategies are IBDP Biology teachers implementing to develop students' understanding of how to write effective practical reports in preparation for the internal assessment (IA)?*).

Laboratory or 'practical work,' as it is often referred to in Australian schools, is an important component of all secondary science curricula. Written practical reports have long been utilised as assessment items within school science curricula (Hodson, 1993; Hofstein & Lunetta, 2004). The written practical report continues to be widely used by contemporary science students and is highly regarded as an effective pedagogical tool for authentic teaching and learning in the sciences.

During the five years I taught the 2009 IBDP Biology curriculum in South Australian schools, I often observed that most students who performed well under high-stakes test conditions and who also had proficient grammatical skills, still perceived that practical report writing was particularly challenging. For example, when composing practical reports many of my students encountered difficulties when attempting to draw inferences from data and provide evidential support for conclusions. My observations are supported by Morgan, Fraga and Mc Cauley Jr.'s (2011) study of high school Biology students who reported that writing practical reports was particularly difficult. Sandoval and Millwood (2005) established that high school science students generally found constructing arguments in which appropriate evidence had to be provided for claims made in relation to empirical data problematic. Additionally, Porter et al. (2010) observed that practical report writing was perceived by university Chemistry students as being particularly challenging.

In my experience, difficulties associated with practical report writing were particularly palpable amongst students studying the first year of the two year 2009 IBDP Biology program. Such difficulties were especially evident when students attempted to effectively address the *Conclusion and Evaluation* criterion of the IA report. Typically, many of my Biology students struggled to attain at the highest achievement levels of the 2009 IA rubric assessment scheme (see Appendix A). Furthermore, these students continued to be challenged by writing practical reports even after several months into their studies, although many made significant improvements by the second year of the IBDP Biology curriculum. My observations concerning students' difficulties with practical report writing were discussed repeatedly and anecdotally corroborated during informal conversations with other IBDP Group 4 subject[1] teachers of varying levels of IB teaching experience and also with external IBDP Group 4 IA moderators.

Conflicting reports within the IBO literature between 2010 and 2012 concerning the 2009 IA protocol, suggested that the IA was under review and that professional opinions about it were somewhat divided. For example, the IBO (2010) reported that based on 275 questionnaires from teachers and/or schools, 92.8 % of the respondents worldwide agreed that the 2009 IA protocol was appropriate for assessing practical skills and applying the scientific method. This view, however, directly contrasted with my own views *and* those expressed by several Group 4 IBDP moderators in a 2012 IBO report prepared by a panel of six IB personnel, including three principal IA moderators and senior IA moderators from different IB global regions[2] and school contexts, who reviewed the 2009 IBDP Group 4 IA in 2011. The 2012 IBO report explicitly acknowledged the need for an IA overhaul in Recommendation 5 that stated: "Group 4 IA has been problematic for many years. The Internal review committee came to the conclusion that the current IA cannot be fixed so proposed developing a new IA" (IBO, 2012, p. 1). Although the IBO's

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[1] IBDP Group 4 subjects include Biology, Chemistry and Physics

[2] There are three regional organisations within the IBO including: (1) Africa, Europe and the Middle East; (2) the Americas and (3) the Asia/Pacific region.

(2012) report does not outline the specific problems associated with the 2009 IA, it proposed that the “new generic criteria for assessment will allow both a wider range of activities satisfying the varying needs of the three subjects (i.e. IBDP Biology, Chemistry and Physics) and more agreement of marks awarded as a result of the application of the criteria” (p. 2).

The IBO’s (2012) report refers to an agreement of marks awarded and indicates a strong intention to improve the IA’s inter-rater reliability. Inter-rater reliability is vitally important, since all summative IA practical reports are initially internally moderated by IBDP Group 4 teachers and subsequently externally moderated by the IBO. It appears that since the IBO experts deemed the 2009 IA protocol ‘problematic’, change was inevitable, with the 2011 meeting ultimately prompting development of the new 2016 IA protocol. Consequently, the development of the 2016 IA protocol led me to question how the current group of IBDP Biology teachers perceived the IA assessment reform, which formed the basis of my second research question (i.e. *2. What are IBDP Biology teachers’ perceptions concerning the introduction of the new 2016 IA protocol in practical work?*).

## 1.1 IBDP Group 4 Subject Curriculum Changes in the Internal Assessment (IA)

International Baccalaureate Diploma Programme (IBDP) Biology is one of the three Group 4 (Biology, Chemistry & Physics) *pure science* subjects taught within the two-year IB Diploma Programme (DP). In 2015, the 2016 IBDP Biology curriculum was first introduced by the IBO to Southern Hemisphere IBDP schools in readiness for final examinations in November 2016.

Four broad changes were made to the IA component in the 2016 IBDP Biology curriculum. The first change to the IA affected the number of summative tasks to be attempted and submitted. The 2016 curriculum requires students to develop their own authentic research question and to design, execute and submit a *single*, open-inquiry investigation for summative assessment. The 2009 IA protocol, however, allowed students to not only undertake several summative IA investigations over the two year curriculum, but also choose the two best examples of each of three different IA report criteria (i.e. design {D}, data collection and processing {DCP} and conclusion and evaluation {CE}). Students undertaking the 2009 IA could, therefore, submit between two to six reports for summative assessment depending upon how many of the three criteria were assessed within a single investigation. Secondly, the length of the IA report is specified in the 2016 IBDP Biology guide to be between six to twelve pages. Conversely, there was no formal page limit set for the 2009 IA reports. A third change involved the assessment weighting of the summative IA report. The 2016 IA constitutes 20% of the final summative grade within all IBDP Group 4 pure science subjects, as opposed to the

2009 IA weighting of 24%. The fourth change relates to the IA criterion-related marking rubric used to assess IA reports. Although the fundamental scientific skills of the 2009 IA remain unchanged, the 2016 IA rubric includes changes to the type, name and number of evaluation criteria, as well as the application of a broader mark-scheme to most criteria. Other innovations associated with the 2016 IA protocol include the introduction of two entirely new assessment criteria, known as '*Personal Engagement'* and '*Communication'* respectively (See Appendix B - 2016 IA rubric and Appendix A 2009 IA rubric).

This study represents the first, in-depth exploration of teachers' perceptions of the 2016 Group 4 IBDP Biology curriculum reform and the identification of specific pedagogical strategies utilised to develop students' practical report writing skills for the summative IA. No other literature study could be located that explored these perceptions and strategies used to assist students with writing IA reports following practical assessment reform in IBDP Biology. Consequently, it is anticipated that this study will address a significant gap in the IB literature and enable the development of a better understanding of the pedagogical challenges involving practical assessment reform, from the teachers' perspective. Furthermore, it is anticipated that this research will help inform a variety of stakeholders involved in planning and/or implementing IA reform in practical work, including IBDP Group 4 science curriculum policy-makers, professional development staff, moderators, faculty coordinators and subject teachers.

The purpose of this study was therefore to explore the two main research questions:

*1. What pedagogical strategies are IBDP Biology teachers implementing to develop students' understanding of how to write effective practical reports in preparation for the internal assessment (IA)?*

*2. What are IBDP Biology teachers' perceptions concerning the introduction of the new 2016 IA protocol in practical work?*

## 1.2 The International Baccalaureate Diploma Programme (IBDP)

**This section is about the IBDP. Readers who are already familiar with this programme will *not* need to read this section and should therefore proceed directly to the Literature Review in Chapter 2.**

***IB Mission Statement***

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect. To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment. These programmes encourage students across the world to become active, compassionate and lifelong

> learners who understand that other people, with their differences, can also be right (IBO, 2017b).

### 1.4.1 Origins and Philosophical Rationale of the IB Diploma Programme

The International Baccalaureate Diploma Programme (IBDP) is a two-year senior secondary curriculum primarily catering for students aged between 16 and 19 years old. It was the first programme the IB developed to provide an international pre-university education for children of educated expatriates working in Geneva for the United Nations during the 1960s-1970s to suit their globally mobile lifestyles (Doherty, Mu & Shields, 2009).

In 1962 the International Schools Association (ISA) organised a conference in Geneva for social studies teachers in international schools, which ultimately resulted in developing the first IB subject - Contemporary History (Hill, 2006, p. 19). The IBDP was greatly influenced by both teachers and parents who supported an internationally recognised diploma that provided "an international passport to higher education" (Hill, 2002, p. 19), as well as global mobility. Currently there are four IB programmes including the Primary Years Programme (IBPYP), Middle Years Programme (IBMYP), Career-related Programme (IBCP) and the Diploma Programme (IBDP) which collectively cater for students ranging from three to nineteen years old (Figure 1). Throughout all of the IB programmes international-mindedness is underpinned by each of the ten Learner Profile attributes (see Appendix C). The IB Diploma currently offers a globally portable qualification accepted by most universities throughout the world (Bagnall, 2005).

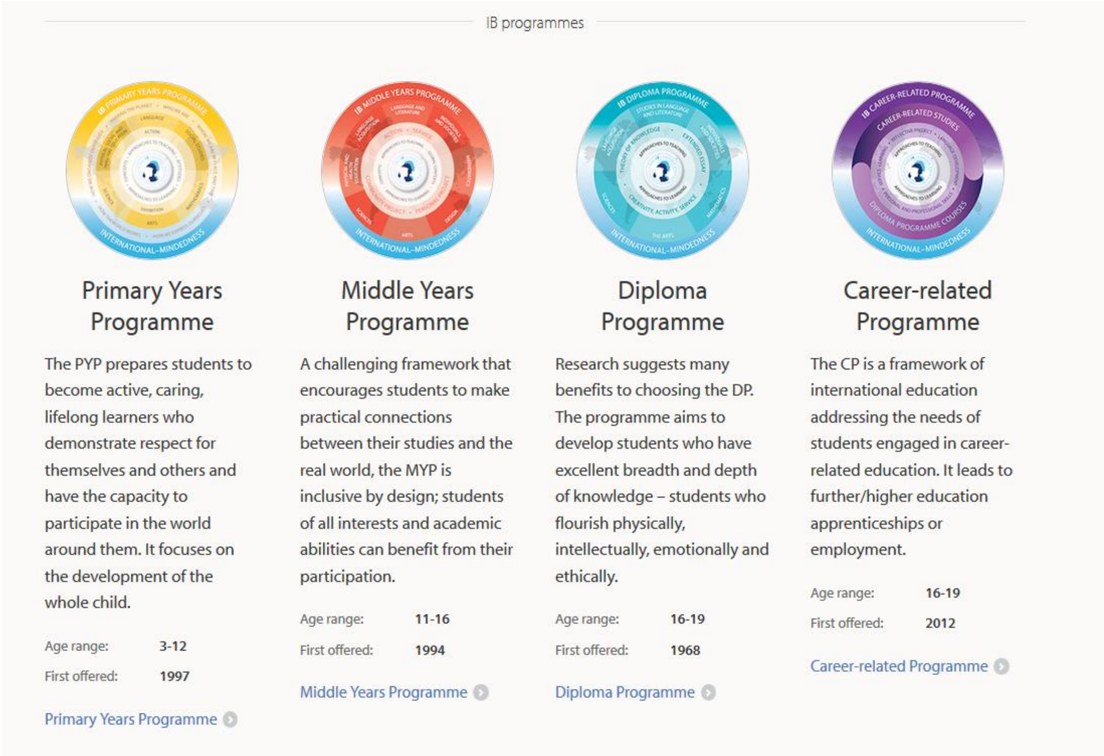


**Figure 1 IB Programmes (IBO, 2017c)**

### 1.4.2 IBDP School Authorisation

Recent IB statistics indicate that on the 16th of March, 2017, the DP curriculum was being taught in 3104 schools within 147 countries (IBO, 2017d). Before schools can offer IB educational programmes, they must undergo a rigorous authorisation process taking anywhere from two to three years to complete. According to the IB, schools intending to provide IB programmes, "must demonstrate that the infrastructure and skills are in place to deliver the programme to the IB's high standards" (IBO, 2017e). IB authorisation requires schools to appoint a DP coordinator and ensure that staff engage in the IBO's *mandatory* professional development. Verification visits and various professional development sessions occur during the authorisation period to guarantee that potential IB schools are well organised and capable of implementing the programme.

Professional development is regularly provided for educators via a wide variety of modes. Teachers new to the IBDP are required by the IBO to attend a face-to-face *Category 1 Workshop –developing expertise in new IB educators*. Category 1 workshops include 15 hours of PD spread across two-and-a-half days, covering topics such as the philosophical basis of the DP, the program standards and practices relevant to each teacher and the programmatic framework relevant to the subject area, like IBDP Biology. The *Category 2 Workshop–developing expertise in the current IB educators* and the *Category 3 Workshop – strengthening skills and sharing exceptional practice* are mainly for teachers with some prior experience in teaching and assessing an IB programme. In addition to workshops, schools can arrange with the IB to have in-school or cluster-event workshops for groups of schools in which experts are brought into a school for professional development. Online workshops are also held periodically throughout the academic year, so that educators who would rather work in a more cost-effective and convenient PD mode, can do so. In IBDP Biology for example, an online course on the IA is regularly held. The *Online Curriculum Centre* (OCC) is a separate website from the IBO website that provides educators with password-only access to a wide range of additional professional development resources, such as subject-related teacher discussion forums, access to exemplars of marked externally moderated scientific investigations, as well as past examination papers and solutions. Teachers may contact moderators through discussion forums on the OCC to clarify issues related to their specific subject area

### 1.4.3 IBDP Schools in the Australian Context

Australia is included in the IB Asia/Pacific group of schools with its Head Office in Singapore. At present, there are 185 IB World Schools operating within Australia of which 71 implement the IB Diploma Program curriculum (IBO, 2017f).

The IB Diploma has become an increasingly popular option as a 'global' alternative to the state and territory-based senior secondary curricula, such as the South Australian Certificate of Education (SACE) and the Victorian Certificate of Education (VCE) offered in Australian schools (Table 1). By 2014, the intake of IB Diploma students had nearly tripled compared with the early 2000s (Savage, 2014). New South Wales currently has the greatest number of IB Diploma schools in Australia, whereas the Northern Territory has the lowest number of just one school.

**Table 1 - IB Diploma Schools in Australia (IBO, 2017g)**

| **Australian States and Territories** | **Number of IB Diploma Schools** |
|---|---|
| New South Wales | 18 |
| Victoria | 16 |
| Queensland | 13 |
| South Australia | 10 |
| Australian Capital Territory | 5 |
| Western Australia | 5 |
| Tasmania | 2 |
| Northern Territory | 1 |

### 1.4.4 IBDP Curriculum

The IBDP curriculum (Figure 2) emphasises academic breadth, rather than the more specialist approach characteristic of the state-based/territory-based curricula currently operating within Australia (Savage, 2014). Although originally designed to be delivered within international schools to cater for "multicultural globally mobile student populations worldwide" (Doherty et al., 2009, p. 86), the IBDP curriculum now offers an 'international-education' alternative to many national education systems throughout the world, including Australia.


**Figure 2 - The IB Diploma Programme Curriculum Model (IBO, 2017 b)**

Students studying the IBDP curriculum are required to choose *one* subject from each of a group of five disciplines that include the following:

Group 1 Language and Literature (mother tongue language only)

Group 2 Language acquisition (a second, ‘foreign’ language)

Group 3 Individuals and Society

Group 4 Experimental Sciences

Group 5 Mathematics

Group 6 Arts

Furthermore, students must select one extra subject from either the Arts or another one from Groups 1 to 5. In line with the philosophy of the IBDP, students may elect subjects at either the standard level (SL) or higher level (HL). The IB recommends that approximately 150 hours of instructional time occurs in the SL course and 240 hours in the HL course. Both the SL and HL programmes are equally challenging, as they are subject to the same standards of assessment rigour (IBO, 2015). It is recommended that a maximum of three or four (but not more than four) subjects are taken at HL, while the rest must be SL subjects.

Additionally, students must undertake a compulsory component known as the ‘core requirements,’ which includes:

*1. Extended Essay (EE)*

The EE is an independent, non-time-tabled research requirement in which students investigate their own topic within one of their six subject areas they are currently studying. Students formulate a research question and conduct independent research culminating in a 4000 word essay that is formally written up according to university-level academic conventions. A supervising teacher guides the student throughout the research process over a one year period. The EE contributes towards the final IB Diploma grade.

*2. Theory of Knowledge (TOK)*

Theory of Knowledge is a philosophy-based subject examining critical thinking and explores the epistemological basis of knowledge. Students explore knowledge claims across the full range of their six subjects, to develop an awareness of their own perspectives and how these differ from those of others. TOK also contributes towards the final IB Diploma grade.

*3. Creativity, Action and Service (CAS)*

According to the IBO, CAS includes three strands, namely:

- Creativity (arts, and other experiences that involve creative thinking)
- Action (physical exertion contributing to a healthy lifestyle)
- Service (an unpaid and voluntary exchange that has a learning benefit for the student) (IBO, 2014).

CAS helps students develop their personal identities through considering ethical principles, based upon the Learner Profile (LP) attributes. Although CAS does not contribute towards the final grade, all students must engage in this requirement to fulfil the IBDP award. The EE and TOK are the most academically challenging areas of DP study and are considered by the IB as excellent preparation for students in their transition from senior secondary school into university and life beyond academia (IBO, 2014).

### 1.4.5 IBDP Assessment

IB Diploma subjects are both externally and internally assessed. External assessment items, such as examination papers are assessed by IB examiners. Teachers, however, assess internal assessment items, which are subsequently externally moderated by the IBO. Although the IBDP includes both formative and summative assessment opportunities, it "primarily focuses on summative assessment" (IBO, 2014, p. 142). Teachers are, however, encouraged to use summative assessment instruments to guide formative teaching and learning. Open-ended, internal assessment tasks are appraised using a criterion-related assessment approach. Assessment items are evaluated according to specific characteristics describing the achievement levels that might be expected and which are consistent with the aims and objectives inherent within a particular subject. Further details about specific assessment guidelines for IBDP Biology are outlined in section 1.4.8.

The final Diploma score is calculated based on a grade from 1 (lowest) to 7 (highest) for each subject, with the maximum being 42 points for six subjects, excluding a maximum of 3 points awarded for the combined result of the EE and TOK. Students must earn 45 points to achieve a perfect score for the IB Diploma program, providing they have also successfully completed their CAS requirements.

### 1.4.6 Group 4 IBDP Subjects

To fulfil the IBDP, students must select at least one of seven Group 4 subject disciplines, including Biology, computer science, Chemistry, design and technology, environmental systems and societies, Physics and sports, exercise and health science (SL only). Environmental Systems and Societies is an interdisciplinary subject that meets requirements for both Groups 3 and 4. The pure science[3] subjects of Biology, Chemistry and Physics are unified by an overarching theme referred to as Nature of Science (NOS) in the 21st century. The five main NOS themes[4] are outlined in detail as 'understandings' within curriculum guides for each pure science subject and include the following:

1. What is science and what is scientific endeavour?
2. The understanding of science.

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[3] 'Pure sciences' will be defined here as including only Biology, Chemistry and Physics from the Group 4 subjects.

[4] Each NOS theme includes several paragraphs documented as separate parts (i.e. 1.1, 1.2, etc.)

3. The objectivity of science.
4. The human face of science.
5. Scientific literacy and the public understanding of science (IBO, 2014).

Every sub-topic within the syllabus statement of a pure science subject is accompanied by a NOS statement outlining how at least one NOS theme applies to the understandings, skills and applications of the sub-topic (see Appendix D). According to the IBO (2014), it is anticipated students will gain an appreciation of how scientists operate and communicate with one another through a strong emphasis placed upon experimental work within the pure sciences. The syllabus format for the three pure sciences is identical ten generic aims that have a strong focus on experimental investigations.

The Group 4 aims are guided by the overarching NOS themes in which students are to:

1. appreciate scientific study and creativity within a global context through stimulating and challenging opportunities;
2. acquire a body of knowledge, methods and techniques that characterise science and technology;
3. apply and use a body of knowledge, methods and techniques that characterise science and technology;
4. develop an ability to analyse, evaluate and synthesise scientific information;

5. develop a critical awareness of the need for, and the value of, effective collaboration and communication during scientific activities;
6. develop experimental and investigative scientific skills including the use of current technologies;
7. develop and apply 21st century communication skills in the study of science;
8. become critically aware, as global citizens, of the ethical implications of using science and technology;
9. develop an appreciation of the possibilities and limitations of science and technology and
10. develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge (IBO, 2014, p. 18).

**1.4.7 IBDP Biology**

As one of the three pure sciences, within the Group 4 subjects, IBDP Biology can be studied at either Standard level (SL) or Higher level (HL) - the main difference between the two levels relates to the breadth and depth of content. The SL syllabus includes six core topics and one option topic, while the HL syllabus includes 11 core topics and two option topics. The six core SL topics are common to the HL syllabus. Copies of syllabus guides for both the 2016 SL and HL IBDP Biology curricula have been included (see Appendix E).

***Summative Assessment - 2016***

Summative assessment in IBDP Biology includes two main components, which are the same for both the SL and HL curricula and include:

1. three examination papers – overall weighting of 80%
2. internal assessment (IA) – overall weighting of 20%

Examination papers primarily assess theoretical content, although they also include questions based upon analysis of secondary experimental data.

The *internal assessment*, the subject of this study, requires that students conduct one individual scientific investigation of their own choice over a period of about 10 hours in the form of a six to twelve page, written practical report. This report includes the same requirements for Biology, Chemistry and Physics, as well as identical generic assessment criteria outlined within a criterion-based, rubric assessment scheme. The IA is a complex task that is rigorously assessed requiring students to develop their own research question accompanied by a justifiable scientific rationale. Furthermore, students may choose to undertake one of a number of possible tasks, some of which may include a traditional hands-on laboratory investigation, extraction of data from a database and graphical analysis or even the development of an interactive, open-ended simulation. The current, 2016 IBDP Biology curriculum comprises five IA criteria that include:

1. Personal Engagement
2. Exploration
3. Analysis

4. Evaluation
5. Communication

Each criterion includes several descriptors that describe specific achievement levels, matched to a marks-band ranging from either 0 to 6, 0 to 4 or 0 to 2 marks. Some achievement levels include descriptors that allocate up to two marks within a mark-band and in these cases teachers are required to make decisions regarding the allocation of either the lower or higher mark to a descriptor, as partial marks cannot be awarded. The IB recommends that teachers adopt a "best-fit approach" (IBO, 2014, p. 152) when marking, so that the final mark allocated represents a fair judgement of a student's overall achievement for each criterion. Marked exemplars of internal assessment investigations are provided by the IBO and can be accessed by teachers in the support material of the Biology section in the online curriculum centre (OCC). The 'internal assessment' is thus *internally assessed* by the subject teacher and then externally moderated by the IBO.

The *Group 4 Project* is an additional compulsory component of the pure sciences that is not formally assessed, but requires students from different Group 4 subjects (excluding Environmental Systems and Societies) to collaborate together on a topic that is either scientific or technological and which may be practically or theoretically based. The Group 4 Project places an emphasis on collaborative group work, rather than the end-product of the activity. It is anticipated students will develop an appreciation of the "environmental, social and ethical implications of science and technology" (IBO, 2014, p.161) and better understand the way in which scientists cooperatively interact in an interdisciplinary manner in an attempt to solve problems. The Group 4 Project is based on science or its applications and must address Group 4 aims 7, 8 and 10 (see Appendix F).

***Formative Assessment***

Formative assessment activities within Biology are solely planned by teachers and generally include a series of tests and investigative activities designed to provide feedback to both students and teachers about the students' learning progress. Teachers usually set one test for each topic, as well as a mid-year examination in both Year 11 and 12 to monitor the students' learning of the theoretical components of the course.

Practical work, however, requires a different approach. Biology teachers are required to plan their own *practical scheme of work* (PSOW) which includes all formatively assessed investigations that students undertake throughout the two year program. Teachers select various activities including several complex open-inquiry experiments that are conceptually demanding, and some simpler, more guided-inquiry investigations. When planning practical activities, teachers consider factors such as their teaching style, availability of resources and the nature of the student cohort. Suggestions for practical investigations are provided by the IB within the Biology syllabus and may include activities, such as short practicals conducted over extended time periods, computer simulations, databases using secondary data, fieldwork, questionnaires and development/use of models. Teachers may participate in discussion forums on the OCC website and share practical resources with other Biology teachers. Upon conclusion of the course, teachers must provide a copy of the class Form 4/PSOW, listing all of the completed formative practical activities to the moderator.

### 1.4.8 IBDP Curriculum Review and Development

The education arm of the IB Board of Governors manages academic policy across all IB programmes, with the Diploma Review Committee (DRC) reviewing each DP syllabus every seven years (IBO, 2017b). The DRC maintains curricula by keeping abreast of global changes, is cognisant of contemporary education research and considers responses to evaluation reviews of current curricula (IBO, 2017b). The review process is inclusive and involves several stakeholders, such as IB schools, teachers, students, alumni, consultants, examiners and moderators are involved, as well as DRC members. The three phases in the review process include evaluation, development and implementation, which can be accessed from the IBO website (IBO, 2017b).

### 1.4.9 Professional Development Opportunities

The IBO provides several different modes of professional development (PD) for teachers which include face-to-face, online workshops, webinars, blended learning and e-learning resources. Schools can avail themselves of PD opportunities that are held within their own school or alternatively, at cluster workshops and regional conferences off-site. Three categories of PD workshops can be undertaken by teachers, which include:

Category 1 which focuses primarily on IB philosophy and implementation of the program and is considered mandatory for teachers new to teaching the IB.

Category 2 which focuses on the delivery of the four IB programmes of education.

Category 3 which provides an opportunity to focus in some depth on an aspect within a specific area of the curriculum such as the *internal assessment* (IA) in IBDP Biology.

# Chapter 2 Literature Review

In order to explore the two research questions, "what pedagogical strategies are IBDP Biology teachers implementing to develop students' understanding of how to write effective practical reports in preparation for the internal assessment (IA)" and (2) "what are IBDP Biology teachers' perceptions concerning the introduction of the new 2016 IA protocol in practical work?", a theoretical framework comprising four schemas was adopted: (1) a constructivist teaching and learning approach; (2) Bereiter and Scardamalia's (1987) metacognitive models of writing; (3) scientific argumentation models and (4) epistemological reasoning models for developing scientific explanations. Science practical report writing is explored from the perspective of pedagogical and learning challenges, the teacher's roles in developing effective pedagogical practices for facilitating students' writing skills and the impact of externally driven curriculum reform on science teachers' perceptions and pedagogy.

## 2.1 Theoretical Frameworks Applicable to Science Practical Report Writing

### 2.1.1 Constructivist influences on teaching and learning in scientific practical report writing

#### *2.1.1.1 Defining constructivism*

Constructivism has probably been the most influential theoretical perspective in science education for the past three decades. This perspective is based upon the premise that learners actively engage in building their own knowledge with the teacher who assumes the role of facilitator rather than transmitter of knowledge (Conner, 2014; Siemears, 2012; Lew; 2010; Osborne, 2000).

Constructivism is underpinned by two main theoretical perspectives: personal constructivism and social constructivism. Firstly, personal constructivism, is based upon Piaget's (1964) ideas that learners individually build upon their own existing knowledge and experiences to construct new knowledge. Social constructivism, however, is an extension of personal constructivism, which emerged from Vygotsky's (1978) notion that the social aspect of learning enables knowledge construction through collaborative interactions with other learners (Walker et al., 2013). Vygotsky (1978) proposed the zone of proximal development (ZPD) concept to describe how students gain help from others such as their peers and teachers, when learning how to acquire new knowledge.

Conner (2014) recognised that constructivism historically focused on learning conceptual knowledge, which prompted her proposition of 'evaluative constructivism' to explain *how* students learn and *when* they should engage with specific learning styles.

Conner's (2014) interpretation of constructivism is underpinned by cognitive psychology principles, such as information processing, self-regulated learning and situated cognition.

#### *2.1.1.2 Constructivist teaching and learning in the science classroom*

Constructivist teachers promote student-centred, socially interactive, collaborative and reflective learning environments that emphasise establishment of a student's prior knowledge. Furthermore, such teachers encourage students to construct accurate scientific understandings through participating in a variety of authentic, engaging activities to address their alternative conceptions. (Conner, 2014; Garbett, 2011; Lew, 2010). Keys (1999) stated that "instruction emphasising inquiry and problem-solving within social, cultural and technological contexts is consistent with constructivist theories of learning science" (p. 119).

#### *2.1.1.3 Scientific inquiry in the science laboratory: An authentic setting for constructivist teaching and learning in IBDP Biology*

The IBO 2016 Biology curriculum guide recognises the human face of science and dedicates a significant section to the nature of science (NOS) that includes multiple references supporting a socially-constructivist, investigative approach to scientific inquiry:

> Both the ideas and processes of science can only occur in a human context. Science is only carried out by a community of people from a wide variety of backgrounds and traditions, and this clearly influenced the way science has proceeded at different times. It is important to understand, however, that to do science is to be

> involved in a community of inquiry with certain common principles, methodologies, understandings and processes (IBO, 2014, p. 7).

According to Keys (1999), open-inquiry investigations lend themselves to authentic purposes for students to write scientifically by "keeping track of procedures and data, reflecting on quality of designs, brainstorming new ideas, making meaning of results and communicating what they have found to others." (p. 120).

Duschl (2008), drawing on the research of Gee (1996) and Lemke (1990), pointed out that contemporary school science requires students to appropriate language skills unique to the scientific domain. Peker et al. (2011) asserted that the language used to construct scientific explanations involves more than simply extracting information from empirical data; it also relies on writers interpreting and linking this information with prior experiences. Yore (2010) contended that school science often emphasises the mathematical and communicative roles of language instead of focusing more on the constructive and persuasive elements that help develop new understandings. Through socially interacting with their peers and the teacher, students engage in talking and listening, which allows them to reflect on both their own ideas and those of others to promote deeper thinking (Yore, 2010). Cavagnetto et al. (2011) proposed that language is crucial in creating an authentic learning environment, "not only on the individual level (personally, while writing or reflecting), but also at the social level through listening to ideas, questioning ideas and defending ideas" (p. 194).

Rivard et al.'s (2000) study of eighth grade science students in Canada, revealed that analytical writing was important in developing simple ideas into more structured knowledge. Additionally, peer discussions amongst the students enabled them to share, clarify and disseminate their knowledge through using questions, hypotheses, explanations and development of ideas. Rivard et al. (2000) concluded that:

> These two modalities appear to be dialectical: talk is social, divergent, and generative, whereas writing is personal, convergent, and reflective. Moreover, writing appears to enhance the retention of co-constructed knowledge over time" (p. 588).

The role of both written and oral language in science learning has been extensively studied in recent decades with most researchers agreeing that language is critical in constructing scientific knowledge. According to Florence and Yore (2004), since language is constructed by humans, "knowledge must be influenced by, though not totally dependent upon the society and culture in which the language exists" (p. 639). Florence et al. (2004) stated that for scientists to become enculturated into the discourse of the scientific community, they must be proficient at using both oral and written language to describe "known events, predictions of future events, speculations of causality, and metaphoric models to help conceptualise science for themselves and their research groups" (p. 638)

### 2.1.2 Writing effective secondary school science practical reports in the 21st century

Cavagnetto (2010) suggested four domains of understanding that enable students to produce effective scientific practical reports: (1) epistemological and linguistic features of the scientific genre; (2) metacognition; (3) scientific explanation and (4) argumentation (Cavagnetto, 2010).

#### *2.1.2.1 Epistemological and linguistic features of scientific genre in practical report writing*

Recent science education trends indicate a wide acceptance amongst researchers that contemporary scientifically literate individuals require more than content and procedural knowledge of science; they must also have an epistemic knowledge (Cavagnetto, 2010). These views are also reflected in several contemporary science curriculum guides (e.g. IBO, 2014; ACARA, 2012) and other key science documents (e.g. PISA, 2015). For example, the 2014 IDBP Biology curriculum guide, nature of science (NOS) statement 3.2 states that "scientists analyse data and look for patterns, trends or discrepancies, attempting to discover  relationships and establish causal links" (IBO, 2014, p. 9). Epistemic scientific knowledge is, therefore, particularly relevant in open-inquiry investigations like the IA in which students must evaluate experimental design and justify claims made in conclusions. In recognising the socio-cultural perspective, many educational researchers suggest scientific learning requires students to undertake a cognitive 'apprenticeship' (Sandoval et al., 2005; Florence et al., 2004; Gee, 2004 ) to enhance their scientific communication. Gee (2004) argued that successful scientific communication arises when students have several opportunities to actively engage within the culture of the scientific semiotic domain. Furthermore, Gee (2004) highlighted that experience and confidence in using domain-specific language, is key to interpreting and using language successfully to promote scientific learning. Halliday et al. (1993) strongly advocated that students should engage with the scientific genre through explicit instruction, before participating within the domain. Hand and Prain (2006), however, recognised that scientific educators need to understand how to help students develop the type of 'scientific habits of minds' that scientists frequently adopt. For example, Hand et al. (2006) pointed out that writing laboratory reports allows scientists to present their findings in scientific journals. Moreover, they claimed that students do not often consider using the "rich dialogues, the redrafting processes, and the revising and tentative acceptance of ideas" (Hand et al., 2006, p. 106) that scientists typically use when composing laboratory reports.

These various literature perspectives of scientific language pose important pedagogical implications for practical report writing in IBDP Biology. For example, the IBO supports the idea that Biology students can build tentative claims to develop effective explanations about experimental data – a notion that is explicitly stated in NOS statement 3.8 of the 2016 IBDP Biology curriculum guide: "although scientists cannot ever be certain that a result or finding is correct, we know that some scientific results are close to certainty" (IBO, 2014, p. 9).

#### ***2.1.2.2 Metacognitive models: Promoting higher-order thinking skills to develop effective scientific writing of practical reports***

Practical report writing involves complex higher-order thinking that is cognitively demanding. Higher-order thinking requires students to develop new cognitive strategies that involve ‘thinking about thinking’ - a phrase often associated with metacognition. Schraw and Moshman’s (2006) updated interpretation of Flavell’s (1995) metacognitive framework comprises two elements: (1) knowledge of cognition and (2) regulation of cognition. Knowledge of cognition involves a personal awareness of learning on three levels: declarative (knowing of self), procedural (knowing how to enact a task) and conditional (knowing when/why to apply specific strategies). However, regulation of cognition involves activities undertaken to control regulation of cognitive processes and involves planning, monitoring and evaluation (Schraw et al., 2006). According to Schraw et al. (2006) cognitive regulation is highly relevant to open-inquiry learning. Planning, for example, may involve students proposing a research question and hypotheses, designing experiments and thinking about data collection and presentation. Monitoring involves checking existing knowledge and the skills needed to enact it, but may also involve collaborating with peers or consulting literature. Finally, evaluating requires reflection as students consider what they learned from the investigation and how to accurately express their knowledge in writing.

Bereiter et al.’s (1987) knowledge-telling (KTE) and knowledge-transformation (KTR) metacognitive models have been used by several contemporary scholars (e.g. Whitehead et al., 2014; Klein et al., 2010; Gunel et al., 2009; Keys, 1999), albeit in various modified formats to inform research examining the link between student writing and learning in school science. According to Bereiter et al. (1987), inexperienced writers often use simplistic cognitive processes to write and devote little effort towards knowledge transformation. Furthermore, Bereiter et al. (1987) contended that skilled writers generally employ higher-order thinking skills, such as problem-solving, that allow them to achieve new and deeper understandings.

Klein et al. (2010) likened the KTR model to two “mental spaces” - the content space and the rhetorical space. Students with highly developed metacognition use their existing knowledge (content space) to explain meaning and think about how to persuasively express understandings (rhetorical space). Whitehead et al. (2014) pointed out that KTR cognitive processing is necessary when writing the discussion and conclusion sections of practical reports, because it “engages students in causal thinking that connects actions and observations to the science that explains results” (p. 493). Bereiter et al. (1987) asserted that the interaction of both the content and rhetorical problem spaces enables reflective writing. Bereiter et al.’s (1987) metacognitive models provide a useful way to explain how novice writers utilise different strategies compared to more expert writers. According to Keys (1999), expert science writers generally consider both the content and rhetorical domains, while novices concentrate on rhetoric more than scientific content.

#### *2.1.2.3 Contemporary research conceptualisations concerning the nature of explanation, argument and argumentation in scientific writing*

Teacher pedagogies that help students enhance the quality of their written practical reports have been widely researched (Braaten & Windschitl, 2011; Ruiz-Primo et al., 2010; Mc Neil, 2008). Most of this research has, however, primarily focused on the teachers’ use of scientific argumentation rather than scientific explanation. Some research suggests that the research bias towards scientific argumentation has been mainly due to many academic scholars misinterpreting the terms ‘explanation’ and ‘argumentation’ (Tang, 2016; Braaten et al., 2011). Osborne and Patterson (2011) were the first researchers to recognise the conflated use of both concepts within the literature and so addressed the issue in their paper.

### Scientific explanation

Many science education researchers (e.g. Tang, 2016; Peker et al., 2011; Mc Neil, 2008) have claimed that scientific explanation is critically important in fostering a student’s enculturation into epistemological scientific practices and effective knowledge construction. According to Osborne et al. (2011) a scientific explanation requires students to “make sense of a phenomenon based on scientific facts” (p. 629) and usually answers a question.  Conversely, Braaten et al. (2011) defined scientific explanation as “communication of reasoning in an effort to make thinking visible or audible within the science classroom” (p. 645). Tang (2016) acknowledged that a scientific explanation is more than a definition or description of an observable phenomenon, since students must provide theoretical accounts of *how* and/or *why* the phenomenon is the way it is. For example, Tang (2016) explained that when students are asked to ‘explain photosynthesis’ they are really being asked to define photosynthesis rather than explain it. However, if asked ‘How is photosynthesis carried out in a plant cell?’ this would require a scientific explanation based on theoretical principles, such as an understanding of leaf anatomy, diffusion and biochemical reactions.

In the past two decades, several epistemological reasoning models have been proposed to conceptualise scientific explanations (Braaten et al., 2011; Veel, 1997; Driver, Leach, Millar & Scott, 1996). Most models include reasoning categories requiring descriptions, causal accounts and the utilisation of scientific theories and models to explain observations. Braaten et al. (2011) identified five key models of scientific explanatory reasoning that emerged from science philosophy:

1. Covering Law - scientific explanations based on patterns emerging from empirical observations;
2. Statistical/Probabilistic –induction from trends/patterns in data in which a cause may or may not be sought to explain observations;
3. Causal – inductive explanations relying on patterns in data that involve searching for a particular cause of the observation;
4. Pragmatic –proposal of different acceptable, but equally valid explanations which can appear irrelevant to other people and
5. Unification – explanations generally utilised for singular events unified into generalisations based upon scientific models or theories.

Braaten et al.'s (2011) study found that grade 6-12 science students mainly utilised Causal and Unification explanatory models when composing scientific explanations. Tang (2016) discovered that in secondary Chemistry classes, the Covering, Causal and Unification models were most commonly used by teachers to assist student learning. Tang (2016) also supported the idea that a scientific explanation is improved if it provides an underlying cause that is not just apparent from empirical observations, but also includes references to scientific theories and concepts. The outcomes of these studies point to the academic benefits that could be gained by IBDP Biology students who develop an understanding of how to implement these scientific explanatory reasoning models in order to compose coherent, well written practical reports.

**Scientific argument and argumentation: Different concepts**

Osborne et al.'s (2011) definition of scientific argument based upon Toulmin's (1958) model of informal reasoning is the most widely utilised approach in analytical argument in science education literature. Toulmin (1958) posited that argument requires using data and warrants to justify belief. Osborne et al. (2011), however, defined an argument as validation of an uncertain conclusion based upon a "claim supported by the data, which act as the premises of the claim" (p. 1417) with the warrant providing the phrasal link revealing how the data supports the claim. Walker et al. (2013) defined scientific argument as "a claim supported by evidence and a rationale" (p. 564) (see Figure 3).

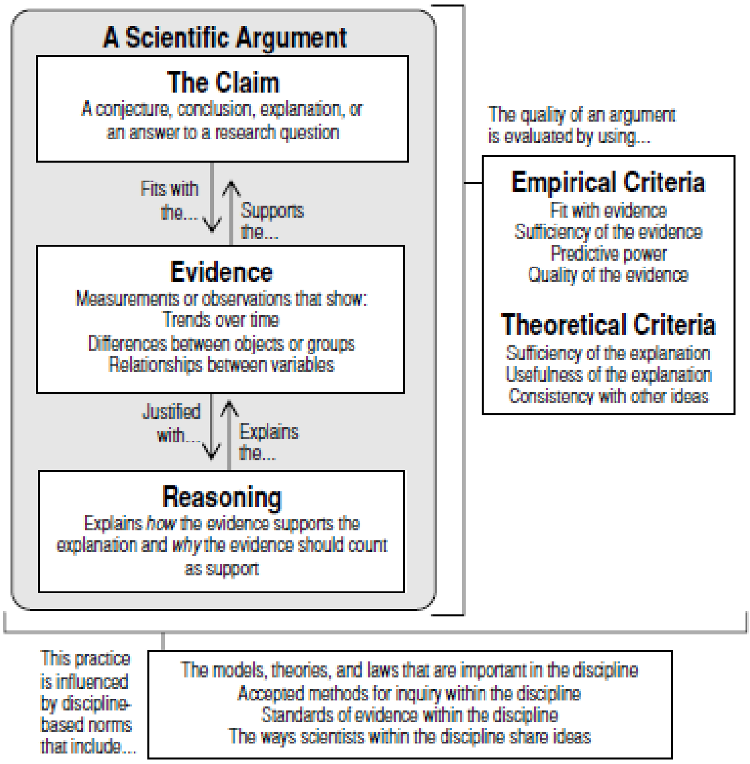



**Figure 3 - The scientific argument framework (Walker et al., 2013, p. 564)**

Osborne et al. (2011) reasoned that students must decide whether an explanation is valid or if it fails to explain, in which case, another explanation is required. Argumentation is the logical discourse *process* students engage in and experience while thinking about how evidence can be used to justify a conclusion (Duschl, Shouse & Schweingruber, 2007). Competency in argumentation can help develop higher-order thinking, thus enabling students to think more critically and sceptically about scientific claims. The validity of using an argumentative writing style is supported by several science education researchers (e.g. Cronje et al., 2013; Choi et al., 2012; Osborne; 2010; Hand, 2008; Hohenshell et al., 2006), primarily because it is similar to the way in which professional scientists write.

## Comparing scientific explanation and argumentation

Scientific explanation entails working out how and why a phenomenon occurs and involves knowledge generation. Argumentation, however, is concerned with justifying a claim to certain knowledge. In practical work, it can be difficult to distinguish between argumentation and explanation, as constructing new explanations following open-inquiry is often vastly different to constructing well-established explanations based on accepted scientific knowledge. Students engaged in constructing new explanations must reflect on prior knowledge, discuss ideas and access resources to help bridge gaps in their knowledge in order to interpret the findings- a process that is similar the way scientists submit their tentative findings to the scientific community for peer review.

The IBO clearly recognises the importance of argumentation strategies in forming credible scientific explanations in practical work. For example, in the 2016 IBDP Biology curriculum guide support for using argumentation strategies is evident in the assessment descriptors for the IA 'Analysis' criterion: "*assesses* the extent to which the student's practical report '*provides evidence* that the student has *selected, recorded, processed* and *interpreted* the data in ways that are *relevant* to the research question and can *support* a conclusion*"* (IBO, 2014, p. 156).

## 2.2 Writing Effective Science Practical Reports: Pedagogical and Learning Challenges

### 2.2.1 Learning challenges for students

Many science researchers and educators in the past three decades have acknowledged that practical report writing is often problematic from a teaching and learning stance (Washburn et al., 2013). Science education literature of the past two decades has highlighted that challenges in practical report writing are often correlated with student difficulties in understanding and appropriating scientific discourse genres. Additionally, cognitive, metacognitive and affective factors also significantly influence how students self-regulate their learning. This section explores some of the major factors that researchers believe can significantly impede a secondary science student's success in practical report writing from both a student and teacher perspective.

#### *2.2.1.1 Appropriation of scientific discourse genres: Student epistemologies about science*

Havdala and Ashekanazi (2007) explored the epistemological views of three undergraduate Chemistry students with respect to theoretical knowledge and empirical evidence. By examining both the students' laboratory practice and written laboratory reports, it was found students held distinctly different epistemological beliefs across the theoretical and empirical evidence domains. Three different epistemological theories were identified, which included the empiricist-, rationalist- and constructivist-oriented views.

The constructivist-oriented student considered both theoretical knowledge and empirical evidence knowledge as subjective and tentative. Thus he/she held an informed view in both domains of scientific knowledge. However, the other two students who demonstrated the empiricist and rationalist views respectively held naïve views in the empirical evidence domain, because they had trusted the knowledge gained through either personal observation (i.e. empiricist) or by mathematical analysis (i.e. rationalist). Furthermore, these students held informed views in the theoretical knowledge domain, believing it was subjective and tentative. Overall, the empiricist- and rationalist-oriented students held partially informed, non-bona-fide views, because they were unable to effectively coordinate theory with empirical evidence. Havadala et al.'s (2007) study concluded that students' epistemological stances strongly influenced how they coordinated scientific knowledge and empirical data together in practical work.

Peker et al. (2011) examined tenth grade Biology students' practical reports by investigating epistemological beliefs underpinning written explanations and their capacity to use exploratory, causal and theoretical explanatory reasoning tasks. Most students held constructivist-empiricist epistemological beliefs, since written practical reports mainly included observational, procedural knowledge recounts rather than explanations of results. The majority of students utilised both exploratory and causal explanatory reasoning processes and showed little evidence of higher-order, model-based reasoning involving integration of theory into explanations. Additionally, most explanations were written as if they had only occurred in the past and were primarily related to the students' first-hand experimentation experiences.

Both of these studies suggest that teachers should consider providing explicit epistemological instruction through developing an understanding of the constructivist-oriented domain of scientific knowledge. One way to do this may be to explicitly teach how to use explanatory reasoning models.

#### *2.2.1.2 Self-regulation: Cognitive, metacognitive and affective influences on learning in science*

According to Schraw et al. (2006), self-regulation involves understanding and managing learning, as well as setting goals, enacting strategies and monitoring one's progress. Self-regulation can be promoted in inquiry investigations, and hence science educators should try to assist students in this area (Pintrich, 2000). According to Trujillo and Tanner (2014), educational psychologists classify the three main learning domains as cognitive, metacognitive and affective. Open-inquiry investigations provide authentic opportunities for students to develop and use cognitive and metacognitive strategies, although the affective component of learning often receives less attention in science classes (Trujillo et al., 2014).

Critical thinking (CT) is an important cognitive higher-order thinking skill that promotes metacognitive thinking processes (Schraw, Crippen & Hartley, 2006; Kuhn, 1999). Even university students have been observed to struggle with CT (Kuhn, 1999; Halpern, 1998). According to Linn (2000), CT requires students to competently identify information, verify its credibility and determine if this *new* information fits with their prior knowledge in order to make conclusions. Linn (2000) asserted that CT skills are fundamentally important in building a student's capacity to write competent practical report explanations.

Norris and Phillips (2003) contended that although some students capably decode scientific text and understand theory, they may not be as astute at analysing, synthesising and critically evaluating written scientific text. According to a study by Porter et al. (2010) students who are deficient in CT skills tend to find scientific practical report writing extremely demanding. For example, Porter et al.'s (2010) study of senior high school science classes of mixed gender, grade (junior and senior) and ability levels, revealed that only 16% could write high quality conclusions without instructional assistance. According to Porter et al. (2010), difficulties with writing conclusions were attributed to students having problems effectively analysing experimental data trends - a skill that was complex for most students and apparently unrelated to chronological age.

Zohar et al. (2013) posited that metacognition in teaching and learning is a key issue in contemporary educational research. According to Garner and Alexander (1989), as students approach adolescence they tend to develop more metacognition, but only on an as needs basis. For example, when students ask questions to gain more information about a concept, they are engaging in metacognition. However, not all students can monitor learning new concepts and recognising when certain cognitive strategies should be utilised or how to improve problem-solving. Other students, however, are more capable at monitoring how and when to apply metacognitive strategies and are able to achieve more positive learning outcomes than those with less metacognitive proficiency (van Opstal et al., 2015; Conner, 2007; Swanson, 1990).

Conner's (2007) study examining a high-stakes essay writing task in high school Biology, discovered that students utilised metacognition differently from one another. For example, most students were aware of their individual learning approach, although there was a significant discrepancy between high achievers and low achievers with respect to awareness of metacognitive strategies. Conner (2007) stated that "low achievers could describe their learning in broad, general terms whereas high achievers could explain how they carried out the strategies in detail" (p. 13). The outcomes of these and many other studies involving older adolescent science students (e.g. Dangremond Stanton, Neider, Gallegos & Clark, 2015; van Opstal et al., 2015; Grotzer & Mittlefehldt, 2012) suggest that teachers may need to consider explicitly addressing metacognition, particularly in the context of scientific writing. Explicit metacognition instruction may help improve reading, higher-order thinking and knowledge generation, as well as understanding of scientific concepts which are all important skills needed for competent practical report writing.

Affective factors such as motivation can also play an important role in influencing the success of a student's learning. For example, students with well-developed cognitive and metacognitive learning strategies, but who lack motivation, will not necessarily achieve positive learning outcomes. According to Schraw et al. (2006), motivation is underpinned by two key elements: epistemological beliefs and self-efficacy. Since student epistemological beliefs were discussed in section 2.2.2.1, the focus here is to consider simply the mediating effects of self-efficacy on student motivation in the sciences. Bandura (1997) proposed four factors that may enhance personal self-efficacy: 1) enactive mastery experiences, 2) vicarious experiences, 3) verbal/social persuasion and 4) physiological/affective states (Table 2). When integrated, these four factors may reinforce one another (Bruce & Ross, 2008).

**Table 2 - Sources Capable of Increasing a Person's Self-Efficacy (Adapted from Bandura, 1997, Ch. 3, p. 79-115)**

| **Number** | **Name of Factor** | **Description of Factor** |
|---|---|---|
| 1 | Enactive Mastery Experiences | Most effective source - based on prior successful achievements or authentic experiences in which individual performed the task capably. |
| 2 | Vicarious Experiences | Occur when another person is observed carrying out the desired task successfully - heightens the belief that the observer can also perform the action. |
| 3 | Verbal/Social Persuasion. | Others convince the person they are capable of performing the task in question. If convinced, the person will be more likely to apply greater effort and persevere despite challenges involved. |
| 4 | Physiological/Affective States | Involves how a person reacts according to physiological and affective states, such as stress, fatigue or mood. |

Trujillo et al. (2014) pointed out that self-efficacy may affect a student's academic achievement and perseverance. Mc Connell et al.'s (2010) study indicated that undergraduate geoscience students with low personal self-efficacy, but who were highly academic, achieved similar grades to those with a higher self-efficacy and lower academic abilities.  In a study of 11$^{th}$ grade Biology students, Alpmen (2016) discovered that individuals with higher personal self-efficacy who valued Biology lessons had a higher achievement potential than other students. Students with higher personal self-efficacy often demonstrate greater persistence with academic difficulties (Usher & Pajares, 2008; Zimmerman, 2000). These studies highlight the important role that science teachers must play in promptly addressing student incidences of low self-efficacy. This is particularly important in IBDP Biology, which is undertaken at a time when students often make important decisions about their future careers.

#### *2.2.1.3 Scientific language*

The characteristically authoritative and somewhat impersonal style, of traditional scientific writing has often been rejected, particularly amongst women and people of non-European cultures (Hildebrand, 1996; Spanier, 1992). Deiner et al.'s (2012) study exploring practical report writing scaffolds found that many undergraduate Chemistry students were reluctant to improve their writing skills, because they believed writing is more relevant to humanities subjects. According to Halliday et al. (1993), student difficulties with scientific writing may be due to its use of lexically dense language. Dawson (2007) contended that numerous contemporary scientific papers written by professional scientists include personal, active language written in the present tense, which is not how traditional school practical reports are normally written. Consequently, it may be time to assess the importance of mandating traditional modes of scientific writing in school science practical reports, which are typically written in the third person, passive voice. These findings pose important implications for IBO Group 4 curriculum developers involved in setting writing guidelines for IA reports.

### 2.2.2 Pedagogical Strategies and Contextual Factors: Mediating Influences on Student Effectiveness in Practical Report Writing

According to Hand et al. (2006), although researchers have claimed for the past forty years that school science instruction needs to move away from a teacher-centred, transmissive approach and become more student-centred, this transition has been exceedingly slow – a view supported by many contemporary science education researchers (e.g. Hofstein et al., 2012; Cavagnetto, et al., 2011; Osborne, 2007). Garbett (2011) claimed that many contemporary science teachers feel uncomfortable relinquishing their control as 'transmitters' of knowledge and assuming the role of co-constructor of knowledge with students. Furthermore, implementing pedagogical strategies that integrate literacy into everyday science teaching and fostering the higher-order thinking skills required in practical reports are challenging tasks for most teachers (Talenquer, Tomanek & Novodvorsky, 2013; McNeil & Knight, 2013; Braaten et al., 2009).

#### *2.2.2.1 Pedagogical mediating influences in school science*

Several education researchers have reported that many science teachers dedicate considerable time and effort to assisting students with low-level cognitive activities during laboratory- based activities (Hofstein et al., 2012; Osborne, 2007; Ruiz-Primo, 2007; Hofstein et al., 2004; Hodson, 1993). Abrahams and Millar's (2008) study involving observations of twenty five practical science lessons in UK secondary schools, revealed that most teachers predominantly assisted students with procedural aspects of practical investigations. When these teachers focused on manipulative procedures, such as handling apparatus, they directed minimal effort towards cognitively challenging students to generate knowledge based upon their observations and experiences.

Lemke (1990) stated that teachers rarely teach students “how to speak, argue, analyse, or write science” (p. 22) and tend only to emphasise these skills either at the beginning or end of tasks. Several researchers (e.g. Cavagnetto et al., 2011; Hand et al., 2006; Rivard et al., 2000; Lemke, 1990) suggested that science teachers should increase opportunities for small group work and whole class conversations amongst students and teachers. By engaging in rich discussions, students may experience the high cognitive demand necessary to construct logical explanations about experimental phenomena and evaluate data. Such discourse is similar to how professional scientists “submit their conversations and text to the scrutiny of peers and use peer criticism to refine and reconstruct their ideas” (Florence et al., 2004, p. 638).

Havdala and Ashkenazi (2007) have suggested that science students need to learn about the two separate, yet interrelated facets of scientific knowledge: theory and empirical evidence, which are key to understanding the nature of science and how it operates. Several researchers have recognised that overlooking epistemic knowledge has resulted in inconsistencies between the goals of science curriculum planners and the daily practice of science classes (Hofstein et al., 2012). Norris et al. (2003) posited that scientific literacy includes two main elements: (1) fundamental sense and (2) derived sense. The fundamental sense involves the students’ reasoning capabilities, whereas the derived sense involves conceptual understanding of science content. The fundamental sense of literacy, however, is not usually explicitly taught in traditional science classes. Furthermore, while the fundamental sense is not unique to science per se, it is essential for effective participation in activities involving the derived sense of literacy, like practical report writing (Norris et al., 2003).

Osborne (2010) pointed out that although argument and debate are frequently undertaken by the scientific community, these discourses rarely occur in school science classrooms. Arguments are claims that must be supported by credible evidence. Evidence can use data and when combined together a persuasive tool is formed that can convince others to *believe* their claims. According to Ruiz-Primo et al.'s (2007) study of 72 middle-school science students, only 18% provided written explanations including claim, evidence and reasoning. This low percentage was thought to be attributed to limited opportunities for students to undertake scientific inquiry. Tang, Coffey and Levin (2010) suggested that how teachers frame inquiry tasks may influence the way they assist student thinking. Additionally, Tang et al. (2010) posited that contextual factors such as class routines, student behaviour, time constraints and high-stakes curricula can all significantly influence student thinking.

McNeil et al.'s (2013) study examined three professional development (PD) workshops. The PD was designed to foster authentic practices amongst seventy elementary, middle and high school teachers' pedagogical content knowledge (PCK) with respect to scientific argumentation. Teachers found the PD workshops useful for developing their PCK for some aspects of argumentation. Overall, 70% of teachers successfully used the claim-evidence- reasoning (CER) framework (refer section 2.1.2.3 – Figure 3) to assess student writing.

A few studies have evaluated secondary science teachers' understandings of scientific argumentation. For example, Sampson and Blanchard's (2012) study found that secondary science teachers had difficulties in critically supporting claims made in explanations about experimental results and tended to rely more on content knowledge than the data. Peker et al.'s (2011) study revealed that Biology students argued minimally with experimental data and teachers did little to assist students improve their written explanations following investigations.

Tang (2016) pointed out that most science teachers are poorly equipped to teach the construction of written explanations because they do not have a clear understanding of the difference between the concepts of scientific explanation and argumentation. Consequently, the CER framework that is normally used for formulating arguments, has been "misleadingly adopted by many science educators to construct explanations, even when there is little argument construction going on in instructional tasks" (Tang, 2016, p. 1437), such as practical reports. Osborne, Erduran & Simon (2004) contended that students need scaffolding tools to assist them due to the difficulties associated with composing persuasive arguments. According to Osborne et al. (2004), competent acquisition of argumentation skills should help students write better quality practical reports. Perhaps it is time for the IBO to think about providing training for Group 4 science teachers in pedagogy supporting the teaching of scientific explanation and argumentation skills in order to better support students with practical report writing.

Giorka (2009) investigated how UK senior secondary school science teachers managed assessing and teaching summative coursework when preparing students for high-stakes GCSE and A-level examinations. This study showed that teachers faced difficulties trying to ascertain the extent of formative feedback required during summative assessment of written reports. Giorka (2009) observed that many science teachers prioritised their assessor role and regarded teaching and summative assessment as separate processes resulting in the provision of either limited or no feedback and help to students. However, some teachers combined the dual roles of teaching and assessing by providing constructive feedback, but still supporting the examination guidelines. For example, one teacher formatively assessed students by communicating to students "what they were doing well, suggestions for improvement and specific guidance on where corrections are needed" (Giorka, 2009, p. 424). Consequently, Giorka (2009) posited that teaching and assessing high-stakes science curricula needs re-examination, as teachers should be primarily focused on student learning. Furthermore, the high-stakes accountability assessment in these curricula was thought to create many challenges for teachers during implementation of summative tasks. Giorka (2009) recommended using an assessment model that placed greater trust in the teacher's ability to assess, as well as "an increase in the weighting of internal assessment and less emphasis on external exams" (p. 428). Additionally, Giorka (2009) suggested teachers should exercise professional judgement when balancing fair marking with the feedback given to students.

Other studies conducted worldwide in this field have revealed similar findings to Giorka's (2009) study (e.g. Westbroek et al., 2013; Torrance, 2007; Yung, 2001).

#### *2.2.2.2 Contextual mediating influences*

Deiner et al. (2012) claimed that time constraints and large class sizes add to the contextual pressures science educators experience when assisting students with practical report writing. A Biology Education Research Group (2014) report found that the correlation between teachers' pay scales and student grades in England resulted in increased accountability of teachers instructing high-stakes curricula. Consequently, in recent years many teachers in England have been forced to focus more on curriculum components with the highest assessment weightings. The idea of correlating teacher pay scales with accountability in high-stakes curricula has serious implications for the 2016 IBDP Biology IA Practical Assessment Scheme that has only a 20% assessment weighting compared to a much higher 80% weighting for examinations. Will the IBO follow the lead of the English education system?

Wallace et al.'s (2004) study of experienced high school science teachers identified two belief constructs influencing their practical knowledge base. The first belief involved contextual factors arising from a school culture that constrained inquiry which led to reduced opportunities for students to engage in higher-order thinking. Secondly, teachers' beliefs about academic rigour, high-stakes exam preparation, efficiency and student capabilities were found to impede their implementation of authentic scientific inquiry. Wallace et al. (2004) cited an example of three teachers who believed their main pedagogical focus was to present canonical theoretical concepts. Another teacher in the same study, however, was preoccupied with time limitations and preferred to concentrate on curriculum theory rather than practical activities. The science teachers in the study appeared to hold competing belief sets about what was best for student learning and struggled to reconcile this issue against a background of culturally-mandated learning goals.

> The culturally based beliefs of exam preparation and efficiency in covering the curriculum exhibited a powerful influence; the teachers also had learning goals for their students that stood in contrast to the culturally supported goals. This causes a substantial difficulty for teachers, who are placed in the position of trying to choose between what they believe to be best for their students with what society has deemed best for their students (Wallace et al., 2004, p. 958).

The studies referred to in this section indicate that tensions experienced by teachers who are held professionally accountable to high-stakes standardised tests are real, widespread and particularly challenging. Section 2.3 examines some contemporary pedagogical approaches trialled by researchers to address the development of students' scientific practical report writing skills.

## 2.3 The Role of Contemporary Pedagogy in Scientific Practical Report Writing

Central to the current study is a focus on pedagogical strategies which IBDP Biology teachers utilise to promote student understanding of writing practical reports to prepare for the summative IA. Cronje et al. (2013) posited that a particular pedagogical challenge for science teachers is how to help students construct competent written explanations based on data obtained during investigations.

Several researchers have posited that in order for students to write competent practical reports they must be capable of writing rhetorically in compliance with the expository conventions of science, in order to develop persuasive and thus effective scientific explanations (Cavagnetto et al., 2010; Osborne, 2007). According to Peker et al. (2011) Biology students who attain competence in rhetorical writing skills are more capable of interpreting findings through causal thinking in which links are made between theoretical scientific knowledge/models and observed phenomena. Additionally, pedagogical practices designed to improve rhetorical writing skills are also often associated with improvements in high-stakes assessments, such as examinations (Keys, 2000).

The development of effective explanatory reasoning and rhetorical argumentation skills has shown a renewed interest by many researchers. For example, over the past two decades, many science education researchers have trialled innovative pedagogical approaches to help teachers improve their ability to assist students write practical reports. This section explores three innovative contemporary pedagogies: the Science

Writing Heuristic (SWH), Argument Driven Inquiry (ADI) and the Premise Reasoning Outcome (PRO), all designed to enhance practical report writing skills.

### 2.3.1 Using the Science Writing Heuristic instructional tool

Hohenshell et al.'s (2006) research explored using the Science Writing Heuristic (SWH) (Figure 3) to determine its effectiveness in promoting conceptual learning of ninety- one ninth and tenth grade science students studying cell Biology. The study revealed no significant difference between the multiple test results of 'control' students who wrote traditional practical reports without scaffolding and the SWH group who wrote reports based upon guided prompts within SWH scaffolds. However, when students were instructed to write a summary report of six practical investigations and then tested a second time using a series of higher-order extended response questions, the SWH group's test results were significantly greater overall than the control group.

The researchers reported that the control group did not perceive that the second writing task of the summary report had a separate focus from earlier traditional practical reports. Consequently, the control group tended to incorporate the pre-existing information documented in their earlier practical reports into their summary reports. Furthermore, the control group did not restructure their text to demonstrate revised thinking and/or elaborated upon their initial ideas. In essence, the summary report for these students was simply that - a report! In contrast to the control group the SWH students displayed a better understanding of the summary report aim. The latter group focused on the overarching ideas in the topic and coordinated their investigative findings, leading to a more integrated understanding of concepts. Hohenshell et al. (2006)

concluded that SWH scaffolds constituted effective preparation for writing summary reports by enabling students to develop a more sophisticated suite of cognitive experiences than the control group.

| |
|---|
| **Science Writing Heuristic for Laboratory:** ______________________________ |
| 1. **Beginning Ideas** What questions do I have?<br>(Students were guided to write testable questions with matching predictions.) |
| 2. **Tests** What did I do?<br>(Students were asked to completely describe how they performed tests to answer their questions with enough detail to allow repeatability.) |
| 3. **Observations** What did I see?<br>(Students recorded what they found from tests and were asked to appropriately represent data.) |
| 4. **Claims** What inferences can I make?<br>(Students interpreted observations and explained what they thought happened.) |
| 5. **Evidence** How do I know?<br>(Students justified claims by providing evidence for each claim.) |
| 6. **Reading** How do my ideas compare with others?<br>(Students compared their ideas with two additional sources, one of which required a citation.) |
| 7. **Reflection** How have my ideas changed?<br>(Students were asked to relate back to their beginning ideas and explain how these had changed.) |

**Figure 4 The SWH student template (Hohenshell & Hand, 2006, p271)**

### 2.3.2 Using the Argument Driven Inquiry instructional tool

Sampson, Grooms and Walker (2011) explored the effectiveness of the Argument Driven Inquiry (ADI) instructional model on the ability of nineteen tenth grade Chemistry students to successfully engage in scientific argumentation and construction of written scientific arguments. The ADI model consisted of seven stages:

1. Task identification
2. Data generation
3. Tentative argument production (claim, evidence, reasoning)
4. Argumentation in small group setting
5. Individual creation of written investigation report
6. Double-blind peer review
7. Report revision

Students completed fifteen different practical activities that corresponded to one of four different emphases:

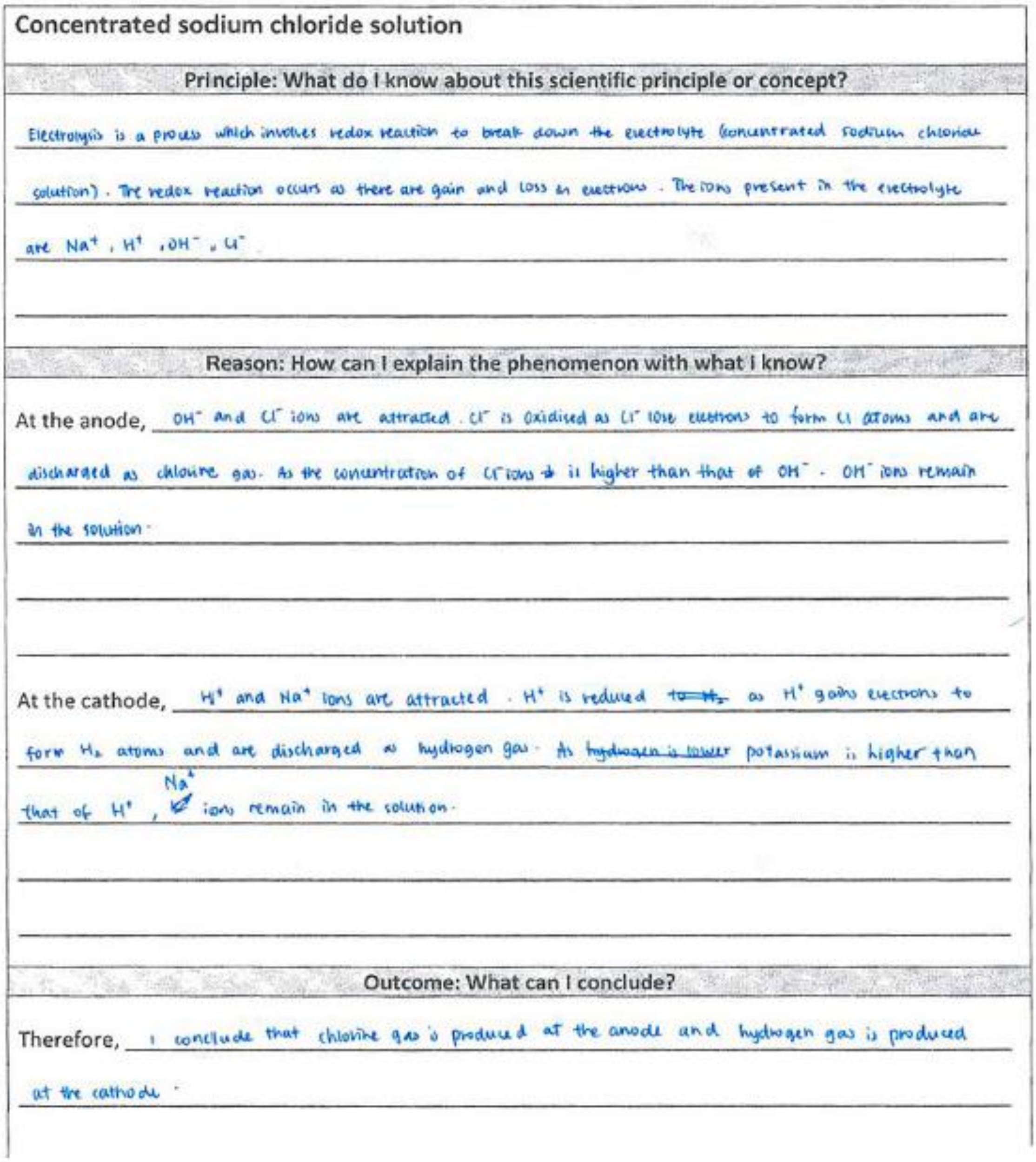
1. Development of new explanations
2. Revision of an explanation
3. Evaluation of an explanation
4. Explanation used to solve a problem

Initially, most students did not understand the criteria guiding the development of explanations and argumentation. Consequently, many students were unsure of how to engage effectively in argumentation discussions or write arguments. Some students used everyday (non-science) contexts to guide their understanding of the terms 'argumentation', 'explanation', 'evidence' and 'reasoning'. Sampson et al. (2011) believed that two main learning issues hindered the students' ability to effectively engage in scientific argumentation. Firstly, students did not utilise theory, models or laws as to evaluate their understanding of scientific phenomena. Secondly, some students limited their discussion to one major idea which they attempted to verify, instead of exploring other more acceptable explanations.

A positive correlation existed between high-level scientific argumentation discussions and the quality of the students' written arguments, although the researchers admitted that one outcome did not necessarily rely upon the other. Instead, it was speculated that students utilised the same sorts of basic understandings of the scientific epistemology that are needed to participate in both processes. Moreover, it was stated that "one way to promote this type of learning in the school science laboratory is to develop new instructional models that focus on scientific content, scientific processes, epistemology and social norms at the same time" (Sampson et al., 2011, p. 253). Furthermore, the study concluded that ADI is a useful way for students to experience scientific practice as it is more authentic and educative than traditional laboratory approaches. Sampson et al. (2011) conceded that further research was required to refine the ADI model and trial it in a wider range of school contexts.

### 2.3.3 Using the Premise Reasoning Outcome instructional tool

Tang's (2016) study examined the effectiveness of his Premise Reasoning Outcome (PRO) tool (Figure 4) in assisting 9th and 10th grade secondary school Physics and Chemistry students with writing scientific explanations. The PRO heuristic is based upon scientific philosophy and linguistics and is typically presented linearly and sequentially for ease of use by both teachers and students even though Tang himself acknowledged that scientific explanations usually involve iterative, non-linear thought processes. The PRO tool comprises three main components: premise (P), reasoning (R) and outcome (O). The premise is the basis of the explanation which is often underpinned by a scientific law, theory or model. Reasoning involves the logical sequence of connectives that follow the premise, while the outcome is the phenomenon itself to be explained.



Concentrated sodium chloride solution

**Principle: What do I know about this scientific principle or concept?**

Electrolysis is a process which involves redox reaction to break down the electrolyte (concentrated sodium chloride solution). The redox reaction occurs as there are gain and loss of electrons. The ions present in the electrolyte are $Na^+$, $H^+$, $OH^-$, $Cl^-$

**Reason: How can I explain the phenomenon with what I know?**

At the anode, $OH^-$ and $Cl^-$ ions are attracted. $Cl^-$ is oxidised as $Cl^-$ lose electrons to form Cl atoms and are discharged as chlorine gas. As the concentration of $Cl^-$ ions ~~+~~ is higher than that of $OH^-$. $OH^-$ ions remain in the solution.

At the cathode, $H^+$ and $Na^+$ ions are attracted. $H^+$ is reduced ~~to $H_2$~~ as $H^+$ gains electrons to form $H_2$ atoms and are discharged as hydrogen gas. As ~~hydrogen is lower~~ potassium is higher than that of $H^+$, $Na^+$ ions remain in the solution.

**Outcome: What can I conclude?**

Therefore, I conclude that chlorine gas is produced at the anode and hydrogen gas is produced at the cathode.

**Figure 5 - Example of a student's PRO scaffold (Tang, 2016, p. 1424)**

In Tang's (2016) study the PRO was introduced to half the student cohort during scientific activities based upon Bybee et al.'s (2006) 5 Es[5] teaching framework. The PRO scaffolds were initially handed out during the *explanation* phase within an investigation and removed during the later *elaboration* phase when students were required to think about their explanations after the investigation, by applying new knowledge to a novel situation. During the early interventional stage, PRO students were given more prompts, guiding questions and sentence starters in the scaffold than non-PRO students with scaffolds being gradually removed as students gained confidence writing explanations. Students who worked with PRO scaffolds were found to write better explanations than control students. Despite these encouraging results, some students found PRO scaffolds difficult to use. It was concluded that the PRO may be particularly useful when teaching theoretical scientific content because it can help students organise their thoughts into coherent, logical written explanations that include causal sequences (Tang, 2016).

In summary, four major implications arose from the reviewed literature cited in this section in relation to developing the practical report writing skills of students in IBDP Biology Firstly, it appears that scaffolding tools improve science students' writing skills by enhancing their conceptual understandings and ability to write rhetorically persuasive explanations. Secondly, students require explicit instruction in the epistemology of scientific discourse, as it is initially difficult for them to understand and use. Thirdly,

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[5] Roger Bybee and his peers created the 5E instructional model framework for thinking about teaching and learning in science in 1989. The model consists of 5 phases including engagement, exploration, explanation, elaboration and evaluation that encourage and support students to formulate their own explanations for scientific problems through collaborating with their peers and the teacher (Skamp & Preston, 2015).

although group work is highly recommended from a social constructivism perspective, it is not the only solution to improving practical report writing. Lastly, pedagogical innovation should be promoted within the ongoing professional development of in-service science teachers.

## 2.4 Externally Driven Curriculum & Assessment Reform: Science Teachers' Perceptions and Reactions

Externally driven curriculum reform is a contentious issue within school science programs worldwide (Ryder, 2015; Fensham, 2009). Assessment reform often accompanies curriculum reform and hence also plays a prominent role in influencing pedagogical practice.

### 2.4.1 The problem with externally driven curriculum reform

Teachers are the key sources of innovation in science classrooms and therefore significantly influence their students' learning (Ryder, 2015; Zhang, Parker, Koehler & Eberhard 2015; Spillane, 1999). When curriculum reform includes major assessment changes, science teachers often find the adjustment professionally difficult. For example, Koh (2011) pointed out that many educational systems worldwide reported that numerous teachers are not adept at "developing and implementing authentic performance assessments due to inadequate training and support during pre-service teacher education programs" (p. 256). Ryder et al. (2013) claimed that educational literature includes many accounts of science teachers who "resent the demands to respond to seemingly constant curriculum change and curriculum policy-makers who find that teachers do not implement curriculum reforms as intended" (p. 491). Finally, Towndrow et al. (2010) pointed out that "top-down rationalist approaches to innovation and change management in laboratory assessment rarely achieve the levels of fidelity desired by policy-makers" (p. 130). Ryder (2015) asserted that "there is less attention given to examining in detail the experiences, motivations and reflections of teachers, and how these might change over time" (p. 88) and argued this was just as important to know, as determining whether curriculum reform had proceeded as planned.

#### 2.4.2 The role of teacher beliefs, decision-making and classroom practice in implementation of curriculum reform

Many contemporary studies have indicated that successful curriculum reform implementation is a considerably complex issue that cannot be based exclusively upon a science teacher's personal attributes. Ryder's (2015) large-scale review of 34 science curriculum studies involving in-depth interviews with science teachers drawn from across the globe, explored teacher beliefs, practices and reflections in light of curriculum reform. The review provided some illuminating insights concerning teachers' reactions during such reform. Ryder utilised Goodson's (2003) categories of personal (specific to teacher), internal (specific to school) and external (specific to system) contexts to group twenty-seven factors identified as being key influences in teachers' responses to reform (See Figure 5). Of the twenty-seven factors influencing teacher responses to externally driven curriculum reform presented in Figure 5, about one-third relate to science teachers' personal attributes, whereas approximately half relate to school-based influences. The implications of Ryder's (2015) review for IBDP Biology is that schools have an important role to play in ensuring that teachers are provided with appropriate professional support when implementing curriculum reform.

**PERSONAL** (TEACHER FOCUS)
Personal factors relate to a teacher's:
P1. Subject knowledge
P2. Pedagogical skills
P3. Beliefs about the purposes of science education
P4. Views about the epistemology of science
P5. Beliefs about how students learn and his/her role in the classroom
P6. Beliefs about the intentions of the curriculum reform
P7. Perceived audiences for his/her work
P8. Professional and personal biography
P9. Professional identity

**INTERNAL** (SCHOOL FOCUS)
I1. Students' differing backgrounds and aspirations
I2. Students' interpretations of what counts as appropriate science curriculum content
I3. Parental aspirations and their visibility to teachers
I4. Availability of teaching resources (e.g. textbooks, practical activities)
I5. Physical teaching spaces (e.g. laboratory provision)
I6. Engagement of teachers in professional development activities
I7. Science department working practices (e.g. collegial, fragmented)
I8. School and departmental leadership style
I9. What counts as appropriate assessment of student learning
I10. Local cultural perceptions of the 'good', 'professional' teacher
I11. School ethos and priorities
I12. Relation of the science curriculum reform to other reforms in the school
I13. Role of inter-school mediators/brokers of reform

**EXTERNAL** (SYSTEMIC FOCUS)
E1. Flexible versus prescriptive national/regional curriculum frameworks
E2. Participation in ongoing, inter-school teacher networks
E3. Other national/regional education reform agendas
E4. Accountability measures (e.g. through external measures of student attainment, school league tables, school inspectorate policies)
E5. Specifications for externally awarded science qualifications

**Figure 6 - Factors influencing teacher responses to externally driven curriculum reform (Ryder, 2015, p. 103)**

Zhang et al.'s (2015) review of 118 science education reform studies found that a teacher's effectiveness strongly influences student learning outcomes. Factors such as subject knowledge, pedagogical skills and epistemological beliefs about science, all significantly impact on reform success. Some other recent reform studies have focused on the intimate relationship between science teachers' beliefs and actions and how these can impact teaching and learning. Building on Nespor's (1987) seminal work on theoretical belief constructs, Wallace et al. (2004) argued that affective elements, such as moods and prior experiences may strongly influence teachers' decisions about incorporating inquiry-based innovations into science lessons and that teacher actions reflect their beliefs – the two elements cannot be separated. Furthermore, when teachers perceive they cannot successfully meet reform requirements, low teacher self-efficacy may result (Bandura, 1997).

Westbroek et al.'s (2016) study used 'goal theory' as a theoretical construct to explain teachers' decision-making processes and pedagogical practices involving Chemistry curriculum reform. According to Westbroek et al. (2016) goals in a teacher context represent the teacher's unique desired state and are mediated by the knowledge/beliefs of the individual. Westbroek et al. (2016) argued that since teachers often manage multiple goals simultaneously, they will never fulfil all goals due to the hierarchical and time-dependent nature of goals. Furthermore, this study revealed that despite the extensive academic qualifications and high level of pedagogical expertise of the teachers and their participation in innovative professional development, some reform elements were still compromised. Moreover, teachers adopted the reformed curriculum in a modified manner according to those aspects that either supported or impeded attainment of their own individual core goals. Lastly, the study highlighted that personal teacher attributes such as pedagogical-style, beliefs about how students learn, the teacher's role in the classroom and their beliefs about curriculum reform intentions played an important role in influencing pedagogy. As Westbroek et al. (2016) stated:

> If a teacher does not act in accordance with a rational innovation proposal, we cannot conclude that the teacher acts irrationally. Rather, we can more wisely view this as sign that we still do not understand a teacher's goals in his/her practical world. Once we know his/her goals almost always the actions of a teacher turn out to be perfectly reasonable (p. 2).

Yung's (2001) case study of three Biology teachers in Hong Kong illustrated how one teacher employed pedagogical strategies that were ineffective in enacting high-stakes practical assessment reform. The teacher's confusion regarding when and how to use formative and summative assessment practices in a school-based summative practical investigation led to adverse student outcomes. These adverse outcomes included a reticence to seek formative feedback, a loss in summative marks and increased student anxiety. Evidently, when teachers interpret reform differently from curriculum developers, it may "ruin the best intentions behind these new forms of school-based assessment…and this would be grossly unfair to all parties concerned - teachers and students alike" (Yung, 2001, p.1002).

### 2.4.3 The role of teacher self-efficacy in facilitating successful curriculum reform

Blonder, Benny and Gail Jones (2014) contended that teacher self-efficacy may significantly influence curriculum reform. Although some researchers are sceptical about whether high teacher self-efficacy leads to greater pedagogical effectiveness (Settlage, Southerland, Smith & Ceglie, 2009; Wheatley, 2002), there is strong research evidence which suggests that teacher self-efficacy affects student achievement (Tschannen-Moran

& Hoy, 2001; Goddard, Woolfolk Hoy & Hoy, 2000). According to Gibson and Dembo (1984), self-efficacy can be conceived according to outcome expectancy and personal self-efficacy such that:

> Teachers who believe student learning can be influenced by effective teaching (outcome expectancy beliefs) and also have confidence in their own teaching abilities (self-efficacy beliefs) should persist longer, provide greater focus in the classroom, and exhibit different types of feedback than teachers who have lower expectations concerning their ability and influence on student learning (p. 570).

High levels of personal self-efficacy have been linked to teachers who willingly trial innovative pedagogies and demonstrate greater persistence and resilience when challenges arise (Cantrell, Young & Moore, 2003), such as might be expected with the introduction of curriculum and assessment reform in IBDP Biology. McCormick and Ayres (2009) found that self-efficacy can be domain-specific. Loughran (1994) observed that secondary science teachers who displayed high self-efficacy were more likely to achieve ‘pedagogical freedom’ (p. 377) resulting in greater student engagement and more effective learning. Of the four sources of self-efficacy proposed by Bandura (1997) (see Table 4, Section 2.2.1.2), *enactive mastery* is believed to have the greatest influence upon teacher behaviour. That is, when teachers have experienced prior challenges similar to the current experience, there is a greater chance that they will display high self-efficacy and overcome such challenges (Blonder et al., 2013).

Many studies support the importance of self-efficacy in positively influencing reform, although some others suggest otherwise. For example, Southerland et al.'s (2012) study used 'conceptual change theory' to explain one teacher's approach to learning that appeared unrelated to teacher self-efficacy. The researchers proposed that teachers were more likely to support and enact curriculum reform if they experienced sufficient pedagogical discontentment - an affective state that occurs when a teacher recognises a "mismatch between his/her science teaching pedagogical goals and classroom practices" (p. 484). Settlage et al.'s (2009) study explored changes in pre-service science teachers' self-efficacy beliefs during three stages in their training and found that many individuals held an excessively high self-efficacy both prior to and during teaching, despite their limited teaching experience.  The researchers believed that teacher over-confidence thwarted the pre-service teachers' own abilities to partake in self-doubt, which limited their academic growth. According to Settlage et al. (2009), self-doubt need not be regarded as a constraint and may even promote teacher reflection enabling them to more successfully implement curriculum reform. This finding has important implications for IBDP Biology teachers who may hold feelings of self-doubt when tackling the challenges of implementing IA reform measures within the 2016 IBDP Biology curriculum for the first time. In other words, self-doubt may better prepare teachers to analyse reform measures more critically and adopt a proactive approach to seeking innovative solutions to pedagogical challenges that may ultimately enhance student learning outcomes.

### 2.4.4 The role of professional development in facilitating successful curriculum reform

Internal factors relating to a teachers' school context interact with personal factors that may contribute significantly to successful curriculum reform. Van Driel et al. (2012) reviewed 44 contemporary studies and found that while most science education PD programmes intend to support reform, they do not usually satisfy teachers' requirements. Zhang et al.'s (2015) study discovered that many teachers believed PD frequently lacked relevance to their classroom needs. Ebert et al. (2010) argued that teachers often bring preconceived beliefs and values to PD sessions, which tend to influence their opinions about the training benefits.

Koh (2011) stated that since assessment is a "key lever for driving teachers' instructional practice, changing or improving classroom practice will require teachers' to improve their knowledge and skills in designing and implementing new forms of assessment" (p. 256), thus enabling them to both teach *and* assess students according to contemporary pedagogies. This means that PD planners should consider how best to foster the teachers' assessment literacy skills in ways that support students' needs. One-off PD programmes that encourage and support teachers to develop appropriate knowledge and pedagogies that align with reform do not often achieve their intended goals (Zhang et al., 2015; Koh, 2011). Koh (2011) suggested, however, that PD that allows teachers to collaborate and discuss assessment strategies within their own classroom context, can be beneficial in promoting pedagogical innovations.

Desimone (2009) proposed that five factors should be included in all high quality professional development: (1) content; (2) active learning; (3) coherence; (4) duration of PD and (5) collective participation.

*Content:* Many scholars agree that a teacher's subject knowledge is a crucial element in science education and that PD focusing on increasing the teacher's understanding of teaching conceptual theory results in improved student outcomes (Desimone, 2009).

*Active learning:* PD effectiveness can be enhanced when teachers engage in active learning opportunities (Doppelt, Schunn, Silk, Mehalik, Reynolds & Ward, 2009), such as being observed by peer/mentor teachers followed by constructive feedback (Desimone, 2009).

*Coherence:* Coherence is the "extent to which teacher learning is consistent with teachers' knowledge and beliefs" (Desimone, 2009, p. 184). Penuel, Fishman, Yamaguchi and Gallagher's (2007) study of 454 teachers found coherence was the most important predictor of change in a teacher's knowledge and pedagogical practice.

*PD Duration:* Many researchers advocate that one-off PD delivered in the traditional workshop manner is not particularly effective and that teachers prefer ongoing, sustained PD, particularly when implementing inaugural curriculum reform (Zhang et al., 2015; Koh, 2011; Monty Jones & Dexter, 2014).

*Collective Participation:* A solid body of evidence exists to support PD that provides opportunities for teachers with a common focus, such as a grade level or subject area, to gather collectively (Koh, 2011; Loucks-Horsley, Hewson, Love & Stiles, 1998).

## 2.5 Conclusion

This literature review highlighted the importance of the social constructivist approach, as the basis for effective science pedagogy in contemporary science classrooms. The constructivist movement heralds the move towards a more student-centred approach whereby teachers play a supportive role as facilitators and co-constructors of knowledge. IBDP Biology is underpinned by a constructivist approach and is also strongly influenced by NOS understandings (IBO, 2014). Pedagogies that include explicit instruction on use of explanatory reasoning categories, rhetorical argumentation and metacognition represent some strategies that many contemporary science education researchers have deemed important in developing the higher-order cognitive skills necessary for effective practical report writing in the sciences. The review has also revealed that many teachers perceive external curriculum reform as difficult, and often do not implement the reform measures according to the precise intentions of curriculum planners. Furthermore, a teacher's capacity to successfully implement curriculum reform is evidently greatly influenced by personal attributes of teachers, school context and systemic elements, such as external curriculum planners.

It is anticipated that the current research may offer some valuable insights about pedagogical strategies designed to promote student understanding of scientific practical report writing. Furthermore, it is envisaged that this research will also offer a unique understanding of the perceptions and inaugural experiences of Biology teachers implementing practical assessment reform in the 2016 IBDP Biology curriculum. Furthermore, I hope that the research findings will be of some benefit to Group 4 science teachers throughout the global IB community. In the next chapter the data collection and analysis process (method) of the current study will be outlined.

# Chapter 3 Method

## 3.1 Introduction

A multiple case study involving three IBDP Biology teachers from Australian schools was utilised to collect data from two main sources: (1) face-to-face interviews and (2) various teacher-generated documents, including exemplars of assessed student practical reports and personal emails. A grounded theory (GT) approach was selected to inductively analyse and synthesise the data.

## 3.2 The Constructivist Paradigm

Constructivism was selected as the most appropriate philosophical stance from which to formulate the current qualitative study based upon its ontological and epistemological assumptions. Ontology concerns understanding the nature of reality and what can be known about it (Punch & Oanacea, 2014). Constructivist thinking assumes that many different perspectives exist (Denzin & Lincoln, 2005), which are socially constructed by individuals directly experiencing a phenomenon (Creswell, 2013). Epistemology involves the nature of knowledge in which questions are asked about the relationship between what people know and how they come to know it. According to Guba and Lincoln (1989), epistemological issues cannot be separated from ontology according to a constructivist stance, because, "If you assert that reality consists of a series of mental constructions, objectivity does not make sense – only interactivity can lead to construction or its subsequent reconstruction"(p. 87). Subjectivist epistemology underpins constructivism and assumes a tightknit relationship must be formed between researchers and participants in which knowledge is co-constructed based on an individual's experiences (Denzin & Lincoln, 2000). For this relationship to develop and support research, researchers must get to know participants by collecting data in the field to seek an emic perspective of the phenomenon.

Productive and collaborative working relationships were developed with the teacher participants by interviewing them face-to-face within their individual school environments and by maintaining regular email communication about the research progress. The interview process created several opportunities to directly co-construct knowledge with participant teachers and obtain numerous direct quotes that provided an emic perspective.

## 3.3 Ethics

Ethical issues may arise at times during research, despite the design utilised (Punch & Oancea, 2014). Creswell's (2013) key ethical considerations for researchers guided the before, during and after phases of the present study.

*Before research*

Institutional ethical consent to conduct the research was sought from and subsequently approved by the Flinders University, Social and Behavioural Research Ethics Committee (SBREC) in Adelaide, South Australia (approval number 5926). Initial contact with schools involved making phone calls to the Principal's Executive Assistant. To ensure informed consent, an email with six attached documents including a formal introductory letter (Principal & Teacher) (Appendix G), an information form (Principal & Teacher) (Appendix H) and two consent forms (Principal & Teacher) (1 and 2) (Appendix I) were subsequently emailed to both the IBDP Principal and potential teacher participant of each school. An important objective of this initial contact was to gain my permission to recruit volunteer teacher participants and access schools during data collection. Participant teachers usually responded by email soon after Principals had consented to the process.

*During research*

Maintaining the teacher participants' anonymity was considered a high priority, since the IBDP Biology teacher community within one of the cities utilised in the study is relatively small and many of its members are well acquainted with one another. Anonymity of teacher participants was also protected by using pseudonyms instead of real names. In order to decrease the perceived level of threat to the teachers' anonymity, only people not known to the researcher were invited to participate in the research. To further minimise the likelihood of potential dilemmas associated with anonymity, a third teacher participant was invited to participate from another major city outside of my hometown.

When analysing transcribed data as part of the member-checking process, participants were invited to remove material that they believed should be excluded from written interview transcripts. For example, one participant excluded transcript details that indicated the names of past schools he had previously worked at.

*After research*

Compensation for research participants is a pertinent ethical concern, particularly in qualitative research involving interviews (Merriam, 1998; Patton, 2015; Punch et al., 2014). In this study, professional reciprocity was considered in light of its potential influence upon data quality. It was important to recognise each teacher's role as a hard-working individual, who had willingly committed valuable time from their busy professional and personal life to participate in the research. Furthermore, it was perceived that the most authentic and genuine demonstration of gratitude could be expressed in ways that did not necessarily involve monetary compensation. For example, teacher participants in this study were sent regular emails that included updates about the research and expressions of thanks for their ongoing participation. The idea of maintaining email contact with the participants helped ensure that they were not left feeling exploited at the end of the interviews. Teacher participants were also offered a

$50 gift card following the interview, as an additional gesture of appreciation for their contributions.

## 3.4 Research Strategy – Multiple Case Study

Stake (2003) asserted that a case study is “both a process of inquiry and the end product of inquiry” (p. 136). Stake (1995) distinguished between three types of case study:

(1) an *intrinsic* case study involves investigating a single case because of an inherent interest in learning more about its uniqueness;

(2) an *instrumental* case study in which the case is of secondary importance and “plays a supportive role, facilitating our understanding of something else” (Stake, 1994, p. 237) - this ‘something else’ is the main issue of interest; and

(3) a *collective* case study that analyses several instrumental cases with the main goal being to develop an even greater in-depth understanding of the issue.

Multiple case studies (i.e. collective case studies) are useful when the researcher believes the phenomenon is not unique to one case, and where several perspectives are perceived to offer a more meaningful insight (Ary, Cheser Jacobs, Razavich & Sorenson 2010); this was the case in the present study. Exploring the phenomenon across more than one case allows one “to understand how they are qualified by local conditions, which can lead to more sophisticated descriptions and more powerful explanations”

(Miles, Hubermann & Sandana, 2014, p. 101). The current research utilised a multiple case study approach, because multiple perspectives involving three teacher participants were requisite in developing insights into and interpretations about the phenomenon. Data collected from cases studies are generally more in-depth and often yield richer descriptions and more insightful explanations (Yin, 2003; Merriam, 1998).

Case study research offers considerable flexibility, as it does not "claim any particular methods for data collection or analysis" (Merriam, 1998, p. 28) and involves the researcher as the primary means of collecting and analysing data. In the current study, qualitative data in the form of semi-structured interviews, email responses and teacher-generated written documents were collected. The interviews offered ample opportunities to pose probing questions to participants to expose emergent themes and uncover more compelling insights that would not be possible using quantitative methods.

Yin (2012) recommended that researchers should decide early on, when planning case studies, how the case will be defined. According to Merriam (1998), "the single most important defining characteristic of case study research lies in delimiting the object of study, the case" (p. 27). Stake (1995) defined the case as a "specific, complex functioning thing…an integrated system" (p. 2) and indicated a case is usually either a person or a program. Miles and Hubermann (1994) defined the case as "a phenomenon in some sort of bounded context" (p. 25) and highlighted the importance of factors such as setting, context and time, to indicate how the case can be contained. Thomas (2011) suggested the case should consist of two parts: the subject and an analytical frame to focus on.

Despite varying ideas about what constitutes a case, it is important that boundaries enclosing the case are clearly set and articulated when commencing the study (Merriam, 1998; Miles & Hubermann, 1994 & Thomas, 2011). Yin (2012) pointed out that it can be difficult to clearly define the case's boundaries, because "spatial and temporal dimensions may be blurred" (p. 6).

In the current research, the case was bounded by the three participant teachers (cases or subjects) that were teaching IBDP Biology in Australian schools (spatial boundary or context), while experiencing the IBO's assessment reform of the IA involving an open-inquiry investigation and the subsequent writing up of a practical report (phenomenon or analytical frame). Some additional participant sampling criteria are outlined in Section 3.5. In the present study, teachers were interviewed during the 2015-2016 Australian academic school years (temporal boundary) when planning and implementing the IA assessment reform for the first time with their Year 11/12 IBDP Biology classes.

## 3.5 Sampling Method

Purposeful sampling (Creswell, 2012) was utilised to select three IBDP Biology teacher participants (cases) prior to collecting data, according to how they fulfilled the following six criteria:

1. Teaching IBDP Biology at the time of the research (2015-2016), with a minimum of two years' experience teaching the subject within Australia.

2. Experience teaching the 2009 IBDP Biology program, as well as teaching during the inaugural transition phase of implementing the updated 2016 IBDP Biology program.

3. A registered teacher in an IBDP school.

4. Willing and able to participate at length for the purpose of in-depth research during the designated study period.

5. Easily accessible to the researcher.

6. Willing to be re-contacted for member-checking and additional clarifying questions.

Purposeful selection of teacher participants was influenced by Patton's (1990) view that when this sampling strategy is used with even very small samples, it can potentially yield "information-rich" (p.169) insights that cannot be attained using quantitative, statistical, probability-based, random sampling methods. Maximum variation sampling is a type of purposeful sampling that aims to maximise diversity of the research participant group and enable several different viewpoints to be presented - "an ideal in qualitative research" (Creswell, 2013, p. 157). A maximum variation approach was employed in the current study to ensure that participants reflected different dimensions of the four criteria: gender, number of years' experience teaching senior secondary school Biology, gender composition of school (single sex or co-educational) and school context (independent or publicly funded). These criteria were considered most likely to yield high-quality, detailed information and broaden the range of perspectives relevant to the research questions. Ritchie and Lewis (2009) suggested that maximising diversity between the samples, while remaining within the case study boundaries, increases the potential of exposing the "full range" (p. 83) of relevant issues. The extent to which the variation could be maximised in the current research was, however, minimal, due to the small number of teacher participants involved. A small number of cases were deliberately utilised, however, to generate a comprehensive body of relevant and in-depth information from each participant.

## 3.6 Research Rigour

Over the past four decades, social scientists have extensively debated how best to enhance, assess and ensure the quality of qualitative research. Today, this debate continues without a consensus being reached (Pereira, 2012). Guba and Lincoln's (1989) model of four research rigour criteria (credibility, transferability, dependability and confirmability) informed the trustworthiness of the current study. Furthermore, the current study was influenced by its compatibility with a constructivist philosophy and qualitative paradigm, the researcher's epistemological stance and the use of a semi-structured interview as the principal data collection method.

Corbin and Strauss (2008) asserted that both researchers and readers should appraise credibility, while Bruner (1998) emphasised that research findings should display verisimilitude, even if they appear context-dependent. Several strategies were used to assess credibility in the current research, including triangulation, peer debriefing and member-checking.

Triangulation was utilised to determine the extent to which the data could be verified (Houghton, Casey & Murphy, 2013; Miles, Hubermann & Saldana, 2014). Two types of triangulation were utilised: (1) multiple data methods, including interviews and analysis of documents (e.g. school practical reports) and (2) multiple data sources (i.e. three teacher participants). The data were compared to determine the extent to which findings could be corroborated. An in-depth examination of three teacher participants' (cases') perspectives from three different schools enabled a more complete understanding of the research phenomena, than if only one case had been explored.

Member-checking, according to Lincoln and Guba (1985), "is the most critical technique for establishing credibility" (p. 414). In the current study, this was achieved by emailing participants a verbatim, written transcription of their audio interview/s for an accuracy check, soon after interviews. Merriam (1998) suggested that interviews enable researchers to gain more intimate insights into the reality of the data. I maintained regular communication with participants throughout the data collection and analysis phases to help refine the accuracy of existing data and allow collection of additional documentation.

Transferability, as proposed by Guba (1981), refers to the applicability of findings to similar contexts, while still preserving the meanings and inferences from the completed study. According to Stake (1995), transferability is enhanced by including thick description, such as detailed contextual and methodological information and presenting several examples of raw data. For example, in the current study, participants' direct quotes extracted from interviews are included, as well as tabulated examples illustrating how raw data was coded and developed into themes through an iterative data collection and analysis process. Thick description enables readers to make their own interpretations about the data and its transferability to their own contexts (Houghton et al., 2013).

Since individual teachers have unique perspectives, it was important to minimise the sample size, so that cases could be examined in sufficient depth without producing superficial findings. Merriam (1998) argued that limiting sample sizes in qualitative case study work is preferable because, “a single case or small, non-random sample is selected precisely *because* the researcher wishes to understand the particular in depth, not find out what is generally true of the many” (p. 208).

Guba and Lincoln (1989) explained that dependability is concerned with demonstrating how consistent the findings are with the data. Unlike the positivist conception of reliability, dependability is not related to replicability – an unrealistic and hence inappropriate concept in qualitative, constructivist research (Merriam, 1998). Nowadays, however, dependability or ‘auditability’ (Creswell, 2013; Houghton et al., 2012; Miles et al., 2014; Ryan-Nicholls, Kimberly & Will, 2009), as it is commonly referred to, usually involves researchers providing documented evidence explaining the rationale behind the methodological and analytical decisions made during research. Examples of documents illustrating the audit trail maintained in this research are provided in Appendix J.

Confirmability, according to Guba and Lincoln (1989), is achievable only when credibility, transferability and dependability have been satisfactorily established by the researcher. Sandelowski (1986) coined the term ‘neutrality’, to describe the extent to which researchers separate themselves from personal bias. This process of exercising ‘reflexivity’ (Fontana, 2004; Jootun, McGhee & Marland, 2009) is important in promoting rigour within qualitative research. While it is acknowledged that ignoring one’s own preconceived ideas is almost impossible, researchers should be transparent about their personal beliefs and the potential for bias (Jootun et al., 2009) during data collection and analysis. In the present study, reflexivity was promoted in several ways, some of which included:

- having regular discussions with my supervisor and professional peers who were willing to question my assumptions;
- constructing a decision trail in which the participants' responses to questions in earlier interviews influenced those that were constructed for subsequent interviews;
- writing memos to allow free-flow of thoughts to illustrate researcher's interpretation at the time of analysis and
- taking care to avoid posing leading questions that may potentially influence a participant's responses and compromise data integrity.

The criteria and strategies for establishing rigour in the current study are presented in Table 3.

**Table 3 - Criteria and strategies for establishing rigour in case study research**

| **Quantitative Criteria for judging rigour** (Yin, 2003) | **Qualitative Criteria for judging rigour** (Guba & Lincoln,1989) | **Guiding questions** | **Strategies employed in current case study to address qualitative rigour criteria** |
|---|---|---|---|
| Internal Validity | CREDIBILITY | How plausible are the findings?<br><br>Do the findings display verisimilitude? | Member checking<br><br>Triangulation<br><br>Peer debriefing |
| External Validity | TRANSFERABILITY | How applicable are the findings to:<br><br>a) other contexts<br><br>b) audience's experiences? | Limited as only three participants were involved. |
| Reliability | DEPENDABILITY<br><br>(Auditability) | How have methodological and analytical changes been recorded and justified over time as research findings emerge? | External auditing (audit trail)<br><br>Documentation e.g. memos and record sheets |
| Objectivity | CONFIRMABILITY<br><br>(Neutrality) | How has researcher bias, values and prejudices been managed? | Employing reflexivity e.g. diaries, memos |

## 3.7 Participant Selection and Context of Setting

The IBO website (www.ibo.org) was consulted when locating authorised IBDP schools within Australia for research. This website includes the names of the schools within each Australian state that currently implement the IBDP curriculum. Oher useful information, such as the subjects taught within each school and the name and contact details of IBDP coordinators, was also located on the IBO website. In the early research phase, seven schools located within my home state were invited to participate in the study. Teachers were chosen according to whether they had taught the 2009 IBDP Biology curriculum and were currently implementing the 2016 IBDP Biology curriculum. By selecting teachers who had taught the 2009 and 2016 IBDP Biology curricula, it was possible to obtain their comparative perspectives on both programmes.

Principals from four of the seven invited IBDP schools politely declined to participate in the research due to their teachers being too busy. Consequently, this response by these schools required me to select a third participant outside of my home state. Eventually, three school Principals, two from my home state and a third from another Australian state, agreed to participate in the study. The Principal from the interstate IBDP school had a particular interest in the IBDP programme, having worked extensively in the past for the IBO.

Table 4 presents relevant demographic information about the three participants and their teaching contexts. The IBDP Biology teacher participants, Andrew, Kerri and Morgan shared some professional similarities that included working in a large, urban school context and experience teaching IBDP Biology for approximately the past three-and-a-half years at the school in which they were interviewed. All participants previously worked in scientific research before transitioning into teaching careers and also held leadership positions within their respective schools. A number of notable differences also existed between the participants. For example, the teacher participants ranged in age from about 31-60 years old, represented both genders and differed with respect to their total number of years of teaching experience.

According to Patton (2015), when common themes arise in the data during exploration of a small sample group of considerable heterogeneity, there is “value in capturing the core experiences and central shared dimensions of a setting or phenomenon” (p. 283). It was important in the current research not only to consider the uniqueness of each case, but also to explore commonalities across cases to enable comparisons that offered information-rich insights. Patton (2015) asserted that “Context envelopes and completes the whole. Without attention to and inclusion of context, qualitative findings are like a fine painting without a frame” (p. 69). In this section, a brief overview of the three teacher participants’ school setting, teaching and academic backgrounds, professional interests and prior work experience is included to provide context to the research.

**Lakeside International Secondary School*[6] (LISS)**

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[6] * denotes a pseudonym

Lakeside International Secondary School (LISS) is in the upper middle-class inner city suburb of Lakeside, located a few kilometres from the central business district of City A. LISS is a public (Year 8-12) secondary, international school with a student population comprising more than fifty different countries of birth. Two-fifths of the students have a non English speaking background (NESB). The school does not include any students of indigenous ancestry, but does offer places for a modest number of international fee-paying students with a high Index of Community Socio-Economic Advantage (ICSEA) (My School Website). In 2015, 59% of the Year 12 IBDP students attained an ATAR of 95% or more.

**Case Study 1: Andrew*- teacher at Lakeside International Secondary School (LISS)**

Andrew is a mid-career teacher, with an Honours degree in the biological sciences. He previously worked in medical research for eight years, prior to becoming a secondary Biology teacher. Andrew's career change was prompted by a need for further challenge, as he found research work was somewhat repetitive. Teaching was recommended to Andrew by a few people who believed he would succeed in the field and enjoy it. Lakeside International is Andrew's second appointment, where he has taught for seven years. Andrew is especially interested in developing student learning resources, such as 'Moodle', as an Information Communication Technology (ICT) learning platform. He is also passionate about ecology and has a specific interest in organisms' adaptations. Andrew enjoys observing his students' receptivity to new learning, as well as the challenges they pose in extending him professionally. Andrew holds two leadership responsibilities within the school, which include roles as a middle sub-school leader and Vocational Education Program (VET) coordinator.

**Arrowhall Boys' College* (ABC)**

Arrowhall Boy's College (ABC) is in the upper middle-class inner city suburb of Castlehill*, located on the outskirts of the central business district of City A. ABC is an independent (non-government) R-12 boys' school, with approximately 1050 students. One fifth of the student population are ESL students. The school has a high Index of Community Socio-Economic Advantage (ICSEA) (My School Website) and does not include students of indigenous ancestry. In 2015, 20% of the Year 12 (SACE and IBDP) students attained an ATAR of 95% or more (My School Website). Individual ATAR statistics for the Year 12 State Higher School Certificate and the IBDP were unavailable on both the Arrowhall Boys' College and My School websites.

**Case Study 2: Morgan* - Arrowhall Boys' College (ABC)**

Morgan is an early-career teacher (ECT) with Doctoral qualifications in biological science. Prior to becoming a secondary Biology teacher she worked in the pharmaceutical field. Morgan's decision to teach was influenced by the enjoyment of teaching undergraduate classes during her PhD studies. Furthermore, Morgan had a certain desire to find a career that was more varied and people-oriented. Arrowhall Boys' College is her second school appointment and is the first school in which she has taught IBDP Biology. Morgan is interested in biochemistry and currently teaches Biology and Chemistry within the IBDP curriculum. She holds a leadership position as a Biology coordinator.

**City View College (CVC)***

City View College (CVC) is in the upper middle-class inner city suburb of Edgely*, located a few kilometres from the central business district of City B. CVC is an independent (non-government) R-12 co-educational school with a high Index of Community Socio-Economic Advantage (ICSEA). Approximately one-fifth are NESB students, however, there are no students of indigenous ancestry. In 2015, 58% of the Year 12 IBDP students attained an ATAR of 95% or more (My School Website).

**Case Study 3: Kerri*- City View College (CVC)**

Kerri is a mid-career teacher with Doctoral qualifications in biological science, who worked in medical research before becoming a secondary Biology teacher. Moving from medical research to teaching was influenced by Kerri's dislike of spending long hours sitting at a computer writing grant applications, as well as his passion for mentorship. CVC is Kerri's first, full-time school appointment. In addition to teaching IBDP Biology, he also teaches IBDP Theory of Knowledge (TOK). Kerri has a particular interest in 'visible thinking' and enhancing understanding in the classroom through questioning and supporting active participation of students in developing their ideas.

## Table 4 - Teacher Participants' Background Information

| Participant Name | Age (years) | Gender | School, Type and City | Years Teaching | Years Teaching IBDP Biology | Educational Qualifications | School Size | Leadership Role in School | Years Working in Scientific Field before Teaching |
|---|---|---|---|---|---|---|---|---|---|
| Andrew | 41-50 | Male | Lakeside International Secondary School (LISS) – Public Co-educational (City A) | 14 | 3.5 | BSc. (Hons) Grad. Dip. Ed. | 1750 | yes | 8 |
| Morgan | 31-40 | Female | Arrowhall Boys' College (ABC) – Independent Boys (City A) | 4.5 | 3.5 | BSc. (Hons) Grad. Dip. Ed. PhD | 1,050 | yes | 6 |
| Kerri | 51-60 | Male | City View College (CVC) – Independent Co-educational (City B) | 12 | 3.5 | BSc. (Hons) Dip. Ed. PhD | 3000 | no | 12 |

### 3.8 Data Collection

Interviews are "one of the most powerful ways in which we understand our fellow human beings" (Fontana & Frey, 2000, p. 645). According to Fontana & Frey (2000), using individual, face-to-face interviews as the primary data collection method is probably the most effective way to understand another person's point of view. Semi-structured interviews were considered particularly suitable in the current study, as they offered a flexible approach to data collection. Although most questions were determined before interviews, several probing questions were used to elicit more depth and detail. Patton's (2002) idea of considering question order was utilised to ensure the least sensitive and hence less threatening questions were near the beginning of the interviews (see Table 5). According to Patton (2002), this method of question order affords participants more time to acclimatise to interviews and develop trust and a rapport with the researcher.

**Table 5 - Interview Questions - Excerpt from Interview 3A - Kerri**

| Sensitive Question | Less Sensitive Question |
|---|---|
| **Qu 5.** Comment on your personal strengths and weaknesses in facilitating student practical report writing skills amongst your students in IBDP Biology? | Qu 1 b. What do you find interesting about the new 2016 version of the IBDP Biology curriculum from the perspective of practical work, which eventually leads up to the final production of a major investigation in Year 12? |

Two photocopies were made of each participant's written interview guide; one for the researcher to read from and the other for the participant to refer to during the interview (see Appendix K). Each interview guide had a cover sheet which outlined the date, time and location of the interview, the names of both the researcher and participant (pseudonym[7]), the participant's teaching position and a brief description of the research.

To minimise disruption to the school site and teacher participants, interviews were arranged on dates and at times and locations that were mutually convenient. Most interviews were conducted at the participant's school within the familiar surroundings of their own office, classroom or private interview room. On one occasion, however, a participant expressed a preference for being interviewed at home, in the school holidays, away from the distractions of school routines.

Prior to each interview, I explained the purpose and importance of the study, how the data would be used and the participant's rights, using an informal, conversational style to help establish a positive relationship. A digital voice recorder and an iPhone (as a back-up device) were simultaneously used to create audio recordings of interviews. Note-taking was avoided, so I could maintain eye-contact during interviews and focus my attention on the participant's speech.

Several strategies were utilised during interviews to ensure that participants were treated with respect, sensitivity and dignity. These strategies involved listening carefully, allowing think-time for more complex questions and using prompting questions or re-

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[7] A pseudonym was used for the purpose of anonymity in order to protect the identity of each participant.

wording questions for clarity. I effectively established trust and developed a friendly, yet professional rapport with the participants. My professional status as an IBDP Biology teacher enabled me to use subject-specific language. Moreover, my in-depth knowledge of the relevant IBDP Biology curriculum and assessment protocols and ability to genuinely empathise with the participants' professional challenges, helped me to form a positive rapport with the teacher participants. Care was taken, however, to maintain an emic perspective throughout interviews. I avoided the urge to pledge allegiances by siding with the teacher participants during interviews to maintain data integrity and allow each individual's perspective to naturally emerge. Creswell (2013) advised that during interviews researchers should "Avoid leading questions; withhold sharing personal impressions; avoid sharing sensitive information" (Creswell, 2013, p. 58). I made a conscious effort not to partake in discussions of a personal and/or sensitive nature in order to respect any perceived power imbalances with teacher participants.

The first round of two interviews with Andrew and Morgan in City A resulted in two- and-a-half hours of data. These interviews were conducted in 2015 when the teachers were experiencing their first year of implementing the 2016 IA protocol with their Year 11 Biology classes. The second round of interviews with Andrew and Morgan occurred in 2016 and constituted another two hours of data. At this point in time, Andrew and Morgan were teaching the same group of students from 2015, who had progressed into Year 12. An opportunity to interview the third participant, Kerri, did not arise until 2016. Consequently, I conducted a longer interview with Kerri in which one-and-a-half hours' worth of data was collected. Kerri's interview included questions relevant to experiences with his Year 11 IBDP Biology class in 2015 and during 2016 when they were in Year 12. Overall, a total of six hours of audio interview data was collected from all three participants.

At the conclusion of interviews, participants were thanked, reassured of their anonymity and confidentiality of data and asked if they had further relevant information to offer. I reminded participants that member-checking would occur later during the study and requested their permission to send follow-up emails in case clarifying questions were required. Once all interviews were completed, I sent an email questionnaire to each participant requesting some demographic information. Once interviews were transcribed verbatim, a written transcript was emailed to the participant to check accuracy, soon after the interview, as part of the member-checking process. Member-checking provided another opportunity for participants to either add or remove information that they believed was inaccurate or could potentially compromise their privacy. Participants were also sent an email requesting permission to collect a variety of artefacts from them. Some of the artefacts collected included teacher-generated formative assessment practical reports, lesson notes and samples of assessed student practical reports. These artefacts helped to add contextual detail to the data and to verify the accuracy of verbal comments from interviews.

## 3.9 Data Analysis

Charmaz's (2006) constructivist grounded theory (GT) approach was adopted as an analytic framework, as it provided "systematic, yet flexible guidelines for collecting and analysing qualitative data to construct theories 'grounded' in the data themselves" (p. 2). Multiple case studies typically involve two analytical stages: (1) within-case analysis and (2) cross-case analysis (Merriam, 1998; Miles & Hubermann, 1994; Thomas, 2011). A within- case analysis was initially conducted to generate initial ideas emerging in the data for each case. This was followed by cross-case analysis to identify thematic similarities and differences between cases.

Data analysis commenced immediately after the first interview and involved repeatedly listening to audio recordings and re-reading interview transcripts to gain a holistic impression of case data. All data, including both audio recordings and written interview transcripts and documents, were stored on NVivo computer software and organised into separate files. NVivo software provided an efficient file management system which helped facilitate systematic analysis of large amounts of data.

The GT coding approach utilised to analyse interview data included three types of coding: initial, focused and theoretical. Each case interview was first coded separately using the *initial* coding technique. Initial coding is the first level of analysis in which the data is 'opened up' to see what is happening and make some sense of it (Strauss & Corbin, 1990). Initial coding involved line-by-line coding, where each line or sentence within the interview transcript was allocated a short, descriptive phrasal code beginning with a gerund (verb ending in –ing) depicting the main action within a particular data segment. According to Glaser (1978), using gerunds enables researchers to concentrate on processes, rather than topics. "Staying close to the data and, when possible, starting with the words and actions of your respondents, preserves fluidity of their experience and gives you new ways of looking at it. These steps encourage you to begin analysis from their perspective. That is the point" (Charmaz, 2006, p. 49).

Utilising this process ensured that initial ideas were grounded in the data and that the integrity of the participants' views was preserved. I maintained a reflexive approach throughout analysis, since this coding method limited the extent to which my pre-conceived ideas, as a fellow IBDP Biology teacher, might influence the data. Giles, de Lacey and Muir-Cochrane (2016) acknowledged that initial coding may require a few attempts before provisional codes are finalised in a way that has the required "analytical grab" (p. 32). Several coding iterations occurred in the current study, as initial coding involved several repetitions to ensure codes closely fitted the data.

**Memoing**

Memoing was also used to analyse data and included both case-based and conceptual memos (Sbraini, Carter, Wendell Evans & Blinkhorn, 2011) that were written to document initial impressions of the participants' experiences and views, as well as my own thoughts about them. Case-based memos were written soon after interviews and allowed for reflection of my own pre-conceived ideas. Memos were quickly written, in a free-flow, informal narrative format to help guide coding. Conceptual memos helped explicate the overall idea/s emerging in response to interview questions. This process enabled me to actively engage with the data of each case in a reflective and critical manner. Reading and re-reading memos assisted in analysing data in more detail. Both initial coding and memoing allowed analysis of each case as a separate entity in its own right before moving onto cross-case analysis (see Appendix L)

**Second Interview**

Following the first interviews with Andrew and Morgan, in which they outlined their experiences with their Year 11 Biology classes, I decided, based on the emerging data to interview them on a second occasion. A second interview was negotiated with both Andrew and Morgan and was conducted during the second year (Year 12) of the two-year IBDP Biology curriculum to explore their perspectives following implementation of the summative IA. Since the third participant, Kerri, was teaching the second year of the curriculum when he was first interviewed, a second interview with him did not occur. Conducting just one interview with Kerri was not a major limitation, since his interview was the longest within the group. Kerri was asked questions that had already been covered to a large extent during interviews with the other participants. Consequently, Kerri's questions were relevant to both the first and second years of his experience with the 2016 IA component of the IBDP Biology program. At the time of Kerri's interview, his students had recently completed the investigative phase of the summative IA and were writing rough drafts of their practical reports. Interviewing participants both before and after the implementation of the summative IA comparisons was an important research strategy designed to further enrich the data quality. Although Kerri was not interviewed before conducting the summative IA, his pre-IA implementation views were collected through his retrospective recounts of practical report writing experiences.

**Focused Coding**

Next, focused coding involved closely examining the initial codes within each case. Initial codes were grouped together into broader categories, according to their frequency and/or importance. This grouping of initial codes was the first foray into a cross-case analysis of the data. Throughout the research period, an iterative process of simultaneously collecting and analysing data, another key component of GT analysis (Charmaz, 2006; Glaser & Strauss, 1967) occurred to inform subsequent data collection. In this way, several initial codes were successively modified to create an increasingly better fit with the existing data, as new data arose. Generating focused codes involved iterations between the initial and focused coding stages. Focused coding synthesised the data from the best-fit initial codes across the three cases (across-case analysis) to provide comparisons of the experiences and views amongst the participants.

This process involved modifying or developing new interview questions to follow areas of inquiry that were not considered earlier. Focused codes were more conceptually sophisticated than initial codes and involved making decisions about which initial codes were most relevant. For example, extensive initial coding of all three cases revealed that a particular group of codes emphasised what participant teachers thought about providing formative feedback to students on written practical reports. This aspect of formative feedback provision was consistently raised by all teacher participants. Since formative feedback is a key pedagogical strategy, it was assigned the focused code 'lacking confidence in providing feedback.'

**Constant Comparisons**

Throughout the analytical phase, the constant comparative method was used to compare both similarities and differences in the data, firm-up emerging concepts, further develop conceptual ideas and finally, compare findings with relevant theoretical and research literature. Table 6 presents sample excerpts from interview transcripts that compare the experiences of participants according to the phenomenon coded as 'lacking confidence providing feedback' and also illustrates the initial codes that led to developing this focused code.

Although participants claimed to lack confidence in providing feedback, this focused code can also be interpreted in a dimensionalised way. For example, Morgan was not particularly confident with feedback. Andrew, however, simply regarded feedback as a challenge that would improve with experience. This example depicts not only the similarities that can prevail across cases, but also acknowledges the subtle and yet important individual differences within each case that cannot be ignored. The unique differences between cases (i.e. Andrew and Morgan in this example), such as degree of self-efficacy with respect to formative feedback, are often only noticed upon close examination of the participants' own words. Care was taken not to generalise from each case, since they are not meant to be representative samples of the population. Instead, my intent was to compare these cases for what they show and to allow readers to make their own judgements about verisimilitude.

**Table 6 - Constant Comparisons of Focused Code, "Lacking confidence providing feedback between interview participants"**

| Excerpt (Selected Examples) | Initial codes | Focused codes |
|---|---|---|
| **1 Andrew**<br><br>"..a challenge um , and then you know, trying to make sure you're providing er.. you know, really specific, quality comments and feedback..."<br><br>"...something that hopefully, you know, you build up with experience". | Challenging process of providing specific, quality feedback to students<br><br>Hoping that with experience quality of feedback to students will improve | Lacking confidence providing feedback. |
| **2 Morgan**<br>"I think the challenge and concern that I have is how much help I'm allowed to give".<br><br>"I think for me the concern is how much help am I allowed to give before I am actually disadvantaging them".<br><br>"I'm not confident on it".<br><br>"I think it would prove useful to do moderating, but I'm sure that wouldn't happen because I am not experienced enough and there's a billion IB teachers". | Concerning issue is how much help teacher can give students<br><br>Lacking confidence in knowing how much feedback to give students on new IA.<br><br>Thinking that becoming a moderator would help to better understand degree of guidance allowable. | |
| **3 Kerry**<br><br>"and I am not that experienced as to guiding them to what an external examiner would consider a 6. I am not really sure what that is ...so partly guided by the old course there probably, so I am thinking that to be safe they will probably look pretty similar to those in the old course"<br><br>"..but the truth of it was I guess, in that feedback on that one draft there was some help there to improve and... I don't know how fair across the board that was, but it seems talking about it now, it's probably normalising the students, rather than keeping them spread out". | Feeling inexperienced in providing adequate guidance in achieving highest level within criterion of new IA.<br><br>Trying to find a balance between providing some help but not too much. | |

As interviews progressed, I compared case-based and conceptual memos by recording similarities and differences across cases. This enabled a re-examination of the initial and focused codes with a fresh perspective, so the future direction of the data collection and analysis could be determined. Memoing helped enhance research rigour, as it progressed through the production of an audit trail that documented evidence of my thoughts concerning the coded data and the emerging theory.

**Final Coding**

According to Charmaz (2006), “theoretical codes specify possible relationships between categories you have developed in your focused (substantive) coding” (p. 63). In the final stage of coding, the focused codes were then subsumed within one of six core categories. The final core categories (theoretical codes) were then represented within one of two broad themes:

1. IBDP Biology Teacher – Pedagogical Strategies for the Internal Assessment (Figure 6)

2. Teacher Perceptions and Experiences of the Internal Assessment (Figure 7)

Each theme is directly related to the research focus on IA practical reports in IBDP Biology and are discussed in detail in Chapter 4.

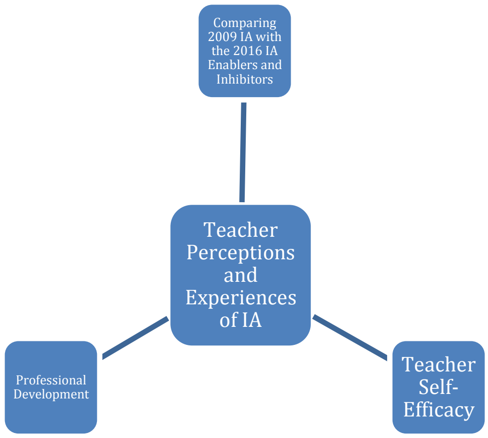


**Figure 7 - THEME 1: Pedagogical strategies for the Internal Assessment (IA)**

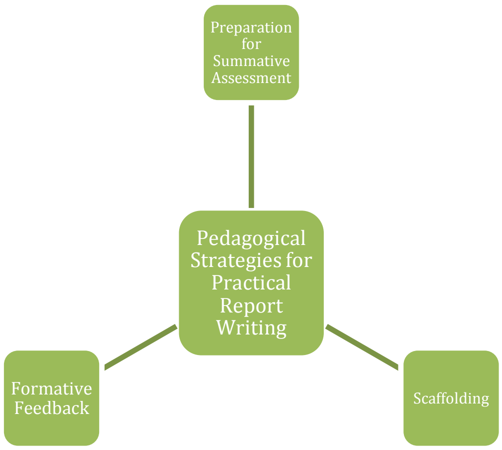


**Figure 8 - THEME 2: Teacher perceptions and experiences of the Internal Assessment (IA)**

# Chapter 4 Results and Discussion

## 4.1 Introduction

This chapter presents the findings and interpretations of the two research questions posed in the current study concerning the pedagogical strategies and perceptions of the teacher participants regarding the IBDP Biology Internal Assessment (IA). Section 4.2 describes the pedagogical strategies teachers utilised to develop their students' understanding of practical report writing skills when using both the 2009 and 2016 IA protocols. Section 4.3 includes a comparison of the teachers' perceptions of the 2009 and 2016 IA protocols within the IBDP Biology curriculum.

## 4.2 Pedagogical Strategies for Practical Report Writing

In this section, the type and range of pedagogies implemented by the IBDP Biology teacher participants to develop the practical report writing skills of students in preparation for the summative internal assessment (IA) investigation are explored.

### 4.2.1 Formative Assessment: Preparation for Summative Internal Assessment

#### *4.2.1.1 Introducing the summative IA protocol and rubric criteria*

All teacher participants distributed marking rubrics and explained assessment criteria to students during whole-class discussions before implementing both the 2009 and 2016 summative IA investigations.

Andrew introduced the 2016 IA rubric (Table 7) to students early in Year 11 and explained the five IA rubric assessment criteria [i.e. 'personal engagement' (PE), 'exploration' (E), 'analysis' (An), 'evaluation' (Ev) and 'communication' (C)]. Andrew explained that he displayed the IA rubric on an electronic whiteboard and would "go through each (criterion) briefly at the start." The IA rubric and formative practical investigations were posted on the Biology Moodle site that Andrew developed, for quick and easy access by students.

Kerri implemented several formative investigations during the first half of Year 11 that focused on specific descriptors within the 'An' and 'Ev' criteria of the 2016 IA rubric. As he explained;

> *I ran several practicals through Year 11 where one or two aspects were assessed and significant individual feedback provided. In*

*each case, I talked through the criteria descriptors using digital projection.* Kerri

The 2016 IA 'Ev' criterion "assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context" (IBO, 2014, p. 157). Table 7 depicts four groups of 'descriptors' that correspond to four quality levels with a mark-scheme ranging from 0 to 6 marks. Notably, three of the 'Ev' descriptors include a two point mark-band (e.g. 1-2, 3-4 & 5-6). According to the IBO (2014), moderators and teachers are advised to employ a "best-fit approach" (p. 157) when allocating marks to a descriptor; this approach enables some marking flexibility.

**Table 7 - Extract of original 2016 Internal Assessment (IA) rubric for Evaluation (Ev) criterion (IBO, 2014, p. 157-158)**

**Evaluation**

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | A conclusion is **outlined** which is not relevant to the research question or is not supported by the data presented.<br>The conclusion makes superficial comparison to the accepted scientific context.<br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **outlined** but are restricted to an **account** of **the practical** or **procedural issues** faced.<br>The student has **outlined** very few realistic and relevant suggestions for the improvement and extension of the investigation. |
| 3–4 | A conclusion is **described** which is relevant to the research question and supported by the data presented.<br>A conclusion is described which makes some relevant comparison to the accepted scientific context.<br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **described** and provide evidence of some awareness of the **methodological issues*** involved in establishing the conclusion.<br>The student has **described** some realistic and relevant suggestions for the improvement and extension of the investigation. |
| 5–6 | A detailed conclusion is **described and justified** which is entirely relevant to the research question and fully supported by the data presented.<br>A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context.<br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the **methodological issues*** involved in establishing the conclusion.<br>The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation. |

The 2016 IA rubric was introduced to all of the Year 11 IBDP Group 4 students (i.e. Biology, Chemistry & Physics) in Morgan's school, via a PowerPoint presentation designed by a science teacher colleague. The PowerPoint presentation included a 'modified' version of the original 2016 IBDP Group 4 IA rubric. The modified version of the 'Ev' criterion displayed in Table 8 includes some descriptor language borrowed from the 2009 IBDP Group 4 IA rubric (refer Appendix B). New descriptors (refer Table 8: left-hand column) were created by the anonymous author, although the quality level mark-bands remained identical to the IBDP Biology 2016 IA rubric.

**Table 8 - Extract 1 of Power Point presentation: Hybrid version of the 2016 Internal Assessment (IA) rubric Evaluation criterion (Anonymous, 2016)**

# Evaluation

| Descriptor | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| **conclusion statement** | standard not reached | outlined but not relevant to the research question or not supported by the data presented | | described, relevant to the research question and supported by the data presented | | described in detail and justified, entirely relevant to the research question and fully supported by the data presented | |
| **conclusion and accepted theory** | standard not reached | superficially compared to the accepted scientific context | | some relevant comparison to accepted scientific context | | correctly described and justified through relevant comparison to the accepted scientific context | |
| **strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are discussed and provide evidence to a clear understanding of the methodological issues involved in establishing the conclusion** | standard not reached | outlined but are restricted to an account of the practical or procedural issues faced | | described and provide evidence of some awareness of the methodological issues involved in establishing the conclusion | | discussed and provide evidence of a clear understanding of the method-ological issues involved in establishing the conclusion | |
| **realistic and relevant suggestions for the improvement and extension of the investigation** | standard not reached | very few outlined | | some described | | are discussed | |

The modified 'Ev' criterion's last descriptor, that states, 'realistic and relevant suggestions for the improvement and extension of the investigation,' includes minimal information to help scaffold student responses. Figure 8 shows another slide from the same PowerPoint presentation, as the one in Table 8 and provides some additional information about the 'Ev' criterion descriptors. The repeated use of the verb, 'show', in the slide shown in Figure 8, may reflect the author's intention to encourage students to include all of its listed points, thereby enhancing the transparency of the 2016 IA rubric.

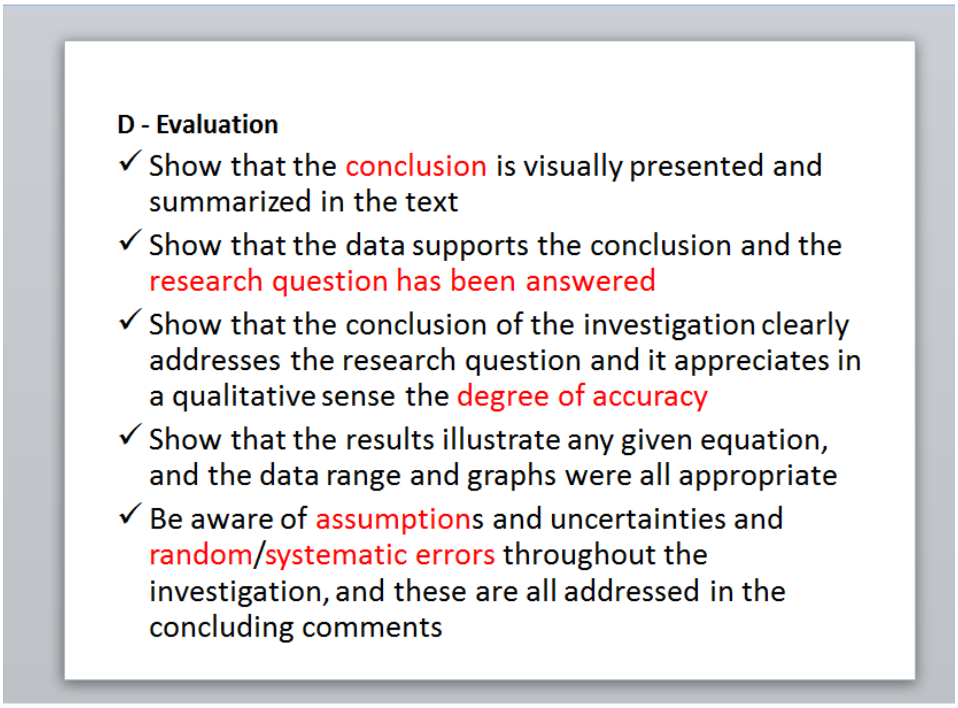


**Figure 9 (Anonymous, 2016) - Extract 2 of Power Point presentation: Additional information on Evaluation criterion**

In the context of the current study, it should be pointed out that the official IA rubric criteria listed in the 2016 IBDP Biology curriculum guide were designed by the IBO and it these that are intended to be used by teachers for summative purposes. Since the modified rubric Morgan used was not formally sanctioned by the IBO, it may have caused some confusion amongst students. Consequently, it is important that all IBDP Biology teachers have an accurate understanding of these IA criteria, so that they can be clearly explained to students before undertaking practical assessment tasks.  Morgan, however, evidently supported using the modified rubric and stated: “they [students] found it helpful and I would definitely do it again.” Morgan remarked that she did not use a modified rubric for the 2009 IA, as “it was just each practical [summative] ongoing, as the same format as all the formative ones – it didn’t need as much explanation.” Evidently, Morgan applied the 2009 IA rubric identically to both the formative and summative practical write-ups. Her greater familiarity with the 2009 IA rubric may have meant that she did not believe further clarification of the IA criteria was necessary. Morgan introduced the 2016 IA summative criteria to students towards the end of Year 11, for formative IA investigations, one term before commencing the summative IA investigation in mid-Term 1 of Year 12. Her rationale for delaying the use of the 2016 IA for formative purposes is discussed in section 4.3.

Few studies are evident in the education literature that specifically examine the assessment of ‘school’ science practical work (Abrahams, Reiss & Sharpe, 2013) and in particular the use of rubrics as assessment tools in this area of the curriculum. Jonsson’s (2014) study of university educators within three different professional education fields (e.g. dentistry, statistics/epidemiology and real estate), revealed that rubric accessibility was prioritised when communicating assessment task expectations to students. The educators gave rubrics to the students before attempting planned assessment tasks and allowed adequate time to explain rubric criteria and clarify assessment expectations. Although the methods used to explain assessment criteria by the educators differed according to the subject discipline, the researchers concluded that “it is not how this is done that is of importance, but that it is done” (Jonsson, 2014, p.849).

According to Montgomery (2002), making rubric assessment criteria transparent to students before assessment tasks usually leads to higher quality work; however, the "rubric needs to be clear and specific as possible when a multi-dimensional task is assigned, as the challenge of the task should be in its completion, not in figuring out the task itself" (p. 37).

Pandero and Jonsson's (2013) reviewed 21 studies based exclusively on empirical data involving primary, secondary and tertiary students across a wide variety of subject disciplines. It was found that when summative rubrics were used for formative assessment, they "may mediate improved performance through (a) providing transparency to assessment, which in turn may (b) reduce student anxiety" (p. 140). The findings of this review suggest that the pedagogical approaches Andrew and Morgan used to clarify the assessment expectations of the IA rubric criteria, probably, at best enhanced their students' confidence in practical report writing.

In the current study, it was difficult to ascertain how modifications made to the 2016 IBDP Biology IA rubric by Morgan's science colleague would have affected her students' learning outcomes. It is possible that by conducting classroom observations or interviews with Morgan's students, it may have been possible to determine the extent to which the modified rubric enabled a better understanding of the assessment expectations of the 2016 IBDP Biology IA.

#### *4.2.1.2 Implementing feedback: The influence of various formative assessment strategies on student learning in science practical report writing*

According to Sadler (2010), formative feedback typically involves making qualitative judgements about the quality of a student's work. Crisp (2007) asserted that feedback may empower learners, but does not necessarily guarantee improved learning outcomes. Butler's (1987) study found that personal praise directed to the individual (ego-involving feedback), rather than the student's task attempt, had a significantly different effects, with the former method leading to significantly less learning improvements than the latter. Sadler (2010) posited that feedback serves two main functions regarding the student's learning task. Firstly, an evaluation of the student's performance is made that may or may not include a grade or mark, along with a rationale explaining how strengths and weaknesses of the work were appraised. Secondly, constructive advice may be provided concerning how the work could have been improved.

Cowie and Bell's (1999) research identified two formative assessment approaches commonly utilised by teachers. In the first approach, known as 'planned' formative assessment, teachers elicit and interpret assessment information and design specific class tasks. The second approach, however, known as 'interactive' formative assessment, occurs spontaneously as learning activities proceed and involves teachers "noticing, recognising and responding" (Cowie et al., 1999, p. 412) to individuals or small student groups. It was assumed in the current research that planned formative assessment was more commonly used than interactive formative assessment, as a pedagogy, since the latter approach was minimally reported during interviews. It may be speculated, therefore, that teachers did not consider interactive formative assessment to be a formal pedagogy, possibly due to its incidental nature in daily classroom practice.

The teacher participants reported providing regular opportunities for student engagement in both confirmatory and inquiry investigations. Although most formatively assessed investigations involved structured-inquiry, students did engage in open-inquiry, although the proportion of these investigations differed amongst the teachers. The teachers perceived that regular feedback involving formative tasks was particularly beneficial for student learning when writing practical reports. The nature and extent of the feedback provided, however, was unique to each teacher. The formative feedback strategies typically used by the teacher participants are now explored.

**Formative feedback strategies**

Morgan, an early career teacher, initially believed that her Year 11 2016 IBDP Biology students would learn more effectively by submitting their first formative practical reports without any scaffolding assistance and little formative feedback. Early in Year 11, Morgan instructed students to submit two formative reports in quick succession and only gave a mark as feedback. As she explained;

> *I thought they would learn more from getting it back with a low mark when it's formative. My strategy really for the first couple*

[formative IAs]*, was to just let them do it and then rip* [give feedback] *into it afterwards.* Morgan

Morgan's comment suggested that she anticipated that her students learning might be enhanced, if she withheld scaffolding assistance for the first two formative practical reports.

A study by Wollenschlagger, Hattie, Machts, Moller and Harms' (2016) may explain why simply providing an assessment rubric to students in the absence of any additional feedback, may have led to the minimal learning that Morgan reported. Wollenschlagger et al.'s (2016) study subjected 120, Year 8 students to three different conditions of rubric feedback: (1) transparency information, (2) individual performance information and (3) individual performance improvement and examined the effect on their overall performance, motivation and self-regulation. The task tested the students' abilities in scientific reasoning in preparation for implementing an experiment. Under condition 1, students were only given a 5-scaled rubric (see Figure 9) prior to the task and no additional feedback after task completion. Condition 2 was identical to condition 1, but additionally, a feedback grade of 1 to 5 was assigned to each student after task completion. Finally, condition 3 included both elements of the first two conditions, but students were also provided with pertinent information about the specific levels of scientific reasoning they had achieved following task completion. The researchers concluded that "students seem to benefit most from rubric feedback if it includes individualised feedback on how to proceed" (Wollenschlagger et al., 2016, p. 8). Although Morgan ensured that the IA criteria were clearly explained to her students, it appeared that she had not fully appreciated the extent of formative feedback that she would need to provide to the students at this early point in the IBDP Biology curriculum. Wollenschlagger et al.'s (2016) study pointed to the importance of individual feedback that informs students how to improve specific aspects of their practical report.

| |
|---|
| When planning experiments, you have to consider the following steps: |
| 1) … At first, you say what you want to investigate. You name a variable. A variable is the one factor that is going to be investigated and modified, i.e. that is varied in the experiment. |
| 2) … You say how you are going to measure the modifications of the variable. |
| 3) … You control other influencing factors that you don't want to investigate, i.e. you keep all other variables constant. |
| 4) … You say with how many objects of investigation, how often or how long you want to run the experiment. |
| 5) … You think of possible mistakes or limitations in your design. Then you plan a new and more appropriate experiment. |

**Figure 10 - Five levels of scientific reasoning with respect to planning experiments (Mayer et al., 2009 in Wollenschlagger et al., 2016)**

Clark (2010) argued that authentic formative feedback should include scaffolding or carefully crafted questions to help students achieve their learning goals. Clark (2010) stated: "simply telling students to 'work harder' or 'recalculate your answer' does not possess the qualities of effective formative feedback, because it does not support (or scaffold) learning by telling students how or why they need to do this" (p. 344).

Furthermore, Clark (2010) asserted that formative learning is enhanced when teachers support students in managing their own learning using metacognitive strategies.

In light of Wollenschlagger et al.'s (2016) and Clark's (2010) studies, it is not surprising that when Morgan returned 'a couple' of practical reports with low marks without prior scaffolding during the early stages of practical report writing, minimal learning was achieved by students. In hindsight, Morgan conceded after the first interview that her early strategy of allowing students to write an IA practical report had not been pedagogically successful. Furthermore, the research has indicated that Morgan may also have needed to provide more 'effective' formative feedback and support for her students, so that they could readily understand how to improve specific areas of their practical report writing and achieve greater academic success. Morgan's relative inexperience as a Biology teacher probably played an important role in her early pedagogical decisions, with respect to practical report writing in Year 11 IBDP Biology classes. Scaffolding pedagogies utilised by teacher participants are examined in more detail in section 4.2.2.

Both Morgan and Andrew acknowledged the importance of providing sufficient report writing practice and regular formative feedback, to support students learning about writing practical reports. As the teachers explained;

> *I think for the kids it's really just a matter of doing it [formative practical report] again and again and again and getting feedback each time and fine tuning, because even though they've said, "Yes,*

*I understand I have to control all of those and yes, I understand that my method has to have a quantity for everything", …. they don't do it. I'll say, "How many, how many, how much, how much" and I'd try and hammer home that it needs to be able to be done exactly the same by another kid in another school, that they've never had a conversation with.* Morgan

*We are doing a number of formative practicals in Year 11. You might do three to five practicals* [per term], *but having one that's written up in detail, so for each of those, they're building up more skills and more understanding of what's required…but providing them with regular practical activity times. Then they become more and more familiar and their depth of understanding about practicals and good practicals and requirements improve.* Andrew

Like Morgan and Andrew, Kerri also emphasised using an approach in which students engaged in regular experimental work and report writing. He also reported providing the students with detailed formative feedback about their reports. As Kerri stated;

*We still did a practical class a week consistently through the year and they were given some extensive feedback on those reports.*
Kerri

Crotwell Timmerman, Strickland, Johnson and Payne (2011) suggested that teacher expectations of student performances should be consistent over time and claimed that students require multiple opportunities to learn and practise writing skills. Evidently, both Morgan and Kerri regularly provided students with extensive written feedback and marks-indicators on both formative IAs and rough drafts of the summative IA. When using the 2016 IA, Morgan typically indicated a marking range, such as 3 to 4 out of 6 marks for the 'E' criterion (see Appendix M) and highlighted mathematical errors with red circles. As the teachers explained;

*I wrote a lot of feedback on those and I gave them the mark scheme and I put on there where it currently was at on the mark scheme for the draft, so they knew where they had to improve it.*
Morgan

*I indicated an indicative score, sometimes blurring the boundaries as a means of feedback and where to improve the draft. This was done with the old course (2009 IA) also.* Kerri

Kerri discussed practical reports in more depth, post-handback during individual mini-conferencing sessions, particularly with students who struggled with writing. As Kerri explained;

> *So struggling students, I think, I probably give them a bit more direction on a really weak IA. When I hand back, it would be a one-on- one. When I hand back that IA it's not just a here they all are in class, but again I wouldn't….. certainly not re-writing it for them in anyway.* Kerri

Deiner, Newsome and Samaroo's (2012) study of college Chemistry classes provided anecdotal evidence that informal mini-conferencing sessions following return of laboratory reports, was more effective than only providing written comments. The researchers conceded, however, that these findings were not substantiated by rigorous research and that further studies were necessary. According to Deiner et al., (2012), verbally communicating detailed feedback to each individual "conveys the message that the instructor reads and pays attention to each student's writing" (p. 1513) and may also assist student confidence. Andrew, in contrast to Morgan and Kerri, only included written feedback without marks on rough drafts of both formative and summative practical reports. As he explained;

> *I haven't gone through and given a mark on each. Notes were provided on each submission. What I've done when I've drafted*

> *students' work is to go through and give them feedback on each of their sections and any bits that were missed, or that they need to look into in a bit more detail or re-word.* Andrew

Interestingly, some literature findings appear to support Andrew's approach to formative learning whereby written feedback is provided without marks. According to Lipnevich, McCallen, Pace Miles & Smith (2014), although it is generally accepted that formative feedback is recommended, it is the 'type' of feedback that is important. Butler's (1988) study, for example, examined the link between intrinsic motivation and assessment methods used in science classes with middle-school Israeli students. Those students who received only written feedback from their teacher without grades or marks, performed more effectively on written tasks than those who either received only grades, or a combination of grades and comments.

Black, Harrison, Lee, Marshall & Wiliam's (2004) study of middle-school students similarly found that although written feedback assisted learning, providing marks or grades could lead to adverse outcomes. The researchers argued that students do not usually read written feedback, preferring instead to take note of marks, which can lead to lost opportunities in improving work quality. Black and Wiliam's (1998) seminal literature review of over 250 feedback studies in a broad range of educational settings concluded that, "even if feedback comments are operationally helpful for a student's work, their effect can be undermined by the negative motivational effects of normative feedback, i.e.

by giving grades" (p.13). These findings are consistent with several other educational researchers (Lipnevich & Smith, 2009; Hattie & Timperley, 2007; Harlen & Crick, 2003).

It is interesting to consider why two teachers in the current study included marks-indicators *and* written feedback. The inclusion of marks-indicators by Kerri and Morgan was probably standard practice within their respective schools. Nonetheless, the extent to which the omission or inclusion of marks-indicators in IA reports influences the students' learning outcomes merits further investigation.

Andrew believed it was important when giving formative feedback, to establish why some students do not perform to their full potential in practical reports. He suggested it was necessary for him to distinguish between students with genuine learning difficulties and those who were simply not conscientious. As he explained;

> *Well, it's really personalising the feedback. Individualising… so it's providing written feedback. It's providing verbal feedback. It's really trying to identify for the individual where is it, that they are falling down, what's their problem. And it's also identifying those who perhaps aren't understanding fully how to do a component* [criterion of IA] *of it, to those who aren't spending enough time on it, where you can see they are just not being thorough enough, they're not putting in enough detailed effort and so you then, you know you change your discussion and your feedback to them.*
> Andrew

Andrew's apparent nuanced understanding of his students' unique learning needs appeared to have enabled him to adjust his pedagogy and individual formative feedback accordingly. It was apparent that Andrew was aware that the students' understandings are influenced by a combination of both affective and cognitive processes. Hattie et al., (2007) suggested that utilising affective feedback processes, such as encouraging students to apply more effort, motivation or engagement to the task, can assist students in their learning. Furthermore, Hattie et al. (2007) posited that cognitive processes, such as providing corrective feedback, suggesting different paths for accessing task-related information and considering alternative ways to improve understanding, may also be useful in bridging the gap between the students' current and desired level of understanding.

A unique feature of Kerri's approach to developing his students' understanding of investigative work was to use a practical log book. Kerri's students regularly recorded their formative practical work details within a log book. Furthermore, Kerri often posed questions about scientific concepts, which his students answered in their log books. During his interview, Kerri reflected on alternative ways that he could use log books in future to improve his students' practical report writing skills. For example, he suggested log books could be used to record information that more closely aligns with the theory underpinning the summative IA report. As Kerri recounted;

*This is their weekly record of practical work; they keep a log book* [in] *which they make some entry. It will be a new title each week after being introduced to the experiment, but usually there's at least some questions to answer, to reflect on and get back to the theory. They're* [entries] *probably more theory-based than questions about variables. I could see that as an opportunity to teach theory, but I am seeing that maybe they* [log books] *should be more focused on areas that are related to the IA write-up too.*
Kerri

In summary, the teacher participants utilised several different formative assessment strategies to assist students with writing practical reports, such as providing detailed, constructive written and verbal feedback, face-to face mini-conferencing sessions between the teacher and student and regular student log book checks. Planned formative feedback was the most common method of formative feedback mentioned by the teachers. In the next section, the teacher participants' uses of scaffolding devices for developing student proficiency in practical report writing are considered.

#### 4.2.2 Scaffolding Strategies

The teacher participants shared some scaffolding strategies in common when supporting students during the formative stages of practical report writing, that included partial report writing, presentation and discussion of assessed report exemplars and the use of tables. Only one teacher used checklists to further student understanding of practical report writing.

#### *4.2.2.1 Partial Report Writing*

The most common scaffolding approach utilised by teacher participants involved partial practical report writing. Partial report writing consisted of separating written tasks outlined within the rubric criteria into manageable sections or 'chunks, as well as focusing on a particular criterion. According to Wood (2015), scaffolding writing tasks can assist students who may be threatened by the perceived enormity of tasks and it may also increase their personal self-efficacy.

> It [scaffolding] separates the task into pieces which by themselves seem to require less effort than the whole. By breaking the task into manageable chunks, students may also find that they experience smaller, more frequent successes (Wood, 2015, p. 23).

Teacher participants regularly instructed students to complete partial practical report write-ups of formative investigations by focusing on at least one or more, but not usually all, of the rubric assessment criteria. Partial report writing allowed students to regularly practise responding to specific IA criteria in order to improve practical report quality.

Andrew's usual approach when using the 2016 IA during formative inquiry practical lessons in Year 11, involved focusing the students' attention on writing reports that included from one to three IA criteria. For example, Andrew assessed the 'An', 'Ev' and 'C' criteria following a structured inquiry investigation about enzymes. Since students were given the experimental design in the enzymes investigation, the 'E' criterion was not assessed. Andrew pointed out that his Year 11 students submitted one practical report per term focusing on only one of the three main assessment criteria (i.e. 'E', 'An' or 'Ev' ). For example, in Term 1 students were summatively assessed for school reporting purposes (not for external moderation) on the 'E' criterion. As Andrew explained;

> *We broke down the sections* [IA criteria] *of the IA, and for the first practical students might have just written up the Exploration* [criterion] *part, and were marked on that. The next practical, they had to focus on the data and the tables, graphing, observations and so on. We deliberately did that to focus in on different sections in Terms one, two and three.* Andrew

Kerri assessed his Year 11 students on at least two assessment criteria within the 2016 IA, as part of their formative learning. In a similar vein to Andrew, Kerri's students submitted some formative practical reports, purely for school reporting purposes. As Kerri explained;

> *With the introduction of a single IA we probably saw a greater need for scaffolding through Year 11…. to help them and we did re-design the course with that in mind. So we are marking part write-ups according to the mark-scheme* [new 2016 IA]. *And* [when] *we've done say, an enzyme practical, we've collected class data and asked them to tabulate, graph and write a conclusion and evaluation on that work. We did an Analysis-Evaluation with our first sort of marked practical piece.* Kerri

At the time of her first interview, Morgan had not commenced using the 2016 IA assessment rubric with her Year 11 class and hence could not comment on her experiences with its use. She did, however, mention utilising partial report writing throughout the 2009 IA. Once Morgan had implemented the 2016 IA rubric for formative IA practical reports with her Year 11 students during Term 4, she usually assessed up to three of the five criteria at a time. For example, her students designed an open-inquiry investigation to test the effect of a factor on seed germination and were formatively assessed on the 'E', 'An' and 'C' criteria. Morgan chose, however, to assess only parts of descriptors within the 'An' criterion, which specifically related to *selection and recording of data.* Furthermore, in this report she omitted the 'An' criterion descriptors of *processing and interpreting data*. Focusing on the whole or parts of descriptors within a criterion, was a form of 'fine-tuned chunking', which possibly enabled Morgan's students to more accurately interpret specific descriptors within an assessment criterion. The three participant teachers also regularly used partial report writing to formatively assess the students' understanding in the 2009 IBDP Biology program. As the participants stated:

> *I usually don't assess all three in one practical. Usually, I would do Design (D) separate from Data Collection and Processing (DCP) and Conclusion and Evaluation (CE).* Morgan

> *We would have tasks with partial report writing requirements.* Kerri

> *Each one of those (D, DCP & CE) would make up an individual focus for a student doing the formative practical.* Andrew

Both Andrew and Kerri's students undertook an open-inquiry investigation in which all five 2016 IA criteria were formatively assessed together at one time in Year 11. Kerri's students wrote a 'full'[8] formative IA practical report towards the end of Term 1 in Year 11. Andrew, however, waited until Term 4 of Year 11 until he believed his students were confident enough to write a full formative IA report. Andrew pointed out that his students received more teacher guidance with this full formative practical report compared to the summative IA report undertaken in Year 12. As he explained;

[8] Full report – is one in which all five 2016 IA criteria were assessed within a practical report (i.e. exploration, analysis, personal engagement, evaluation and communication)

> *In Term four … they did a full write-up* [IA report], *and we did a full marking using the new* [2016] *IA criteria. We gave them some guidance about a general topic, but then that was it, so it wasn't sort of full rein like for the actual IA this year.* Andrew

Morgan's students, however, did not write full formative practical reports using the 2016 IA. As mentioned earlier, Morgan delayed using the 2016 IA rubric until Term 4 in Year 11 (refer section 4.2.1). Her decision to delay using the 2016 IA was largely based on the rationale that the students had not had sufficient opportunities to practise using the new IA rubric criteria and that Morgan, herself, lacked confidence in using the rubric at this time.

#### *4.2.2.2 Using IA Rubric Assessed Exemplars of Practical Reports*

Each teacher participant described utilising assessed practical report exemplars to scaffold their students' understandings of the required standards and formatting procedures for the 2016 IA. Exemplars are defined here, as past copies of student practical reports that were previously assessed either by an IBDP Biology teacher or Group 4 moderator. Although teacher participants all utilised exemplar reports as scaffolding tools, they chose different pedagogical approaches to use them and in some cases, accessed them from different sources.

For example, both Morgan and Andrew sourced summative 2016 IA practical report exemplars from the Teacher Guidance Support Materials (TGSM) section of the

IBDP Biology page on the OCC website. The OCC exemplars had been assessed by IBO moderators using the 2016 IA rubric and included their written feedback and marks-indicators. According to Jonsson and Svingby (2007), Orsmond, Merry and Reiling (2002) and Sadler (1989), providing exemplar reports with assessment rubrics enables students to better understand how to attain various achievement levels. In the current study, the teacher  probably would also have learned more about the IA assessment protocol by reading through moderator comments on exemplar reports.

Research conducted by Lipnevich et al. (2014), however, concluded that when undergraduate psychology students were given rubrics separately from exemplar reports, they produced higher marks than when rubrics and exemplar reports were provided together. The researchers believed this may have been due to students being forced "to examine what they had done and look to see how it met the requirements of the task, rather than trying to imitate the exemplar without checking the understanding of the task" (Lipnevich et al., 2014, p. 551).

Morgan distributed exemplars to Year 12 students as they were writing their summative IA report rough drafts. She believed it was important that students could examine an outstanding example of an IA report, as well as one that was below satisfactory.  Her perception was that distributing exemplars of opposing quality highlighted the exceptionally high standard students would require to attain a high achievement level in the summative IA. She also pointed out that students perceived that an exemplar report on smoke-treated gum tree seeds from the OCC had been especially helpful as a scaffolding device. As Morgan recounted;

> *I gave them exemplars from the OCC of a really good one and a really bad one. I got them to look at the moderators' comments of those and also have a look at how they are marked, to get a feel for what they needed to produce. If they were saying, "Oh, I don't know how to present this", then I would give them some guidance and then I'll say, "Have a look at the exemplar that got an 'A'* [grade] *and see how they did it and then you can use that for your own template as well."* Morgan

Andrew was still using 2009 IA exemplars to illustrate high standards of achievement with his 2016 IBDP Biology Year 11 students when I first interviewed him in August 2015. He had obtained some 2009 IA reports from past students, while others were sourced from the OCC website. Andrew pointed out that he had requested permission from past Year 12 students to use their IA practical reports for teaching purposes. At this point in time, Andrew explained, he was updating his Moodle site and planned to include several resources to reflect IA changes within the 2016 IBDP Biology curriculum. Furthermore, he planned to include the latest moderated-assessed 2016 IA exemplars from the OCC on the Moodle site before students commenced the summative IA.

Unlike Morgan, however, Andrew distributed only ‘high quality’ exemplar practical reports via the Biology Moodle site. Andrew also annotated exemplars to highlight incorrect or missing details, a strategy he used for both the 2009 and 2016 IA protocols. Andrew appeared unconcerned that his students were provided with 2009 IA exemplars up until October 2015, despite his utilisation of the 2016 IA rubric for formative assessment throughout Year 11. Andrew asserted that the ‘An’ criterion in the 2016 IA differed little from the DCP criterion in the 2009 IA. As he explained;

> *What’s up on the Moodle is an exemplar that scored either full marks or almost full marks from the previous* [2009] *IA. For the results section, getting across raw data, observations, processed data, examples of calculations, uncertainties, graphing, and then observations from the graph, they are able to see that as well from the previous 2009 IA.* Andrew

Like Andrew, Kerri explained that when implementing both the 2009 and 2016 IA protocols, he had also shown students only ‘good’ exemplars of summative IAs. Unlike Andrew, however, Kerri’s exemplar reports were exclusively sourced from past students and were not electronically available to current students. Kerri’s approach involved discussing exemplars and displaying them via a data projector presentation. Unlike Morgan and Andrew, Kerri did not source moderator-assessed exemplars from the OCC. As he explained;

*I guess in those earlier write-ups before the IAs, there is some scaffolding there. We show some good examples of write-ups from past students. But we don't hand them* [exemplar reports] *to them. We don't give them electronic copies of anything. Just ones we have kept for some reason or other.* Kerri

Kerri had recently completed implementing the summative 2016 IA investigation, at the time of his interview in the middle of 2016. At this time, his Year 12 students were writing up rough drafts of the summative IA. Kerri was aware that moderator-assessed exemplar reports existed on the OCC website. He mentioned he had considered giving 2016 IA moderator-assessed exemplar reports to his students but had decided against it. Instead, he showed some exemplars of his past students' 2009 IA reports when he introduced the 2016 summative IA rubric to his Year 11 class. Kerri's decision to present outdated 2009 IA exemplars throughout the 2016 IBDP Biology program, rather than IBO moderated 2016 IA exemplars, may have confused some students. Kerri's decision not to distribute moderator-assessed exemplars may have been strategically motivated, so that his students were not influenced by what Lipnevich et al. (2014) referred to as 'imitation'. Kerri explained his uncertainty about accessing the OCC for moderator-exemplar practical reports:

*I personally don't use it* [OCC] *much. I don't know why* [pauses], *whether I feel like they should be on top of that themselves,* *whether I am a bit archaic and not very on top of my IT. I am not sure.* Kerri

Morgan proposed that when teaching future IBDP Biology classes she would consider providing exemplar reports *without* marks and comments, so that students could individually assess them. This idea arose out of discussions within her science faculty. As she explained;

> *I do think we* [Morgan and her IBDP science colleagues] *were talking about giving the students an exemplar and getting them to mark it themselves, which I think is quite a good exercise for them.* Morgan

The idea of students assessing exemplar reports may have indicated a move by Morgan's Science Faculty to enact a more student-centred learning approach in science classes. Student assessment of exemplar reports as proposed by Morgan, is somewhat similar to a peer review process, which is widely supported in the literature as an effective formative feedback method (Sampson, Grooms & Walker, 2011; Osborne, Eduran & Simon, 2004). For example, Sampson et al. (2011) suggested that peer review may improve the students' quality of rhetorical writing in practical reports. In peer review, anonymous practical reports are usually distributed to small groups of students, along with peer review feedback sheets including assessment criteria. Students collaboratively appraise a report's quality and provide written feedback to the author. The difference between Morgan's proposed approach and conventional peer review, however, is that her students would not be reviewing their own class' reports, but instead those exemplar reports accessed from the OCC website. Although students would not be receiving specific peer feedback on their own practical reports, it is likely that Morgan's idea of assessing moderator-assessed exemplar reports (minus the moderator feedback) would still be a valuable learning experience. According to Sampson et al. (2011), peer review can help develop the students' awareness of the requirements of high-quality reports, encourage metacognition and help students to value evidence. Developing metacognition may assist students to develop higher-order cognitive skills, such as critical thinking and problem solving, when constructing scientific explanations in practical reports.

Some empirical evidence exists that suggests exemplar quality may be important in engaging students in self-regulation during writing tasks. For example, Lipnevich et al.'s (2014) study found that students who were given several written assignment exemplars of varying quality, preferred analysing the highest quality exemplars and tended to ignore those of a lesser quality. Although all three teachers in the current study provided good quality exemplars to students, it is possible that other confounding factors, such as using outdated (in the case of Andrew and Kerri) or low-quality (in the case of Morgan) exemplars may not have achieved the teachers' desired intentions.

Deiner et al. (2012) suggested that students should be given copies of a writing scaffold and the report structure, before commencing practical report writing, to allow students time to practise writing and gain feedback, while they gradually "internalise the cognitive strategies contained in the scaffold" (Deiner et al., 2012, p.1514). It should be pointed out that Deiner et al.'s (2012) scaffolding tool was not an assessed practical report exemplar, but was a questionnaire that students had to answer before writing a particular section. Deiner et al.'s, study found that writing quality significantly increased when students utilised a scaffold compared to when no scaffold was provided.

#### *4.2.2.3 Using Checklists*

Andrew was the only teacher in the current study who gave students checklists to help clarify their understanding of the rubric assessment mark-scheme. He located a useful 2016 IA checklist[9] (see Table 10) written by an anonymous author via a web link listed on the OCC website. Andrew explained that although this IA checklist was not formally sanctioned by the IBO, it had been extensively reviewed by IB teachers worldwide and included their opinions, which he personally valued. As he explained;

> *I went through it, and I thought "Okay, well, that's really good at helping you to go into some of the nitty gritty* [detailed writing in practical] *of* [the] *report and look for, have they included this.*
>
> Andrew

[9] This IA checklist will henceforth be referred to as the 'OCC checklist'.

According to Andrew, the IA checklist helped him ascertain the information that needed to be either included or omitted in the 2016 IA report. He also believed the checklist was useful in formatively appraising the students' summative IA rough drafts. Table 10 shows a comparison of the 'Ev' criterion descriptors of the IBO's official 2016 IA rubric and those shown in the OCC checklist. Andrew gave the OCC checklist to students before they undertook their IA investigations. The OCC checklist is considerably more detailed than the IBO's IA rubric. For example, the first dot point in the OCC checklist prompts students to think about how appropriate the apparatus was in obtaining relevant data and to incorporate these ideas into the 'Ev' section of the IA report. Conversely, the 2016 IBDP Biology IA does not specifically mention 'apparatus' in the 'Ev' criterion, but instead refers to more generic information, such as a "detailed conclusion described and justified" (IBO, 2014). Many students may have found the 2016 IA descriptor to be rather unclear. It is likely that Andrew's use of the OCC checklist would have enhanced the transparency some of the rubric criteria for the students. As he explained;

> *It seems fairly detailed, and when I've drafted students' work....I go through and give them feedback on each of their sections* [IA criteria], *and any bits that were missed, or that maybe they need to look into in a bit more detail or reword.* Andrew

Andrew also used checklists as part of his teaching approach when assisting students with the 2009 IA.

**Table 9 - Comparison between the IA rubric assessment descriptors and the OCC checklist descriptors for the Evaluation criterion in the summative IA investigation**

| IBDP Biology IA Rubric Criterion | IBDP Biology Rubric Mark Scheme Descriptors (IBO, 2014) | Andrew's IA OCC Checklist Descriptors from Teacher Resource Exchange on OCC Website (Anonymous, 2016) |
|---|---|---|
| **Evaluation (5-6 marks)** | • A detailed conclusion is described and justified which is entirely relevant to the research question and fully supported by the data presented.<br>• A conclusion is correctly described and justified through relevant comparison to the accepted scientific context.<br>• Strength and weaknesses of the investigation, such as limitations of the data and sources of error are discussed and provide evidence of a clear understanding of the methodological issues involved in establishing the conclusion.<br>• The student has discussed a realistic and relevant suggestion for the improvement and extension of the investigation. | **a) Evaluation**<br>• appropriateness of apparatus in obtaining relevant data is commented on.<br>• weaknesses in methodology are discussed.<br>• reliability of data is commented on.<br>• precision and accuracy of data is commented on.<br>• outlier data or irregularities in data are addressed.<br>• significance of uncertainties in the trend line is determined.<br>**b) Suggested Improvements**<br>• where limitations are determined to be significant, specific improvements are proposed.<br>• Improvements effectively address the limitations (not just be more careful)<br>• Improvements are given which are possible within the context of the school laboratory.<br>**c) Further Research Questions**<br>• at least 2 further research questions are stated with clear independent and dependent variables.<br>• research questions are an extension from the conclusion and evaluation.<br>• short explanation for each question is given to establish its importance and relevance.<br>**d) Conclusion** |

| | | |
|---|---|---|
| | | • an introduction is given.<br>• a conclusion is clearly stated, "in conclusion..<br>• conclusion given is correct and clearly supported by the interpretation of data.<br>• key data from the analysis is given and trends are discussed.<br>• extent to which the hypothesis is supported by the data is explained.<br>• variation in the results is reported, showing strength of the conclusion.<br>• scientific reasoning is used to show validity of the relationship.<br>• how the conclusion is generalized and discussed. |

Andrew attended a school cluster meeting, with other IBDP Biology teachers and moderators in his home town during the time his Year 12 students were writing their summative IA practical report drafts. The meeting enabled Andrew to gain a deeper understanding of the IBO's expected assessment requirements. For example, Andrew learned that his prior belief that 'personal engagement' (PE) was assessed by the *teachers'* judgement of the extent of student engagement *during* implementation of the investigation was incorrect. At the cluster meeting the moderators explained that instead, the *students were required to justify in writing* why they had chosen the research question, to indicate their personal engagement with the research topic. As Andrew explained;

> *Well, if someone's doing a study that relates to some medical condition, they might be able to form a link that "Within my family so and so has diabetes. I've been interested in this, and therefore I'm going to be looking into secondary data from the World Health Organisation." Once that came out, then I said, "What's your research question? Why have you chosen it, what's the justification for you choosing this?" And if they can answer that, I say "Right, you've got to make sure you put that down."* Andrew

Following the cluster meeting, Andrew and an IBDP Biology colleague from his school, collaboratively created a second IA checklist, referred to here as the Moderator

Informed (MI) checklist to more accurately scaffold the students' understanding of the summative IA practical report requirements, see Appendix M). The MI checklist includes a two-page summary of information derived from two main sources that included: (1) the IBDP Biology IA moderators at the school cluster meeting and (2) an IBDP Physics teacher/IA moderator at Andrew's school. Andrew explained that his Physics teacher/IA moderator colleague shared some useful information with him about IA assessment based upon his experiences attending formal IBO meetings and feedback about marking. It is probable that Andrew believed, since he had obtained credible, face-to-face advice about IA assessment from Group 4 IBDP IA moderators, that this information should be included in the MI checklist. Andrew posted the MI checklist onto his Moodle website and discussed it with his students before they completed their summative IA practical report. As Andrew explained;

> *From information that we had, we put together a couple of pages on various dot points to support and advise us on different areas. Because this is the new IA....we're trying to work out, based on as much as we can read, to prepare our students and help them. As we get further information, then we want to pass that on. I think we've tried to scaffold it as much as we can, without trying to have students just led by the nose.* Andrew

Andrew's preparedness to go to seemingly extreme lengths to develop the MI checklist within such a short time-frame pending the moderator meeting, demonstrates his professional integrity. Moreover, it also highlights Andrew's long-term uncertainty about assessing 'PE', despite attending a formal 2016 IBDP IA Biology workshop. Apparently, Andrew felt compelled to inform students of the new IA information he had learned from speaking face-to-face with moderators, so they would not be academically disadvantaged. It can be speculated that the high stakes 20% weighting allocation of the 2016 IA may have been a key factor influencing Andrew's decision to develop the MI checklist.

Apart from distributing the IA rubric assessment mark-scheme to the students, neither Kerri, nor Morgan handed out checklists. Morgan openly acknowledged her reluctance to provide additional written checklists to guide students, in case their IA marks were adversely affected. Morgan explained she had *heard* from her colleagues about a nearby IB school, that gave students checklists for the 2009 IA, which evidently resulted in students' marks being downgraded at moderation, as the teacher had apparently provided 'too much' help. Morgan conceded she was unsure about the extent of guidance IBDP Biology teachers should provide. Her apprehension about providing checklists is encapsulated in the following comment:

> *I feel a bit iffy*[10] *about how much guidance you're allowed to give in the old* [2009 IA] *one anyway, because my colleagues were saying if you give them a checklist, it's frowned upon in moderation really heavily… How much is fair and how much isn't? And because he* [colleague] *said there was another school where they'd given a checklist* [and asked], *Have you included units? Have you included whatever, whatever, whatever? And that school got really marked down in the moderation because they'd given too much guidance.* Morgan

Morgan's decision not to provide checklists, suggests she readily adopted the role of assessor rather than teacher, when assessing summative practical reports. Her comments indicated that by rigidly following the IBDP Biology practical assessment guidelines, Morgan believed she would avoid having her students' reports being "marked down" during moderation. Similar responses to high-stakes summative assessment have been highlighted in the literature (e.g. Giorka, 2009; Yung, 2006; Yung 2001) in which science teachers were conflicted by their dual assessor and teacher roles following external assessment reform. In Giorka's (2009) study involving nine science teachers, only two teachers reported having actively prioritised their role of teacher over that of assessor during summative coursework practical tasks. The same two teachers employed

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[10] "Iffy" – slang for 'unsure'

several different pedagogical strategies to assist students during the learning process. For example, some of these strategies included providing formative feedback in the form of constructive written comments on practical reports, posing oral questions and explaining how coursework could be improved.

The remaining teachers in the study were, however, reluctant to provide little, if any formative feedback for summative coursework because they tended to view teaching as separate from assessment. The researchers concluded that teaching and assessment of science coursework needs to prioritise ‘learning’. Furthermore, the study emphasised that teachers need to be professionally competent and confident in providing student feedback, such that “the balance between ‘being fair’ and providing the kind of feedback that leads students to improve should be a focus for considered attention” (Giorka, 2009, p. 425) and that experience played a role in increased competence and confidence in assessment. Finally, it was posited that teachers required increased support from schools and curriculum policy-makers to tackle the difficulties associated with the dual roles of teaching and assessing.

#### *4.2.4.4 Other pedagogical strategies*

Andrew claimed he explicitly instructed students in key strategies to assist students with formative practical report writing prior to experimental investigations that often involved conducting a whole-class discussion outlining the assessment criterion requirements. For example, when discussing the ‘An’ criterion, Andrew described the conventions for formatting data tables:

> *I would be quite explicit. I would start with – so we would have gone through doing proper scientific tables, proper layouts, headings, columns and rows, units, uncertainties…. possibly even provide an exemplar about how students have laid out tables. I will use whiteboards. I will put up some examples on electronic smartboard. So what I find the students respond to really in this case is very explicit, giving direction, showing examples - and then there's lots of notetaking and some questions. - Then also on the Moodle having an exemplar* [IA report] *or two, that they can see a properly, well done IA.* Andrew

Morgan encouraged students to use tables not only when displaying quantitative data in the 'An' criterion, but also to help format their *written* responses to qualitative assessment criteria. For example, in past IBDP Biology classes, Morgan instructed students to present the independent, dependent and controlled variables of the experimental investigation in a table, as part of the 'design' (D) criterion in the 2009 IA rubric scheme. Additionally, in the 2009 IA 'conclusion and evaluation' (CE) section she encouraged students to present written information about experimental design improvements and justifications in tables. Morgan claimed that using tables for some text, served two main advantages. Firstly, she believed using tables reminded students to include pertinent information, such as controlled variables, that might otherwise be omitted from reports. Secondly, she asserted that students performed better when certain text was tabulated, rather than simply presented in a paragraph. She did not, however, explain *how* this strategy enhanced the 'quality' of written explanations. As Morgan explained;

> *I'd make them do a table of their variables; what it is, how it's measured and how it's controlled or what units. For the table I want, what the problem was, how significant it was, whether it would have actually impacted the results or not, and then a realistic improvement. I do find when they put it [information] in a table, they do a lot better job than when they write it in a paragraph.* Morgan

Although Kerri did not mandate specific formatting conventions in practical reports, he acknowledged that students often presented some written text in tables. Kerri allowed students to choose their own formatting styles. Furthermore, he acknowledged that practical report formatting methods had been quite variable over time, the students were often influenced by one another. As Kerri explained;

> *There tends to be trends* [that] *come and go through the class, but a table with strengths and weaknesses has been pretty common. I think they probably picked it up by osmosis* [conversations with other peers], *rather than me telling them to do it. I don't tend to*

*force them to do this or that in the formatting of the IA. My feeling is it probably gets around just from them seeing each other's work.* Kerri

Kerri appeared to support a social-constructivist approach amongst his students by allowing them to collaboratively decide on the way reports were presented. He pointed out that most of his students presented graphs similarly because of the structured manner in which he explicitly instructed them in graphical and statistical processes, using Excel software. Kerri stated:

*I think there is a bit of variety there. They are quite individual because we do Excel graphing. They look pretty similar there, but the design of the tables looks different.* Kerri

Overall, all three teacher participants used partial-report writing and display of practical report exemplars to assist students develop an understanding of both the standard and presentation required in formal IA practical reports. Andrew and Morgan provided explicit advice on formatting of most sections of practical reports. Kerri provided explicit advice on presentation of numerical data, but allowed students to choose their own approach to present the remainder of the report, through peer collaboration.

Duschl (2008) pointed out that what is missing from pedagogical discussions nowadays, “is how we know, what we know and why we believe it” (p. 269). It seems that there has been a long history of emphasis on the ‘what’ of science, rather than establishing the reasoning behind knowledge claims. It is strongly recommended therefore, that even the most highly qualified and/or experienced teachers, such as those in the present study, should consider expanding their pedagogical repertoire to include a more diverse array of contemporary pedagogies designed to develop the students’ scientific reasoning skills. For example, by incorporating a wider range of contemporary pedagogies, such argumentation practices into IBDP Biology classes, teachers may better assist students to generate the high-order thinking and metacognitive awareness skills they require to write rhetorically persuasive and thus more effective scientific explanations in IA reports.

## 4.3 Across Case Teacher Perceptions Concerning Nature and Implementation of Internal Assessment Protocol

### 4.3.1 Professional Development as a Response to Curriculum Reform: Formal and Informal Training Issues in Implementation of 2016 IA Protocol

In this section the teacher participants' perceptions and experiences in relation to professional learning about the 2016 IBDP Biology summative IA are explored. Case study vignettes of the teachers' professional development (PD) experiences are presented, followed by an across-case comparison.

#### *4.3.1.1 PD Case Study 1 – Andrew*

Andrew participated in a variety of IB training experiences during his four years of teaching IBDP Biology. Although he had not undertaken any formal IB training in the 2009 IBDP Biology curriculum, Andrew initiated his own informal training with Science Faculty colleagues, with prior experience implementing the IA. Andrew's colleagues mentored him during the early stages of teaching the 2009 IBDP Biology curriculum to enhance his understanding of the summative IA. As Andrew explained;

> *For the old one* [2009 IA]*, I didn't do any formal training. I went through and marked all of the very first IAs and I gave them a mark with comments. I selected three individual ones and gave them to each of the two colleagues, who looked at my comments and marks, and then gave me feedback on them, which was basically yes, you are on the right track. They would highlight*

> *particular things that they have found moderators in the past have picked up on.* Andrew (before 2016 IA)

Andrew attended his first official IBDP Biology PD conference on the 2016 IA in 2014, during his second year teaching the 2009 IBDP Biology curriculum. Andrew described the PD experience as follows:

> *So it* [the conference] *was really about seven to eight months prior to me doing the first practical. Well, one day of the course for one section, for one period, they* [the workshop leaders] *went through the new assessment criteria and talked about changes to the old* [2009] *course and the new mark-scheme. It probably really just helped in the sense of getting me some understanding of the new criteria, the weighting and the marks.* Andrew (before 2016 IA)

Andrew developed an awareness of the 2016 IA rubric criteria and mark-scheme, before implementing the 2016 IBDP Biology curriculum (in 2015), during an IB-planned workshop in 2014. Andrew appeared enthusiastic about collaborating with his new Biology colleague, as evidenced by the following comment:

> *So one of the problems last year* [2014] *was that I ended up being the sole teacher of a Year 12 IB class last year. This* year [2015]*, now that I've got a new group, there is a second class* [additional

> 2016 IBDP Biology class] *and she's a new IB teacher, but an experienced Biology teacher and so, we are able to meet and work together to go through and discuss the IAs and practical reports and requirements. So I think that's going to be beneficial. I'm not just learning it by myself, but I've got a colleague who's learning it as well, so we can compare and we can do a bit of moderating.* Andrew (before 2016 IA)

Andrew perceived that collaborating with his new Biology colleague would be mutually beneficial and planned to hold an IA debriefing session with her after external moderation was completed. As Andrew explained;

> *The aim is [….].this year that myself and the other Year 12 IB teacher will get together to sort of debrief. I mean, not only once we've marked the IAs and put in our marks, but next year when we get our marks back and find out how they've gone.* Andrew (after 2016 IA)

Andrew's attendance at a local school cluster meeting (referred to in 4.2.2.3) with other IBDP Biology teachers and moderators helped clarify his understanding of the IA criteria and assessment process. Furthermore, Andrew's desire to improve his understanding of the 2016 IA is clear in the following interview excerpt:

> *Well, a number of people* [Biology teachers at school cluster meeting] *have said, "Okay, they* [referring to IBO], say this, [state criteria descriptors in the 2016 IBDP Biology IA rubric], *but when it comes down to marking it and the moderator going through it, what do they* [moderators] *want to see? We need to know what a moderator wants to see, otherwise our students are going to be disadvantaged.* Andrew (after 2016 IA)

Andrew also used the OCC website as an informal online PD mode to access IA resources, via both prior to and after implementing the IA investigation. As he explained;

> *I might have got some* [exemplar practical reports] *off the OCC site. I think there is a link in the Resources link. There's also a website – 'I Biology'. That was really useful. The whole section on the IA is there; the lab reports and rubrics. Now under the new curriculum, there's 'Bioknowledgey* [IA website]*'. It's got a similar layout* [to 'I Biology'] *and a link for the practical scheme of work.* Andrew (before 2016 IA)

> *I think it* [OCC IA checklist – see Table 11 in section 4.3.2] *came from the TRE and so people* [IBDP Biology teachers] *put something up and the others do reviews. You look at reviews to see other IB teachers' opinions on that particular piece* [IA report], *that's been put up.* Andrew (after 2016 IA)

#### ***4.3.1.2 PD Case Study 2 – Kerri***

Kerri spoke enthusiastically about his PD experience at a 2009 IBDP Biology conference. Interestingly, his enjoyment of the conference seemed to be related to the positive rapport he developed with his workshop leader, with whom he could professionally relate. As Kerri explained;

> *I really enjoyed those couple of courses. It was nice having a leader that was really into Biology, so I enjoyed the few days I spent with him in the old* [2009 IA] *course. So that was fun. We marked an IA and had a look at various complexities in the course. I pretty much enjoyed doing that.* Kerri

Kerri also explained that he had not attended a conference for the 2016 IA because it occurred in his holidays. Of noteworthy interest were Kerri's comments about the significant professional learning benefits he derived from IA ‘cross-marking’ [internal moderation] sessions with other IBDP Biology teachers at his school. As Kerri explained;

> *I probably learned more* [compared to the IBDP workshops] *with my peers here* [at school]. *Sitting down and cross-marking them, because we’ve got such a big school and that wasn’t necessarily always easy, when you develop a feeling that this student is really awesome and this was a great practical write-up and somebody else disagrees.* Kerri

Kerri’s desire not to participate in formal, non-mandatory training concerning the 2016 IBDP Biology curriculum was based on the rationale that he had already attended two PD workshops in the previous two years’ holiday periods. He did, however, acknowledge that the 2009 IBDP Biology conference which he had previously attended was particularly helpful with respect to assessing IA reports. Kerri stated that he to learn the nuances of assessing summative IA reports with his Biology colleague, who had attended the 2016 IBDP IA Biology workshop. As he explained;

> *It’s like you’ll actually sit down and start reading one* [IA report] *and marking it. We work in the same office and we spend a lot of time talking to each other. Where we’re up to with our teaching, how did we do that, anything that worked really well, whatever, some homework, everything. I’m not really knowledgeable about*

*the new mark scheme. I am going to find out, when I have to apply it. Because that's exactly what we'll do - nut out the scheme.* Kerri

#### ***4.3.1.3 PD Case Study 3 – Morgan***

Morgan's school organised for her to attend a Category 2, 2009 IBDP Biology curriculum conference in 2013 - in the year before her appointment at the school. It is evident that Morgan found the process of engaging in assessing exemplar IA practical reports, as well as receiving constructive feedback from other teachers and IA workshop leaders, a valuable professional learning experience. As Morgan explained;

> *I found that* [2009 workshop] *really helpful. Because we did marking of samples and then getting feedback from everyone else about what they marked and how I marked it. I could see where I was wrong, because IB was completely new to me. I was shocked by some of the things they* [moderators] *got 'not at all' (i.e. marked an IA criterion 'zero' marks). I was like, "What? But their method, it's fantastic" and they* [moderators] *said, "No, they* [student who wrote report] *didn't actually say at the end how to record or what to record and therefore they didn't record any data. So, it's a zero." That really helped me to reinforce to the students you have to put in your method how you are going to*

*record it, and what to record. It really helped me to understand the mark scheme better.* Morgan (before 2016 IA)

Morgan also attended a 2016 IBDP Chemistry conference in 2015 and discovered there was considerable overlap between the 2016 IBDP Biology and Chemistry courses with respect to the IA. Despite Morgan submitting a PD funding request to attend a 2016 IBDP Biology conference, the school declined by explaining that she had already attended a 2016 IBDP Chemistry conference.

Morgan's inability to attend the 2016 IBDP Biology conference prompted her to initiate other strategies to improve her understanding of the IA protocol. For example, she explored the TRE discussion forum on the OCC website to determine if other Biology teachers had posted any useful advice about the IA. Morgan also discussed the 2016 IA with her Chemistry colleague/mentor who had a well-developed professional network with several Group 4 IBDP teachers/moderators in the northern hemisphere. Morgan perceived that her mentor's professional network may also help deepen her understanding of the IA.

Morgan was the only teacher at her school who taught the 2016 IBDP Biology curriculum. Although there was one other IBDP Biology teacher and an IB coordinator who once taught the 2009 IBDP Biology curriculum, neither teacher had taught, nor was intending to teach, the 2016 IBDP Biology curriculum. Morgan admitted she had thought about discussing the new Biology curriculum with these other teachers but had decided against it, because she perceived they were not up to date with the new curriculum. Moreover, she admitted she was not proactive in forming professional networks off-campus. As she explained;

> *I guess I should use the OCC more than I do. I tend to go there when I need something, rather than just be involved in the community, so it probably would be worth cultivating that, because I'm only a new teacher. I've only been teaching since 2012. I don't really have a lot of connections. My connections are also inexperienced teachers.* Morgan (before 2016 IA)

Prior to the implementation of the 2016 IA, Morgan believed she would locate useful information about the IA on the OCC website. However, after reading the teachers' posts on the TRE forums, she realised they did not provide the information she required. As she explained;

> *I find the forums really tedious and not that helpful. You look in the subject and you think, "Oh, this is going to be good" and it's just somebody has asked a question and nobody has bothered to answer which I guess is partly my fault too, because I never answer either, but I don't find them valuable.* Morgan (after 2016 IA)

Consequently, Morgan's overall understanding of IA assessment was primarily derived by speaking directly with her IBDP Group 4 science colleagues. As she explained;

> *In the past, my colleagues have said that the moderators want as much information as you can give them on how you've come up with where you've put the mark.* Morgan (after 2016 IA)

In the next section, an across-case comparison of the teacher participants' professional development experiences is discussed in light of the IA protocol.

***4.3.1.4 Across-Case comparison of Biology teachers' professional development***

The PD strategies undertaken by teachers in the current study can be broadly divided into two groups: formal and informal PD. Two groups of formal PD were identified: (1) IBDP Group 4 conferences and (2) mandated school meetings/workshops involving Biology teachers discussing subject-specific content. Informal PD is defined here as any subject-specific PD that teachers organised themselves to interact in professional discourse "with others at a range of levels" (Tytler, Symington, Darby & Kirkwood, 2011, p. 876). In the current study, three main 'levels' of teacher-initiated, informal PD were identified: (1) professional collaboration with science colleagues on-site at the teachers' own schools; (2) online professional networks and (3) off-site meetings with Biology teachers and moderators from other schools.

Two key themes emerged in relation to the Biology teachers' acquisition of knowledge, skills and understandings in relation to the IBDP Biology IA in the current study:

1) Teachers' perceptions of the effectiveness of PD

2) Factors influencing teachers' accessibility to and uptake of non-mandated PD

These themes are explored using an across-case comparison of the teacher participants' experiences with PD.

### a) Teachers' Perceptions of the Effectiveness of PD

***Formal school-initiated PD***

**I. Group 4 IBDP conference/workshops**

Overall, teacher participants in the current study agreed that formal IBDP Group 4 IA workshops helped advance their understanding of IA criteria. Moreover, they found that assessing exemplar practical reports was beneficial, because they could discuss their difficulties and misconceptions with workshop leaders and other teachers. This finding is supported by Tytler et al.'s (2011) study involving science and maths teachers who claimed that conferences provide a key role in developing the teachers' professional competence within a subject area.

Svendsen's (2016) study found that when teachers undertake PD programs involving reflection with colleagues, in the presence of guiding mentors, they are more likely to construct new knowledge and perspectives. This finding bears some similarities to the participants' IB workshop experiences in the current research. Furthermore, Svendsen's (2016) study revealed that once teachers shift their perspective after learning new assessment methods, there is a greater likelihood that classroom teaching and learning will improve.

Kerri's explicit use of positive-affect verbs, such as 'enjoyment', 'fun' and 'nice' when describing his last IA workshop experience, indicated that affective outcomes were important for him. Few literature studies were found that referred to affective benefits of science education PD programs. Lucardie's (2014) study, however, found that adult learners perceived that fun and enjoyment experienced during learning, motivated them to learn new knowledge and skills, assisted their concentration and helped develop social networks.

**II. School-based Professional Learning Communities (PLCs)**

Kerri engaged with his IBDP Biology peers during formal, compulsory school-based PD meetings and stated that they were professionally "probably more powerful", than IBDP Biology conferences. Furthermore, Kerri's comments concerning school-based internal moderation of IA reports, suggest that he recognised that the professional learning community (PLC) of which he was a part, significantly contributed to his professional learning. Koh (2011) reported that many studies on teacher PD suggest that;

> Teachers can improve their classroom practices when they collectively review student work to do the following: analyse what

> has been learnt by students, uncover students' misconceptions and reflect on their own curriculum or instructional adaptations necessary to promote student understanding. Such an active learning approach has been recognised as one of the core features of effective professional development (p. 273).

Kerri's admission, that not all his peers agreed with his evaluation of IA reports during an internal moderation PLC meeting at his school, was professionally courageous, although probably quite confronting for him. Fostering a professional faculty environment, where colleagues openly share their opinions and sometimes disagree, implies there was probably a high degree of mutual respect and trust between Kerri and his colleagues. Kerri's acknowledgement that his colleagues' constructive feedback encouraged him to think differently about his assessment strategies, is a view that has wide support in the literature.  For example, Svendsen's (2016) study of Norwegian science teachers' participation in a year-long school-based PD programme discovered ongoing professional reflection provided teachers sufficient time to reflect on their pedagogy and "led them to think differently about their own teaching" (p. 321). Following these reflective periods, teachers were more inclined to trial new pedagogies.

Monty Jones and Dexter's (2014) study revealed that science and mathematics teachers perceived formal, school-based PD to be professionally beneficial. Moreover, teachers valued their involvement in school-based PLCs, because they had time to discuss ideas, collaborate and build positive relationships with their peers during working hours. Another study by Dogan, Pringle and Mesa (2015) reported that most research studies they reviewed, indicated that PLCs influenced changes in teachers' cognitive knowledge and practices and also shaped affective outcomes including "teacher confidence, self-efficacy, leadership skills, collegiality, sense of accountability, change in culture of professional practice and empowerment" (p. 578). These studies indicate the positive and often powerful influence that collaborative, school-based PLCs may have upon teacher learning. Many other studies (e.g. Zhang et al.; 2015; Koh, 2011; Moyer-Packenham et al., 2011; Desimone, 2009) support the idea that ongoing, school-based PD encourages pedagogical reflection and innovation.

***Informal (Teacher-Initiated) Professional Development***

**I. One-to-one professional collaboration with science colleagues within teachers' schools**

The teacher participants spoke positively about collaborative working relationships they had formed within their science faculty and the cognitive and affective benefits that were derived. Van Driel et al. (2012) suggested that collaborative teacher learning experiences typically promote active learning. Furthermore, Lewis, Baker and Helding (2015) concluded that science teachers acknowledged that positive collaborations assist with implementing new teaching ideas; "this underscores the value of engaging teachers in communities of practice" (p. 926).

In the present study, science faculty interactions generally included regular informal mentoring and collaborative peer planning, organisation and evaluation sessions amongst teachers. The teachers appeared to find engaging in self-initiated, informal mentoring sessions with more experienced colleagues was an especially powerful form of PD. Each teacher participant identified at least one expert teacher (mentor) within their science faculty from whom they regularly sought professional advice. In Morgan's case, for example, this was her Chemistry mentor. Tytler et al.'s (2011) study involving the PD of science/maths teachers in rural Australia, discovered that mentoring was mostly informal and usually teacher-initiated - a finding which resonates with the current study. Ryder et al. (2013) also acknowledged the importance of having on-site expert teachers with prior, successful experience in implementing novel pedagogies who are capable of mentoring their colleagues.

Lewis et al.'s (2012) research revealed that science teachers recently trained in curriculum reform have "acted as formal and informal mentors to newer participants, and these more experienced CISP (Communication In Science Inquiry Program) teachers shared the results of trying new approaches in their own classrooms" (p. 928). Andrew's comments about checklists in section 4.2 indicate that his new Biology colleague may have motivated him to collaborate and experiment more often with novel teaching strategies. Andrew's comments about his Biology colleague imply that their relationship was professionally balanced. However, it is likely, given Andrew's prior teaching and research experience and his recent, formal PD in IBDP Biology, that he may have eventually assumed the mentor role in this collaborative partnership.

Monty Jones et al. (2014) found that teachers perceived informal face-to-face conversations amongst colleagues beneficial, as key information could be exchanged efficiently in a way that was unconstrained by school-determined meeting schedules. The aforementioned studies support the current research findings, whereby IBDP Biology teachers perceived that informal, collaborative PD was valuable in stimulating professional growth when implementing the 2009 and 2016 IA protocols.

**II. OCC website**

The Teacher Resource Exchange (TRE) is an online discussion community (ODC) in which IB teachers share professional ideas and resources. With respect to the TRE, the IBO are careful to point out on the OCC website that

> None of the resources added by teachers to this site are endorsed by the IBO. The IBO cannot guarantee that material found in these resources is accurate or useful. Teachers should exercise their professional judgment, therefore, when assessing the value of any resources they may wish to use (OCC, 2017).

Teacher participants, Andrew and Morgan searched the TRE for various informal online PD opportunities, but had different perceptions about its usefulness. Andrew thought the TRE was professionally beneficial, as it includes links to teacher-developed websites that offer professional advice and IA teaching resources. Andrew selected website resources and incorporated these into lessons. Morgan, however, believed the

TRE was unhelpful and became frustrated by the teachers' questions, for which no responses were provided by other online users. She acknowledged that were she to contribute to the OCC, it may expand her professional networks. The extent of perceived usefulness of the TRE by teachers in the current study may be related to both their intention and online social media confidence.

Some studies have discovered the immediacy aspect of ODCs can be advantageous, due to fast response rates and quick resolutions to problems (Duncan-Howell, 2010; Mageau, 2012). This was not the case, however, for Morgan. Duncan-Howell's (2010) study of 98 Australian online teacher-users indicated teachers found that reading numerous emails on ODCs was time-consuming. This may explain why Morgan grew impatient with the TRE, as much time was wasted searching for relevant topics and awaiting responses. Interestingly, aside from time constraints, none of the disadvantages cited by Duncan-Howell (2010), including dealing with side-tracked discussions, dominating users, misunderstandings and people pushing personal agendas, were raised by teachers in the current research.

Trust, Krutka and Carpenter's (2010) global survey-based study involving 1417, P-12 teachers revealed that professional benefits of ODCs could be conceived from four different perspectives including affective, cognitive, social and teacher identity. Furthermore, Trust et al. (2010) stated that 96% of survey respondents altered their teaching practice due to perceptions gained via this online professional learning network (PLN). Many teachers believed that PLNs facilitated improved student learning outcomes.

Duncan-Howell (2010) posited that Australian teachers retain their online discussion memberships for primarily professional and emotional reasons, with 92.85% stating their needs were met in this regard. Additionally, other advantages of ODCs included subject-matter relevancy and peer discussion opportunities at mutually convenient times (Duncan-Howell, 2010). None of the teachers in the present study appeared to derive any of the professional benefits stated by Trust et al., (2010) or Duncan-Howell (2010), except for Andrew, who appeared to draw some cognitive benefits, such as obtaining useful teaching resources, from recommended websites.

Mageau's (2012) study involved the views of leading practitioners in 'community of practice' education about online communities. Nussbaum-Beach, a participant in Mageau's (2012) study, suggested that new online users should source information for personal use *and* also contribute to the online community. Nussbaum-Beach stated that;

> It's out of co-constructed knowledge that a sense of community and a sense of ownership begins to develop, as people begin having really powerful conversations about what they're working to develop, whether it's lesson plans, an innovation they're working on or a shift in PD. (Mageau, 2012, p.13)

The findings of these studies pose important implications for IBDP Biology teachers who could professionally benefit by utilising resources and/or positively influencing the PD of others by actively contributing to ODCs. Furthermore, both the IBO and IBDP schools should consider actively encouraging teachers to regularly use the TRE, to promote professional growth.  Consequently, teachers who participate in knowledge co-construction through ODCs, are probably more likely to develop sustained, extensive professional networks that potentially lead to positive teaching and learning outcomes for both teachers and students.

**III. Off-site school cluster meetings with IBDP Biology teachers and moderators**

Andrew attended informal, off-site, school cluster meetings with other IBDP Biology teachers and moderators from nearby schools. School cluster meetings provided alternative PD opportunities that were professionally advantageous. For example, Andrew gained a broader perspective of the challenges associated with the 2016 IBDP Biology IA through professional discourse with other educators outside his own school. Importantly, he refined his understanding of the IA protocol during face-to-face meetings with IB moderators, who directly addressed both his and the other teachers' misconceptions. Moreover, Andrew resolved his misconceptions about the interpretation and assessment of the PE criterion. Of noteworthy interest is that Kerri, a Biology teacher in another capital city within Australia, who did not attend a 2016 IBDP IA training workshop or take part in off-site PD, also held the *same* misconception as Andrew in relation to the PE criterion.

Tytler et al. (2011) claimed that teachers benefit by engaging in different PLCs, including those with professionals from other schools. It appears that PLCs are effective in enabling teachers to clarify their understandings of curriculum and assessment issues.

The teacher participants appeared to enjoy formal IB-run conferences/workshops and found them to be professionally quite helpful. It was evident, however, that formal on-site school PLCs were even more effective at disseminating professional assistance with the IA protocol. All three teachers engaged in regular professional collaborations with more experienced colleagues and fount it one of the most useful modes of informal PD.

#### ***4.3.1.5 Factors influencing teachers' accessibility to and uptake of non-mandatory PD***

**a) Formal: IBDP Group 4 PD conferences/workshops and OCC online resources**

The timing of formal, school-funded PD appeared to significantly impact the teachers' access to training, but did so in uniquely different ways. For example, Andrew did not attend a 2009 IBDP IA Biology conference workshop before teaching the curriculum, as its timing did not coincide with when he was appointed to his school, but he was able to attend a 2016 IA IBDP Biology workshop before implementing the new curriculum.

Morgan and Kerri, however, had both previously attended 2009 IBDP Biology IA workshops, although neither of them attended a 2016 IBDP Biology IA workshop for different reasons. Morgan's school denied her request even though she was teaching *both* the IBDP Chemistry and Biology curricula at the time. Her school may have rejected her request to attend the 2016 IBDP Biology conference due to budgetary and/or school timetable constraints, although this was not established during her interview. Furthermore this situation illustrates the tensions that can exist when the needs of schools and teachers are in competition. From a PD perspective, it could have been beneficial for the school to allow Morgan to attend the Biology conference, as she was an early career teacher, a permanent staff member, the only IBDP Biology teacher in her school and she did not have another Biology colleague to mentor her in the 2016 IA protocol.

In Moyer-Packenham et al.'s (2011) study, specific attention was focused on training teacher leaders during the formal Maths and Science Partnership PD program. Training future teacher leaders helps create a group of experts in a certain discipline or area, who could potentially build capacity within a particular school or school cluster. Increasing the number of onsite teacher experts could provide additional professional benefits for more staff, once PD funds diminish. Although pertaining to rural teachers in isolated schools, Tytler et al. (2011) suggested that secondary subject-specialist teachers who lack sufficient numbers of colleagues in the same discipline are at a disadvantage. When secondary specialist teachers are few in number, teachers may not be able to form a local subject-based PLC. Tytler et al., (2011) stated that PD must reach "beyond the school boundaries" (p. 877) as a means of contributing to the professional growth and effectiveness of teachers. The findings of the studies by Moyer-Packenham et al. (2011) and Tytler et al. (2011) indicate that there could have been valuable teaching and learning benefits for Morgan's school, if her school had funded her attendance at the 2016 IBDP Biology conference.

In contrast to Morgan, Kerri's school invited him to attend a 2016 IBDP Biology conference. Kerri, however, had attended two PD workshops during his recent holidays and decided to not attend the 2016 conference. Kerri's decision to forgo the conference illustrates that teachers, like many other professionals, need to balance their personal lives with non-mandatory, after-hours professional learning. The teachers in the present study were funded by their schools to attend IBDP Group 4 conferences on at least one or more occasions. Despite schools providing conference funding, it appeared that additional non-monetary or 'personal' costs strongly influenced the teachers' uptake of formal, teacher-initiated PD in the present study. For example, scheduling of IBDP Group 4 conferences also appeared to influence teachers' accessibility and uptake of formal PD. Conference timing may also affect whether schools decide to fund teachers to attend PD. Moreover, it appears that when schools do fund PD, not all teachers will be motivated to forgo personal time, especially when attendance is not mandatory.

Fields, Levy, Karelitz, Martinez-Gudapakkam & Jablonksi's (2012) conducted a study of 37 science teachers from eight schools in Boston, USA. Of these teachers, twenty-five percent stated that insufficient time or inconvenient scheduling of conferences caused them to not take up PD opportunities. Burton and Frazier's (2012) study revealed that the main reasons that exemplary American science teachers did not undertake PD were "a lack of time and money" (p. 186). The findings of these two studies concerning science teachers' non-mandatory conference attendance appear to concur with those in the current study.

Morgan's school's decision to reject her Biology conference request, may not have greatly bothered her, since the 2016 IBDP Chemistry IA protocol was essentially the same as the IBDP Biology one – a point she raised in her interview. As the only practicing IBDP Biology teacher in her school, Morgan had to select alternate PD strategies, such as accessing IB online discussion forums and engaging in professional dialogue with her Chemistry colleague/mentor, to refine her understanding of the IA.

Both Andrew and Morgan reported that externally moderated practical report exemplars located on the OCC website's *Biology Resources* link, provided valuable learning opportunities. Wilson (2013) suggested that online PD can provide "just in time assistance and that it is potentially more scalable than PD that presses on local resources" (p. 312). Kerri's reluctance to access the OCC website was unclear. It can be speculated, however, that factors such as time constraints or a genuine preference for using face-to-face PD, could have influenced his decision about not accessing the OCC.

**b) Informal IBDP Biology PD**

The teacher participants appeared proactive in networking with more experienced colleagues/experts either within and/or outside of the school setting, to further their knowledge and skills during the implementation of both the 2009 and 2016 IBDP Biology curricula. There were, however, notable differences between the teachers' personal motivations to access various informal, teacher-initiated PD opportunities. Of the three teachers, Andrew willingly sought out, and apparently participated in, the greatest variety of informal PD. Moreover, Andrew probably established the most extensive professional network, as evidenced by his highly socially-oriented approach to PD. For example, he attended local school cluster meetings in his own time, collaborated informally with peers in school-based mentoring and pedagogical planning/evaluation sessions and also accessed the TRE online discussion forum on the OCC website and IB Biology resources links for PD resources. Neither Morgan nor Kerri, however, appeared to have invested an equivalent effort to that of Andrew, in relation to developing professional networks *outside* of the school context through informal PD.

In a German study of 139 secondary teachers from 198 schools, Richter, Kunter, Klusmann, Ludtke and Baumert (2011) reported that uptake of in-service training peaked at mid-career with older teachers reading more professional literature than their younger colleagues, who engaged more in professional collaborations. These findings were inconsistent with those in the present study, in which there was no correlation between age and preferred PD mode or between phase of career and preferred PD mode. It should be pointed out, however, that the teacher participants in the present study were 'second career' teachers. Consequently, they did not represent a typical age-career phase trajectory, attributable to a young university graduate entering the teaching profession as their first career.

According to Hubermann's (1989) career stage model, Morgan, in her fourth year of teaching, was transitioning into the stabilisation career phase (4-6 years) from the beginning teacher career phase (1-3 years), even though she was in her mid-thirties. During this time, teachers often feel overwhelmed, as they move towards a new stage, with many seeking promotions and networking opportunities. Interestingly, Morgan held a leadership position as a Biology coordinator at her school with only four years' teaching experience.

Richter et al.'s (2011) study also found that teachers with high work engagement and/or leadership positions, accessed more formal PD than teachers with high work engagement, but no leadership responsibilities. Once again, these findings do not support those of the present study, in which all three teachers held leadership positions, but showed considerable variability in their uptake of both the mode and variety of formal PD.

In terms of informal PD, the school cluster meeting Andrew attended (see section 4.2.2) was not mentioned, nor presumably attended, by Morgan, who worked in the same city as Andrew. A possible explanation for Morgan's non-attendance at this meeting was that she did not communicate with the school cluster network. Alternatively, her non-attendance at the meeting could have been due to time constraints, or that she perceived this PD mode was not required at the time, since she previously admitted to being reticent to develop off-site professional networks. Whether she had intended to or not, Morgan's absence from the school cluster meeting probably represented a missed opportunity to both deepen her IA knowledge and develop useful local professional networks.

Evidently, uptake and access to formal PD such as IB conferences is highly dependent upon the scheduling and number of conferences already attended within an academic year. Informal PD appears to be more commonly utilised by all three participants, presumably because it is more accessible, sustained over a longer-period and occurs mainly during school hours.

### 4.3.2 The 2009 Internal Assessment: An Across-Case Comparison of Teacher Perceptions

This section explores some key enablers and inhibitors that participant teachers perceived influenced their capacity to effectively implement the 2009 IA protocol. The teachers' perceptions of the 2009 IA were included for comparison with the 2016 IA, to ascertain whether the latter protocol was regarded as an improvement or not.

#### *4.3.2.1 Teacher Perceptions: 2009 IA Enablers*

***Enabler 1: More than one opportunity to undertake and write-up a summative IA task***

The teachers acknowledged that when students had than one opportunity to undertake a summative IA, it could assist them to improve the quality of subsequent practical reports. Both Andrew and Kerri utilised similar methods to implement summative IA practical write-ups. For example, Andrew instructed students to undertake a 'full' summative IA practical investigation in which all three criteria (i.e. D, DCP and CE) were assessed within the same report on at least two occasions. As Andrew stated,

> *I think with the 2009 IA where the students need to submit two full written reports or a minimum of two, that the students would be able to do quite different areas of focus, using different research techniques and types of data collection. It was also good for them that they could make up or improve from their first one and so whilst it's summative, they would use it formatively to help them. We would offer the opportunity for students to do a third one but that was their choice too, if they felt that they wanted to improve upon something in one of their other IAs. A quarter to a third of the students took up that opportunity.* Andrew

Similarly, Kerri's students completed three full IA practical reports in which the two best ones were selected for the final summative grade. As Kerri explained,

> *I think that doing three practicals* [summative IAs] *had strengths. It doesn't matter how well I scaffolded the students during the eighteen months beforehand, I think that first practical write-up*

*always had some errors. Some students achieved very highly from the start, but most students needed the first IA write-up to start to realise what was required. But most of them, certainly giving them an opportunity to fail, or to learn what is required with having more than one IA was a good thing. I liked that they had three chances.* Kerri

Morgan, however, managed the summative 2009 IA process differently to Andrew and Kerri. She instructed students to complete six IA practical reports, of which three included only the D criterion and the other three included both the DCP and CE criteria. The two best D, DCP and CE criteria were chosen from the six practical reports for summative assessment. Morgan's rationale for not completing three criteria within one practical report was partly influenced by affective factors that could potentially impact on the students.  As she explained;

*The kids (students) got to practise over and over again, to get it right. I liked it better when they had a chance to spread them* [i.e. summative practicals] *out, because they might just be having a bad week or something's going on, or their girlfriend broke up with them or their mum's got cancer. If they were not doing it as well, you could say, "improve it for the last one."* Morgan

Although not directly related to the practical write-up process, the teachers agreed that undertaking more than one summative investigation enabled students to experience a wider variety of research topics and experimental techniques. As they explained;

> *The students would be able to do quite different areas of focus using very different research techniques and types of data collection.* Andrew

> *In the old version* [2009 IBDP Biology] *I like that you can assess them on a variety of topics.* Morgan

> *The pressure was on that every student had to make the equipment work and they faced different problems. I guess it was closer to the real world. I think most of the time you spend in a lab as a scientist you are probably getting the method to work, so it was probably quite authentic in that way.* Kerri

***Enabler 2: Simplistic use and interpretation of marking scheme in assessment rubric***

Only Kerri perceived that the 2009 IA rubric mark-scheme was beneficial, by contending that it simplified the assessment process. He also believed that the 0-2 mark-band for each aspect within the assessment criteria helped clarify how full marks could be attained. Kerri stated:

*I think it* [2009 IA rubric] *did simplify the marking. I think it did give me quite a concrete goal or message to give the students about what's required for a 'complete'* (i.e. full marks- see Table 12).
Kerri

Finsson and Ormsbee (1998) acknowledged that rubrics with narrow mark-bands make it easier for assessors to distinguish between the different levels of responses. Gunes, Katircioglu and Yilmaz (2015) found that when using rubrics with university Psychology students, grading was more objective and consistent. Kishbaugh, Cessna, Horst, Leaman, Flanagan, Graber Neufeld and Siderhurst's (2012) study involving undergraduate Biology/Chemistry instructors and their students, reported that instructors agreed that rubrics enabled easier and more time-efficient grading. Furthermore, Kisbaugh et al.'s (2012) study revealed that the students either agreed or strongly agreed that rubrics helped improve clarity of assessment task expectations. These studies suggest that rubrics can be both an effective and time-efficient method that can simplify assessment, although Sadler (2009) warned that efficiency alone should not be grounds for rubric use.

All teacher participants agreed that having more than one chance to write an IA (as stipulated in the 2009 IA) was more academically advantageous to students.

#### *4.3.2.2 Teacher Perceptions: 2009 IA Inhibitors*

***Inhibitor 1: Unfair rubric marking scheme***

There was a high degree of consensus amongst participant teachers regarding the perceived lack of fairness in using the 0-2 mark-band to assess the three aspects within each rubric criterion in the 2009 IA. The teachers believed that the narrow mark-band enabled students to more easily attain one mark rather than zero or two marks per aspect. Andrew argued that two students could potentially both achieve one mark out of two for an aspect, even if the quality of their individual reports was vastly different. The *Evaluating procedure/s* aspect within the CE criterion in Table 11 clearly illustrates Andrew's point. As Andrew stated,

> *Often there were times, you could have two different IAs and you'd have to give both of them, a one* [1 mark] *for a particular component and yet, one of those ones could be barely above a zero really and the other one, could almost have been a two* [2 marks]. Andrew

**Table 10 - Conclusion and Evaluation: Aspect 2 descriptor (rubric extract - 2009 IA)**

| Levels/marks | Aspect 3 |
|---|---|
| | **Evaluating procedure (s)** |
| **Complete/2** | Evaluates weaknesses and limitations. |
| **Partial/1** | Identifies some weaknesses and limitations, but the evaluation is weak or missing. |
| **Not at all/0** | Identifies irrelevant weaknesses and limitations |

From Table 11 it can be inferred that students who identify any relevant weaknesses and limitations could attain one mark for Aspect 3, regardless of the *number* of these factors and whether an evaluation of any kind is included. The inclusion of the word 'some' in Aspect 3 could create ethical dilemmas for teachers during assessment. For example, if student A identified *one* relevant weakness and *one* relevant limitation, without an evaluation, they could be awarded one mark. Conversely, if student B included *three* weaknesses and *three* limitations, along with an evident, albeit weak, evaluation, they could also score one mark. How then, can a teacher justify the fairness of this marking schema, when student B has clearly addressed Aspect 3 more comprehensively than student A? Presumably, student B utilised their higher-order thinking skills to a greater extent than student A and should probably attain more marks for their response. Morgan's comment succinctly summarises the conundrum that the teacher participants evidently experienced when using the 2009 IA marking scheme to assess student work, when she asserted;

> *In the old scheme* [2009 IA]*, it's hard to get two marks and hard to get nothing* [0 marks], *so you're just left with lots of ones* [1 mark per aspect]. Morgan

Kerri struggled with using the rubric from a philosophical perspective believing that the quality of a student's overall response is more important than the constraints imposed by rubric descriptors. As he explained;

> *There was probably a lack of appreciation of the quality of other areas they could drop to one mark, even if the rest of the description in that practical write-up was outstanding. I think it had its weaknesses and from my perspective, particularly, it led to a method of marking the practical where you only need find fault to drop to one mark* [from 2 marks] *and it was obvious that it wouldn't be a zero. I am not particularly like that as a teacher. I am more interested in how well they* [students] *did and the ideas that they had and would prefer to mark on a reward basis rather than a negative marking approach.* Kerri

It is interesting to note that Kerri's comments made here about the 0-2 markbands, appear to contradict the more positive views he expressed earlier in the interview (see section 4.3.2.1 - Enabler 2). A possible explanation for Kerri's contradictory comments is that he simply needed more time to think deeply about his personal experiences using the 0-2 markband. Bennett (2016) suggested that using rubrics as assessment tools for complex writing tasks may stifle creative, insightful and higher-order thinking. If this idea is true, then what is the point of the assessment task?

> The quantification of essentially qualitative work is highly reductive: it reduces complex, multifaceted and rhetorical factors to single numerical digits for the purpose of ordering and ranking variations in thinking and writing. The problem with any reductive estimation of thinking and writing is that it moderates uniqueness; it seeks to resolve and unify rather than recognise and value differences in thought and expression (Bennett, 2016, p. 57).

Rubric critics have questioned whether the end product of assessment realistically reflects the student's cognition, or if it indicates how effectively they can follow prescribed criteria (Bennett, 2016; Sadler, 2009). Not all educational researchers agree, however, with these criticisms of rubric use in assessment tasks. There has been some recent research, however, which supports the view that rubrics confer benefits for both teachers and students.  Pandero and Jonsson's (2013) review indicated that rubrics enable clarification of learning goals, leading to improved student outcomes. Crotwell Timmerman et al.'s (2011) study found that when undergraduate Psychology students' laboratory reports were regularly subjected to rubric assessment schemes, instructors could more easily identify skills students had either readily attained or found difficult. Furthermore, the researchers also discovered that when rubric criteria expectations are consistent students can "learn and practise those skills repeatedly in order for gains to be seen" (Crotwell Timmerman et al., 2011, p. 533). Similar findings supporting rubric use for assessment have been reported in several other studies (e.g. Pandero & Romero, 2014; Pandero et al. 2013; Montgomery, 2002).

The 2009 IBDP Biology curriculum guide suggests that teachers rely on their professional judgement when allocating marks to a specific aspect within an IA criterion and states:

> […] a student's work may contain features denoted by a high achievement level descriptor combined with features appropriate to a lower one. The highest descriptors do not imply faultless performance and moderators and teachers should not hesitate to use the extremes, including zero, if they are appropriate descriptions of the work being assessed (IBO, 2007, p. 21).

***Inhibitor 2: Pedantic nature of data collection and processing assessment expectations***

Two teacher participants suggested that the IB's expectations regarding certain assessment descriptors in the DCP criterion in the 2009 IA reports were overscrupulous. Morgan, for example, expressed frustration that students had to include errors relating to uncertainties for all recorded measurements. Furthermore, she found that the differences between 2009 IBDP Biology and Chemistry curricula in relation to IB guidelines for error bar usage created confusion when assessing DCP. As Morgan explained;

> *I guess the errors and the error bars. I sometimes get a bit confused about what is required in each subject and I sometimes have to go back and check. Not super confident. It's frustrating that it's* [protocol for error-bars and uncertainties] *not the same for all of them* [Group 4 subjects]. Morgan

In contrast to Morgan, Kerri was more concerned with the IB's expectation concerning the extent of precision of decimal places in the DCP section. As Kerri commented;

> *It was a very pedantic approach, the number of decimal places, without them* [the students] *necessarily understanding the basis of precision in the data. I'm just sort of ticking boxes really. We're not very rigorous as to whether it really is + or – 0.1* [for uncertainty

error]. *I feel like we're only doing that* [assessing uncertainties in DCP] *to satisfy trying to get a 'complete'* [full marks]*. If they* [students] *had eighteen decimal places, I would say, "You need to be more consistent with the presentation of your data." Again that was a complicated thing. So if you calculate an average, does the average still have the same number of decimal places as the original data?* Kerry

***Inhibitor 3: Problems with implementing open-inquiry investigations***

Students planning IA investigations must formulate their own experimental design, although teachers may provide prompts. A prompt may be a general aim or problem to solve or a general research question to investigate, without the suggestion of any variables. Alternatively, teachers may provide research questions and a dependent variable. The 2009 IBDP Diploma Programme Biology Guide (IBO, 2007) guides teachers in this regard:

> An example of such a teacher prompt would be to ask the student to investigate the effect of a factor that influences enzyme activity. This could then be focused by the student as follows: Does ethanol concentration affect the activity of bovine catalase?"

> It is not sufficient for the student to simply restate the research question provided by the teacher (p. 25).

Following research investigation prompting, a student usually further refines the aim, problem or research question and selects appropriate variables to investigate. When a common research problem is investigated by the whole class, whereby each student must individually design an experiment and choose an independent variable, logistical difficulties can arise due to students using similar materials and apparatus. Morgan's summative 2009 IA investigation involving beetroot pigments is a good example of how logistical difficulties can adversely affect experimental work. In this specific experiment, Morgan found it difficult to provide sufficient apparatus for the students and also wasted a lot of time trouble-shooting various methodological complications. Her subsequent decision to forgo further summative investigations involving all *three* IA criteria was largely influenced by her experiences with the beetroot experiment. As Morgan explained;

> *In the last class that I took through to Year 12* [with the 2009 IA], *I got them to do one* [summative IA] *that went all the way through* [included all three criteria- D, DCP & CE]. *It was a nightmare logistically, because we were looking at pigment leaching from beetroot cells. They* [students] *all had different things they were bathing the cells in, to look at how much pigment came out into*

*the solution. We had a colorimeter, so they could measure the intensity quantitatively of the pigment that had leached, but we only had one colorimeter. All students needed to take 15-20 samples and it was just a nightmare. I'm not keen on doing a D, DCP and CE.* Morgan

Morgan's experience with the beetroot experiment indicates that when insufficient results are collected, the student's ability to write a credible, full (three criteria) summative IA report can be compromised. Consequently, teachers would either have to repeat the investigation or introduce a new one. Given the time constraints in delivering the IBDP Biology curriculum, most teachers would not have time to repeat many summative investigations. It is possible that Morgan's inexperience as a Biology teacher may have resulted in some of the difficulties she encountered when implementing the beetroot investigation. For example, a more experienced teacher may have first checked that there was sufficient equipment available for each student and also conducted a pilot experiment beforehand, to assess potential procedural difficulties.

Like Morgan, Andrew also found implementing a full three rubric criteria IA investigation could be problematic, but for different reasons. Andrew's main challenge involved the logistics of managing a large class size during the investigation. This often involved Andrew simultaneously supplementing each student's individual apparatus needs during the IA investigation. As Andrew explained;

> *Last year well, Year 11, I had a class of seventeen. There were two classes. In Year 12 there was one class of twenty six, so that* [class] *was quite challenging for the IA. They* [IBDP Biology students during the experimental phase of IA in class would say] *"Oh, I just need this and just need that." And I'd be fetching stuff* [apparatus & materials]. Andrew

In Andrew's case, it appears evident that the implementation of a 'full' IA is logistically stressful from a teacher perspective, as many students do appear to anticipate the specific number or type of apparatus needed until the experimental phase of the investigation.

Overall, it is evident that the primary concern of the three teachers was that the 0-2 markband was not sufficiently broad enough to provide a valid assessment of student achievement.

### 4.3.3 Teacher Perceptions of the 2016 IA Protocol and Issues of Low Teacher Self-Efficacy

A significant theme emerging from the current research was that self-efficacy affected the teachers' implementation of the 2016 summative IA. Self-efficacy is the belief in one's capabilities (Bandura, 1997). According to Tschannen-Moran, Woolfolk Hoy and Hoy (1998), teacher self-efficacy is defined as a "teacher's beliefs in her or his ability to organise and execute the courses of action required to successfully accomplish a specific teaching task in a particular context" (p. 22). Furthermore, Tschannen-Moran & Woolfolk Hoy (20010 contend that teachers may be one of the greatest influences on a student's learning. Successful science education reform often depends upon a teacher's belief in their ability to positively influence student learning (Pendergast & Main, 2016; Levitt, 2001; Cronin-Jones, 1991). Many researchers have acknowledged that highly efficacious teachers are capable of positively influencing student learning (Haigh & Anthony, 2012; Tschannen-Moran, Woolfolk Hoy & Hoy, 1998).

Most studies examining teacher self-efficacy, however, typically involve primary and pre-service teachers and are mainly based upon quantitative research (Blonder, Benny & Jones, 2014; Davis et al., 2006). According to Klassen, Tze, Betts and Gordon's (2011) review involving teacher efficacy studies conducted between 1998 and 2009, only 15 % investigated science teachers' self-efficacies. Additionally, very few literature studies exist that have explored self-efficacy of in-service secondary science teachers (Haigh et al., 2012). In this section the teacher participants' perceptions of the enabling and inhibiting factors that influenced their self-efficacy when planning and implementing the 2016 IBDP Biology IA protocol are explored.

#### *4.3.3.1 Teacher Perceptions: 2016 IA Enablers and High Teacher Self-Efficacy*

***Enabler 1: A more appropriate mark-scheme and a good choice of assessment criteria***

Overall, the teachers supported the 2016 IA criteria (Appendix A) and their corresponding mark-bands. Kerri, however, agreed only with the ‘personal engagement’ (PE), ‘analysis’ (A) and ‘evaluation’ (Ev) criteria’s mark-bands. Although Morgan was initially hesitant to use the 2016 IA rubric, she conceded it was better than the 2009 IA rubric, once she had gained some experience using it. As she explained,

> *I think the rubric* [2016 IA] *is better. I think the weighting* [of assessment] *of the sections is better.* Morgan (after 2016 IA).

Andrew and Kerri used the 2016 IA for formatively assessed practical tasks with their Year 11 students. Andrew that perceived the 2016 IA mark scheme, with its broader range of marks in the mark-bands (with the exception of the PE criterion) was a positive innovation. Additionally, Andrew thought the new mark-bands enabled students to potentially attain grades that more accurately reflected their cognitive capabilities. As Andrew explained;

> *I think the ‘conclusion and evaluation’* [i.e. CE criterion in the 2009 IA], *because it contained analysis and evaluation components*

*together. The good students could get it, but it was harder for the mid-range students to get. So that's*[11] *sort of now* [2016 IA] *been split into the 'analysis' and 'evaluation' separately and so I think a good, solid, hard worker should be able to get a 5 [marks] for 'analysis' and possibly the 6* [6 marks] *there. So it's good in a sense that the marks are now broader, they're more spread out there. And so the fact now, that you've got the 'exploration', 'analysis', 'evaluation' and 'communication' sections to all have ranges from zero to six or zero to four, I like that. ….give a truer reflection* [of students' abilities compared to 2009 IA]. Andrew (before 2016 IA)

Similarly, Morgan supported the 2016 IA criteria's broader mark-bands due to more accurate differentiation between students of varying abilities. Notably, Morgan's assertion about the 2016 IA mark-scheme was made only *after* she had implemented the summative investigation with her Year 12 students. As she explained;

*It* [2016 IA] *is easier I guess, to ascertain the higher achievers from the lower achievers.* Morgan (after 2016 IA)

[11] Analysis and evaluation are now separate criteria within the 2016 IA, whereas in the 2009 IA, these two criteria were combined together into the one criterion, 'conclusion and evaluation'.

Andrew also believed the 2016 IA mark scheme would allow more accurate assessment of practical reports than the 2009 IA. Andrew supported the inclusion of the communication (C) criterion [worth four marks], because he perceived it informs both teachers and students precisely where marks can be validly deducted for communication-based errors. Conversely, the absence of a C criterion in the 2009 IA mark scheme, appeared to create some confusion amongst teachers, when assessing reports with communication-based errors. As Andrew explained,

> *It's interesting to have the four marks for 'communication'. I don't think that was how the marks criteria for the old system* [2009 IA] *worked. If someone was making communication errors, it wasn't so clear where you'd take the marks off. I think there might be a difficulty that someone's done a really great 'analysis', but they have not done well with the structuring and wording of a particular paragraph. This will hopefully allow you to separate that out.* Andrew (before 2016 IA)

When asked whether he thought the two marks maximum score for the PE criterion was appropriate, Kerri responded,

> *Yeah, I do. Very much so, and so those two marks being there, perhaps does drive an outstanding student, or at least a student*

*that is very engaged, to find something they are particularly involved with, otherwise I guess it becomes insignificant and difficult to assess whether somebody should get a one or a two; it's a problem.* Kerri

Both Morgan and Kerri supported inclusion of the new PE criterion in the IA, because it allows students to explore areas of personal interest. Kerri recognised that PE could lead to original experimental work being undertaken - an outcome considered an important aspect of scientific endeavour. Andrew's perception was that PE provided a welcome change, from the strong curriculum focus on scientific content. All teachers unanimously supported the PE criterion, as evidenced by their comments:

> *That* [PE] *would make it more interesting for them. It could be really good, because they are going to choose an area that they are interested in.* Morgan (before 2016 IA)

> *I mean the first point; it's very interesting that there are marks in there about personal engagement. That's interesting, unusual…good yeah, because the course, is just so heavy on exams.* Andrew (before 2016 IA*)*

> *I personally like that there is some drive to really do your own thing and this is the first year that we've attempted it. We have*

*made steps to personalise it and every student doing something different was already a hard task to achieve. I liked the idea of self-design practical work. I liked the rigour with the demand of the accuracy in the write up. I really liked that is was individual. I kind of like that it motivates the possibility of an original experiment being done*. Kerri

The teachers also supported the Ev criterion:

*I think it's* [2016 IA] *good.* Kerri

*'Evaluation' - the new one* [2016 IA] *where it says in the scientific context. I think that's good that they have put that in*. Morgan (before 2016 IA)

*I think I like the way the 'evaluation'* [Ev criterion] *is set out and described* [in 2016 IA]. *I think the students should be able to achieve the fives and sixes* [5 & 6 marks] *by being thorough with working through carefully.* Andrew (before 2016 IA)

When asked whether six marks was an appropriate mark-band for the A criterion, Kerri explained;

> *When I see the data, I can see how many repeats there are and that there is an average and a standard deviation and it's the data that's the big part. It's what does the results show, that's what generally you look for in a scientific report, how good that graph looks, how much work has gone into making the data strong. I think it's* [2016 IA] *good*. Kerri

***Enabler 2: Only one IA to mark***

Andrew and Kerri both supported the IB's requirement of *one* summative 2016 IA report being submitted compared with two reports in the 2009 IA. Prior to the 2016 IA, Andrew posited that planning, organising and implementing the summative IA would be less time-consuming compared to the 2009 IA. As he stated;

> *So there should be a reduction in the time set aside for all of that planning and preparation. So that's the benefit of going to the new system* [2016 IA]. Andrew (before 2016 IA)

After Andrew completed the 2016 IA, he maintained the view that undertaking one IA was more efficient. As he explained;

> *Well, it's* [2016 IA] *better in the sense that we're just having students do one* [IA report]. *We generally have larger classes, and*

> *one of the problems with the old* [2009] *IA was that you needed to set up, run, draft and mark at least two pieces* [practical reports] *for each student, and for some, three. So that's good.* Andrew (after 2016 IA)

Similarly, Kerri supported the one IA requirement, because it increased his marking efficiency, but he advised that students required more scaffolding compared with the 2009 IA. As he explained;

> *Surely it is nice for me to just mark one IA but with the introduction of a single IA, we probably saw a greater need for scaffolding through Year 11.* Kerri

Prior to implementing the summative IA, Andrew posited that schools should consider how to manage situations in which students perform below par in the summative IA practical report prior to moderation. As he explained;

> *I guess that will be interesting, to review whether we feel that we need to do the optional second IA. I don't think that's how it's meant to be done*. Andrew (before 2016 IA)

Andrew also speculated that some IB schools may allow students a second opportunity to improve their IA result as follows:

> *Now, I think some schools, maybe particularly schools with small numbers of students, will allow them to do a second one, and then they just submit their best result*. Andrew (after 2016 IA)

Furthermore, Andrew believed that undertaking one IA would not disadvantage his students, because they had sufficient formative preparation in Year 11 to proficiently manage the IA task criteria in readiness for writing the summative report in Year 12. As Andrew explained;

> *And so where you've decided to make it so Year 11 is really to prepare students as much as possible, Year 12 is a lead-up to your IA,* [to] *spend time possibly extending it or for some they might have to go back over it*. Andrew (after 2016 IA)

Andrew and Kerri supported a reduction in the both the marking load and experimental logistics associated with implementing one summative IA. Kerri's statement that there was a "greater need" for scaffolding Year 11 students implies that perhaps students required more formative practice in writing practical reports before attempting the summative IA. It is unclear from Kerri's comment whether he used a greater variety of scaffolding tools and/or if students were afforded more opportunities to hone their practical report writing skills before submitting the summative IA.

The teacher participants all agreed that the 2016 IA was an improvement in terms of assessment criteria and the broader mark scheme.

**Perceptions of High Teacher Self-Efficacy**

The following interview excerpts illustrate the teachers' responses, when asked to describe their perceived individual teaching strengths:

> *I think the explicit teaching, I can almost see the students absorb what you go through and with intense note-taking or listening and questions. I think I do that well and also providing them with a number of different support resources through the Moodle.*
> Andrew (before 2016 IA)

> *I think I'm good at helping them brainstorm* [research topic]. *I would have a good idea about what they would realistically be able to measure and record… and what they are going to be able to achieve. I think I'm good at helping them understand that if their hypothesis was not supported that it doesn't mean that they were wrong or that it was a failure… and then to help them figure*

*out why it wasn't supported or what they could have done*.
Morgan (before 2016 IA)

*I think I'm pretty strong in making it* [practical report write-up] *seem achievable for them. I think that the way we go ahead with Excel with standard deviation is terrific. Everybody in the class seemed to have got a handle on that pretty quickly, without too much effort*. Kerry

The greatest similarity between the teachers' responses was that there was little discussion about pedagogies designed to assist students in writing explanations in practical reports. Teachers mainly focused on helping students during the planning and procedural stages of open-inquiry. According to Velthuis, Fisser and Pieters (2015) science teachers with a high content knowledge tend to have a correspondingly high self-efficacy in teaching science concepts. One might infer from this study that teachers with scientific research experience, as those in the present study, might also display high self-efficacy in pedagogies that enhance the students' higher-order cognitive skills required to interpret and explain experimental results.

Andrew used verbs, such as 'absorbing', 'listening' and 'taking' [notes] to describe student actions during his lessons and cited several examples of traditional, didactic teaching strategies for assisting students with developing the IA report. It is, however, difficult to ascertain the extent to which he utilised alternative pedagogies without observing his classroom teaching. The IB's philosophical underpinnings are, however, based upon constructivism. Constructivist teachers typically promote student-centred learning, where learners actively co-construct new knowledge by building on prior knowledge in a socially, interactive and collaborative environment. Moreover, constructivist teachers facilitate learning by encouraging students to collaborate with one another in many different engaging activities.

In contrast to Andrew, Kerri perceived his teaching strength involved assisting students to manipulate quantitative experimental results. Kerri's pedagogical emphasis on mathematical processing, analysis and presentation was highly evident throughout his interview. For example, Kerri's numerous references to statistical analysis and use of Excel software indicated that he possibly held strong rationalist epistemological beliefs about science. According to Havdala et al.'s (2007) research, science students who displayed rationalist epistemological approaches found it difficult to coordinate theory with empirical evidence in inquiry investigations. It would have been interesting to determine how effective Kerri's students were at linking theoretical concepts to their empirical evidence in practical reports. Morgan asserted she had high self-efficacy in her capacity to help students analyse experimental data and appeared to see herself as a co-constructor rather than transmitter of knowledge. Morgan did not, however, explain how she developed the students' higher-order thinking skills when analysing data.

#### *4.3.3.2 Teacher Perceptions: 2016 IA Inhibitors (Pedagogical Challenge Types) and Teacher Self-Efficacy*

Ten inhibiting factors, referred to here as *pedagogical challenge types (PCTs)*, arising from the introduction of the reformed 2016 IA protocol, were identified from the teachers' interview data as follows:

PCT 1. Understanding the nature and extent of formative feedback of summative IA reports

PCT 2. Interpreting 'personal engagement' criterion and marks allocation

PCT 3. Interpreting 'analysis criterion'

PCT 4. Coping with time-constraints

PCT 5. Selecting IA research topics

PCT 6. Managing experimental IA investigation

PCT 7. Deciding on depth required in practical report

PCT 8. Using the new mark-scheme

PCT 9. Applying the 'communication' criterion to ESL students' work

PCT 10. Providing one opportunity for summative IA

The ten PCTs evidently contributed to low[12] self-efficacy according to teacher self-reports. At least five different PCTs were experienced by teachers during implementation of the 2016 IBDP Biology IA. Table 11 illustrates the correlation between each PCT and the duration of low teacher self-efficacy for teacher participants.

**Table 11 – Correlation between 2016 IA Pedagogical Challenge Types and Duration of Low Self-Efficacy**

| 2016 IA Pedagogical Challenge Type (PCT) | Number of Short-Term PCT's Contributing to Teachers' Low Self-Efficacy | | | | | | | | | Number of Long-Term PCT's Contributing to Teachers' Low Self-Efficacy | | | Total number of PCT's Contributing to Teachers' Low Self-Efficacy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Only Prior to IA | | | Only During IA | | | Only After IA | | | | | | |
| | A | K* | M | A | K | M | A | K | M | A | K | M | |
| 1 | ✓ | | ✓ | | | | | | | | ✓ | | 3 |
| 2 | | | ✓ | | | | ✓ | | | | ✓ | | 3 |
| 3 | | | ✓ | | | | | | | ✓ | ✓ | | 3 |
| 4 | | | | | | | | | | ✓ | ✓ | | 2 |
| 5 | | | ✓ | | ✓ | | | | | | | | 2 |

[12] The terms 'low' and 'high' self-efficacy are used comparatively and do not necessarily indicate extreme ends of the teacher self-efficacy spectrum.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **6** | | | ✓ | | ✓ | | | | | | | | **2** |
| **7** | | | ✓ | | | | | | | ✓ | | | **2** |
| **8** | | | ✓ | | | | | | | | ✓ | | **2** |
| **9** | | | | | | | | | | | | ✓ | **1** |
| **10** | | | | | | | | | | | | ✓ | **1** |
| **Total number of challenges per person** | **1** | **no data** | **7** | **0** | **2** | **0** | **1** | **0** | **0** | **3** | **5** | **2** | |
| **Total number of challenges per group** | **8** | | | **2** | | | **1** | | | **10** | | | **21** |
| **Total number of PCT by type per group** | **10** | | | | | | | | | **10** | | | |

Short-term PCTs[13] are defined here, as those that occurred in a fixed period either prior, during or after implementing the 2016 IA investigation. Since Andrew and Morgan were both interviewed *prior to and after* implementing the 2016 IA, their data reflected their self-efficacy perceptions at these times. Kerri's interview, on the other hand,

[13] Short-term PCT's will be referred to from now on as *prior*, *during* or *after* in relation to the implementation of the summative IA investigation.

occurred *after* implementing the 2016 IA, so his data was collected only in this period. No interviews were conducted with any participants ‘during’ IA implementation. Consequently, inferences were made about teachers’ perceptions of PCTs during IA implementation by analysing their retrospective reflections in interview and member-check data.

A total of eleven short-term PCTs occurred across seven of the ten different PCTs and of these, at least two contributed to the low self-efficacy of each teacher. Morgan experienced the greatest number of seven short-term PCTs in six areas (1, 2, 3, 5, 6, 7 & 8) with all occurring in the ‘prior’ period. Both Andrew and Kerri experienced two short-term PCTs which belonged to different areas and times in relation to IA implementation (i.e. Andrew: 1 - ‘prior’ & 2 - ‘after’ and Kerri: 5 & 6 - both ‘during’).

Conversely, the long-term PCTs persisted longer than short-term PCTs and included the periods prior to, during *and* after IA investigations. There were eight (1, 2, 3, 4, 7, 8, 9 & 10) different long-term PCTs. PCTs 3 and 4 evidently contributed to the low self-efficacy of both Andrew and Kerri. Both Morgan and Kerri experienced long-term low self-efficacy with PCT 1. Additionally, long-term low self-efficacy was attributed exclusively to PCT 2 with Kerri, PCT 7 with Andrew and PCTs 9 and 10 with Morgan. An across-case comparison of the teachers’ perceptions of and experiences with the ten different PCTs is explored in this section. Additionally, the extent of each PCT’s influence upon teacher self-efficacy throughout both the short-term and long-term periods, in relation to the 2016 IA reform, is also discussed.

***PCT 1: Understanding the nature and extent of formative feedback of rough drafts of summative 2016 IA reports***

According to the data in Table 11, the teachers experienced low self-efficacy with the nature and extent of formative feedback on IA reports. Andrew implied that his self-efficacy was lower, in the period prior to, but not during, IA implementation when he stated:

> *It's* [2016 IA] *a challenge ... and then you know trying to make sure you're providing really specific, quality comments and feedback … something that hopefully you build up with experience.* Andrew (prior)

Both Kerri and Morgan, however, found PCT 1 persisted over a significantly longer period compared to Andrew. The impact of PCT 1 was unique for each teacher. Andrew's low self-efficacy in relation to PCT 1 related to concerns about his effectiveness in providing high quality formative feedback when assessing IA reports. Despite his concerns, Andrew assumed he would develop greater efficacy as he gained more experience using the 2016 IA protocol. Bandura (1997) described *enactive mastery* experience as a self-efficacy source based upon one's prior successful enactment of a task.

Prior to implementing the 2016 IA, Morgan acknowledged her low self-efficacy with providing formative feedback to students on practical reports. Unlike Andrew, however, Morgan's concerns related to the extent and type of feedback 'allowed', according to IB guidelines. As she explained;

> *My colleagues were saying that if you give them a checklist, it's frowned upon by moderation really heavily. I think for me, the concern is how much help am I allowed to give, before I am actually disadvantaging them. I'm not confident on it. It's going to depend on the teacher as well isn't it? Like, if you go, well actually, like we'll pretend that draft* [rough draft of IA] *did not happen. How many* [teachers] *are actually going to follow the rules* [IA guidelines of IB] *and how many aren't? So, I find it really hard to know how much is ok, and how much isn't*. Morgan (prior)

As mentioned in section 4.2, Morgan's idea about 'disadvantaging' her students appeared to stem from the hearsay of her IB science colleagues at her school. Morgan had heard that a nearby school provided too much scaffolding assistance to students in summative IA practical reports. This extra assistance apparently led to the student results being downgraded during external moderation. Morgan's strong sense of professional integrity appeared to reinforce her determination to adhere strictly to the IB assessment guidelines, rather than risk compromising her students' grades. Her admission that she was 'not confident' may have been due to her limited teaching experience. Morgan's acknowledgement that not all teachers 'follow the rules' suggests she may have been questioning not only her own professional integrity, but also that of her peers. Furthermore, unlike Andrew, a more experienced teacher, there was no evidence prior to IA implementation that indicated Morgan's self-efficacy with PCT 1 would increase until external moderation was completed.

Kerri's low self-efficacy when using the new mark-bands, appeared to persist over the long-term. As he explained;

> *I am not that experienced as to guiding them to what an external examiner would consider a 6* [full marks]. *I am not really sure what that is [……] so partly guided by the old course there. So, I am thinking that to be safe they will probably look pretty similar to those in the old* [2009 IA] *course*. Kerri

Andrew and Morgan's self-efficacy regarding formative feedback appeared to significantly increase once they gained experience using the 2016 IA rubric. Andrew's use of a checklist sourced from the TRE on the OCC website guided his formative feedback and also helped scaffold student responses. As he explained;

> *So it* [teacher checklist] *seems fairly detailed. So, what I've done when I've drafted students' work is to go through and give them feedback on each of their sections and any bits that were missed, or that maybe they need to look into in a bit more detail or reword*. Andrew (after)

According to Bandura (1997), a vicarious source of self-efficacy relies on one witnessing another person enacting the desired task. Andrew's self-efficacy was evidently increased by using another teacher's idea (i.e. checklist) rather than observing the person first-hand assessing IA reports – a type of vicarious self-efficacy source. Morgan, however, did not use checklists to scaffold the students' written responses of the summative IA report. The following interview excerpt clearly demonstrates Morgan's increased efficacy in using the 2016 IA once she had mastered using it with her Year 12 class:

> *I used the mark-scheme as it was and just when I gave it back to them, underlined the bits in each statement that were or were not present. I think the sentences are quite well designed to include everything that you need to assess. But they* [IB] *make it quite easy to assign that mark in each block* [criterion]. Morgan (after)

***PCT 2: Interpreting personal engagement (PE) criterion and marks allocation***

All teacher participants experienced low self-efficacy when using the PE criterion at some point in time. For Andrew and Morgan, low self-efficacy with PE occurred within a short-term period, but for Kerri it was a long-term concern. The following interview excerpt illustrates Morgan's concerns with PE *prior* to implementing the IA:

> *How can you really assess 'personal engagement' based on a workshop? I think it's going to be really subjective. I mean probably seeds in a soil tray is not going to come across that they're really passionate about it. And I think it's going to be moderators relying on teachers' opinions of whether the kid was interested or not and of course they* [students] *are going to say they were interested.* Morgan (prior)

Morgan's perception in the 'prior' period was that teachers could write comments on summative practical reports to indicate the students' interest displayed *during* the IA investigation. Morgan initially believed that moderators evaluated PE according to teachers' comments. Prior to IA implementation Morgan was unaware that her assumption about PE assessment was incorrect. Andrew, however, appeared confident about PE during the IA process, until he attended the school cluster meeting with moderators. It was at this time when his students were writing their rough IA drafts, that he first realised he had misinterpreted the PE assessment process. Like Morgan, Andrew believed teachers assessed the students' engagement levels *during* the IA investigation. As he explained;

> *One of the areas that's different that I think has often had people wonder about, was this first one* [criterion] *about 'personal engagement'. And the initial reading* [understanding prior to school cluster meeting] *that I had, was that as the teacher of your class, that you would be observing students, you'd be interacting with your students, and when they hand in their write-up, and you're marking it, you're also taking into account what they've done in class and how engaged they've been. And that would go towards my marking of it*. Andrew (after)

Eventually, Andrew discovered that PE was evaluated by judging *how well students could justify their choice in the research topic.* As he explained;

> *And what was interesting was that this moderator was saying that the moderator needs to be able to see just from their write-up, that's where they* [the student] *will get their mark for 'personal engagement', no matter whether they have been highly engaged and taking a big lead role in class. So my understanding is what they want to see is students come up with a research question. They want to see; why has that student chosen that research*

> *question? What's the justification that indicates personal interest or significance, or their curiosity for that*. Andrew (after)

Andrew questioned the validity of the PE assessment method used by moderators and perceived it could potentially disadvantage his students' grades by stating that:

> *Perhaps as the teacher, if their sample* [IA reports] *goes in for moderation, and the sample should have various comments on it, where you've given marks or not given marks and so on, that within the 'personal engagement'* [PE criterion*] that a teacher might need to put on a comment about that during the lesson they were fully engaged. I would be quite disappointed if a moderator were to, just from reading, go, "This is a one out of two," because in their* [moderator's] *mind they* [students] *haven't met the criterion*. Andrew (after)

Both Morgan and Andrew enhanced their self-efficacy when summatively assessing PE, but did so differently. Andrew's self-efficacy with applying the PE criterion was evidently heightened, albeit to some extent, by discussing the issue with IB moderators' at a cluster meeting. Conversely, Morgan relied upon observing IB moderated practical report exemplars from the OCC website, to develop her understanding with PE assessment. As she explained,

> *I have seen some of them, as well-marked with track changes. The teacher puts their evidence of 'personal engagement' shown here or appropriate data analysis used. So when I'm marking, I have thought I would do it the same way, electronically, or even if I do it on paper first and go back and do it on an electronic copy. I thought it was quite good. My opinion* [about PE] *is less bad than it was before.* Morgan (after)

Morgan evidently enhanced her self-efficacy of PE assessment through utilising the moderators' comments and assessment technique ideas on the online assessed exemplar reports; this represented another form of vicarious self-efficacy.

Kerri's low self-efficacy in applying the PE criterion occurred after his students submitted drafts of the summative IA reports. Kerri's use of the pronoun, 'we' rather than 'I', suggests he was probably not the only IBDP Biology teacher at his school who was perplexed by PE assessment. As he explained;

> *But we* [Biology Faculty] *do wonder […] out of those two marks for personal engagement, what to do there. That is something we are not sure of. Do you just see it as something that was not possible and not give them two, or give two to everyone? I don't know. I am thinking that they'll not get zero, so I am thinking most of my kids will probably get a one and then some kids who did show that*

> *extra, get a two. It's a very subjective assessment. I guess being in class with them… some of them were more engaged and involved in it.* Kerri (after)

Kerri appeared to have maintained over the long-term the same misconception that Andrew and Morgan had *before* they learned how to correctly assess PE. That is, Kerri believed PE assessment was based upon the *teacher's perception of the students' interest displayed during the investigation.* Andrew, on the other hand resolved his misconception when students were writing up the summative IA reports. Kerri, however, was still unaware of the correct PE assessment protocol when his class was writing up their summative IA reports. Since Kerri had not met face-to-face with moderators, nor accessed the OCC to view moderated-assessed exemplar reports, he could not have known of his misconception. Kerri's misunderstanding of PE assessment may explain why he thought evaluating student engagement *during investigations* was subjective. The ad hoc nature in which Andrew and Morgan discovered their misconceptions about PE assessment is troubling, given they had both attended formal IBO IA workshops. It appears that the workshops had not made the PE assessment process particularly clear.

These misinterpretations were unusual because all three teachers were teaching at different schools during the research period. Furthermore, two teachers attended formal IB 2016 IA workshops where they were explicitly informed about the new assessment criteria by IB workshop leaders prior to IA implementation. An additional concern was that two teachers unknowingly misinterpreted the PE criterion assessment process throughout most of the two year IBDP Biology program. The 'chance' realisation by one Biology teacher that he had misunderstood the PE assessment process for just over one year whilst attending a school cluster meeting, caused him to seriously question the IBO's endeavours regarding IA transparency.

***PCT 3: Understanding aspects of data processing, presentation and analysis***

As pointed out earlier, Morgan used the 2009 IA rubric to formatively assess practical reports up to one term before implementing the 2016 IA. However, once she commenced using the 2016 IA, her self-efficacy with data manipulation gradually increased. As Morgan explained;

> *The main issue is errors* [error bars] *and uncertainties…but other than that, it's sort of, not that different from what they've done before in terms of making an appropriate graph and making an appropriate table and showing your sample calculations. I think that I didn't need to give them as much guidance on how to do stuff*. Morgan (after)

Morgan believed that using the 2016 IA for formative assessment helped increase her self-efficacy in the (A) criterion:

*Actually doing it has helped me understand the mark-scheme better, even in the drafting which areas… They* [students] *have real problems with uncertainties and errors* [error bars]. *They* [IB*] have taken a lot of weight off the uncertainty and errors because it's just because they* [students] *don't find it easy. Makes me wonder if everybody was doing it badly forever and ever*. Morgan (after)

Morgan indicated that her past students had difficulties understanding the concepts of uncertainties and error bars in the 2009 IA. Consequently, she supported the IB's decision to reduce the emphasis on measurement error in the 2016 IA. Morgan's experience with errors and uncertainties is another example of how mastery experience can increase self-efficacy. Andrew and Kerri also had some long-term concerns with the (A) criterion in the 2016 IA. The following comment highlights Kerri's ongoing concerns with data analysis:

*What was the error in that measurement? I'm not really sure to be honest what the general IB is expecting, in that sort of error analysis.*

*There are some problems in Excel when doing a line of best fit [……]. It can give you a very loose exponential line that goes below the axis, which I'm not sure how to fix up. In previous IAs I have had them print it with no trend line and draw it in by hand. My*

> *skills are perhaps missing there. I don't know what sort of trend line to add sometimes and it is an interesting problem, in itself, whether to make it linear or polynomial. Even though I had been a researcher, I'm not really sure how you go about that choosing which one. It's hard for me to communicate that to the kids*. Kerri (after)

Like Morgan, Kerri was unclear about error analysis and uncertainties in the 2016 IA. Despite his strong scientific background, he lacked confidence in advising students about choosing appropriate trend-lines for graphs when using Excel software. Although Kerri's concerns were valid, they were not unique to the 2016 IA, as they also applied to the 2009 IA. Kerri's low self-efficacy with parts of the 2016 IA 'A' criterion was not reconciled in the short-term, as it was for Morgan. Andrew, on the other hand, was unclear about the extent of statistical analysis that could be carried out in the, A criterion. As he explained;

> *I'm trying to understand with the processing of the results sort of how much more they are expecting than in the old IA. But* […] *concerns about how much <u>more</u> statistical analysis. So those were some concerns*. Andrew (after)

Andrew's concerns about statistical analysis, however, appeared to be adequately addressed by the moderators at the cluster meeting. Once again, it appeared Andrew's self-efficacy was enhanced by the verbal/social persuasion of IB moderators, who clarified the IB's stance on using statistical analysis. As he explained;

> *They were also talking about how the stronger IAs this time round, they are sort of taking the IAs slightly further, even more towards a mini Extended Essay (EE), [….].utilising where they can some statistical analysis of the results, which in the previous IA you would want to get enough data that you could calculate the standard deviation and put that on the graph. Here, they want that as well, but if you're also able to look at doing t-tests if appropriate, then do that as well. It's not compulsory. It really depends on the study that they're doing and the data they're getting. But yeah, if relevant they really should do it*. Andrew (after)

***PCT 4: Coping with time constraints***

Both Andrew and Kerri explained that time constraints were problematic, irrespective of the IA protocol utilised. Morgan, however, did not raise the issue of time constraints presumably because she had a small class of only six students. Andrew, however, had a much larger class of twenty-five, as did Kerri, who had eighteen students.

Andrew believed his intermittent class absences due to various administrative responsibilities, regularly disrupted the students' learning and hindered his marking efficiency. Moreover, he believed his students would benefit from undertaking multiple formative IA practical report write-ups, but time constraints made this idea impossible to achieve. As Andrew explained;

> *One challenge is the other part of my job as a coordinator. At times I have been away from class. So at times that's been disruptive. Trying to provide more opportunities for them to do write-ups is difficult with the time available and getting IAs marked and back to the students in a timely manner*. Andrew (prior)

Kerri acknowledged the powerful formative learning outcomes often associated with post-practical student discussions of open-inquiry, but continued to prioritise teaching theoretical content due to time constraints. As he explained;

> *I don't very often at all follow up the practical lesson with a lesson about what was that about and I think that is largely this is a very jam-packed theory curriculum driving me. The day after a practical, it might be worth spending time looking at how could we have done that better and I can see that would teach them a lot about doing practicals, but I don't take the time. It feels like nearly*

> *every lesson we do a different part of the course and it's really a lot of theory.* Kerri (after)

As illustrated by Kerri's comments here, the decision to forgo post-practical discussions, in order to continue teaching scientific content often occurs when teaching curricula comprising high-stakes examinations. Wallace et al. (2004) found that teachers may hold competing beliefs about what is best for their students learning when high-stakes examinations are involved. When high-stakes examinations are coupled with other contextual factors, such as time constraints and content-laden curricula, implementation of authentic scientific inquiry can be mediated. Consequently, students can often miss out on valuable learning opportunities such as investigative practical work. The view that contextual factors can impede successful curriculum reform enactment has been raised by several other contemporary researchers (e.g. Deiner et al., 2012; Tang, 2010).

***PCT 5: Selecting topics for 2016 IA Research***

Prior to the summative IA, Morgan acknowledged her low self-efficacy in helping students select research topics. During her first interview, Morgan reflected upon her past teaching experiences and suggested using a PMI (Pluses, Minuses & Interesting points) process to help students choose research topics. As she explained;

> *I'm a bit nervous about that one* [IA topic selection]*. I guess we're going to have to do some, maybe the sort of, same kind of ideas*

> *that we do with the research project* [i.e. SACE Research Project] *when you're trying to pick your project for that, where you do the little boxes with the diagrams, the pluses and minuses*. Morgan (prior)

The following interview excerpt clearly illustrates that Kerri also experienced low self-efficacy with research topic choice:

> *We* [Biology Faculty] *probably had a list of twenty five different ideas or something like that. We do have a list of possible practicals and we tick them off. Students supposedly choose the one they are most interested in and then that's it, so each kid does something different. So at least we feel like we're sort of achieving some differentiation there - maybe some personal engagement. Some students came to me and it was a bit disappointing. I tried to get a couple of associations. Maybe they could spend some time in a lab at a university. Maybe this wild IA in genetics or behaviour or something might be achievable, but basically in no case did it eventuate. I did have a couple of those more engaged students feeling a little less than happy working with something on a list and looking at potato cores or something […] and we weren't really able to offer it. And whether that's the school's fault or it*

*was expected that a student would use their own resources to set up everything, I don't know, but I think the ambitions of the IB were not realised, in that situation. We overall, as a college, sort of find that really hard to get the creativity really high without actually telling them what to do*. Kerri (after)

Both Kerri and Morgan were challenged by the issue of students choosing their research topics. Like Morgan, Kerri acknowledged that topic choice was constrained by the school's available resources. Both teachers predicted limited resources could impede personal engagement. Kerri's large class size required a higher number of engaging research topics to be organised compared to Morgan's class. Kerri's initial idea of contacting a nearby university, so students had a greater likelihood of pursuing their personal research interests, was not successful. Consequently, Kerri provided students with a list from which to choose topics.  The advantage of this latter idea was that Kerri knew the experiments could all be undertaken at school, during school hours, with adequate resource availability. However, the disadvantage of the teacher-generated list was that some students were not enthusiastic about the listed research topics.

Morgan used a very different approach to topic selection than Kerri. Following implementation of the investigative phase of the IA, Morgan solved the problem of facilitating research topic choices with her students. As she explained;

> *We spent a couple of lessons actually brainstorming topics and then making very sure that they were all separate* [different] *from each other. So we had six students in the class and it ended up two doing seeds, but with different factors. One did yeast, one did catalase, one did human exercise and one did fruits, so they were all quite different from one another. One of the students is really into sports, so he was, straight away, "I'll do something with sports" and then the ones who did seed stuff* [plant experiments] *were a bit more, "ah, I don't know what to do." Then I would say, "Well, you're doing seeds, so find some way that seeds are relevant to you." But they both actually managed to find a decent spin on it for 'personal engagement'. One of them related it to his own garden, where he grows plants at home, looking at efficiency of watering, so I thought it was fine*. Morgan (after)

Morgan explained that most students required minimal help when choosing research topics and concluded that topic selection was easier than she had originally expected. Furthermore, by allowing students to play a more central role in facilitating their own topic choices, Morgan enhanced her self-efficacy with respect to research topic choice.

Although Kerri genuinely tried to resolve the research topic issue, his approach did not appear to increase his self-efficacy as significantly as Morgan's approach. Kerri's approach to topic choice was more teacher-centred than Morgan's and therefore some of Kerri's students may have felt disengaged with their research topic, because they had little say in choosing topics they wanted to pursue. Morgan's use of a more student-centred, social constructivist approach in which she acted as a facilitator, is widely recognised by many researchers as effective pedagogical practice (Conner, 2014; Garbett, 2011; Lew, 2010). It can be speculated that overall, Morgan's students were more satisfied with their research topics than Kerri's, since they probably believed they had more choice. It is likely that when students exercise more control in their learning, such as research topic choice, they may be able to more validly justify their personal engagement with the research topic – a key assessment criterion in the 2016 IA protocol.

***PCT 6: Managing the open-inquiry investigation of the 2016 IA***

Morgan's low self-efficacy was probably influenced by a past negative experience involving the 2009 IA beetroot pigment leaching investigation (refer to section 4.3.2.2, 2009 IA Inhibitor c – *Difficulties in implementing open-inquiry investigations*) and the moderator feedback she received about it. Morgan's problems centred on the students' use of large sample sizes, shortages of apparatus and challenges related to using live tissue. Her low self-efficacy when managing the 2016 IA investigation is clearly explained in the following quote:

*It makes me worry about the new protocol, how much logistically it was difficult when they all had to do so many samples and if they all have to do something different. I actually got a comment on my moderation* [2009 IA]; *"Was this really 5 hours?" I was like, it was really more like ten*! Morgan (prior)

Prior to the 2016 IA, Morgan appeared uncertain about how to allocate time to the summative investigation and report write-up. The IBDP Biology guide (IBO, 2014) specifies that "ten hours of teaching time" (p. 149) should be allocated to the IA. Morgan was frustrated by the IB's imprecise details about how the ten hours would be utilised for the specific phases of the summative IA. The time allocation issue was not resolved at the 2016 IA, IBDP Group 4 workshop and therefore Morgan devised her own solution. As she explained;

*I went to a workshop and everybody was saying, "Well, is it ten hours of classroom time, is it ten hours of total time, is it ten hours of instruction time?" Well they* [workshop attendees] *kind of all agreed that it was ten hours of classroom time, but whether that was actual time to work on it* [IA investigation experiment and practical report write-up] *themselves* [students] *or intensive instruction, wasn't really clear. It should take approximately ten hours. I can't remember the wording exactly and that's why we*

> *had this huge debate* [at workshop]. *I think when we spend time actually designing the practicals, I think some of those ten hours are going to have to be doing research in class and asking me what is ok and what isn't.* Morgan (prior)

After IA implementation, Morgan explained that she initially allocated just over ten hours of class time for students to plan, research and carry out the practical component and discovered that report write-ups generally required over ten hours of class time. She accepted it was difficult to precisely specify time allocation, due to the unique nature of each student's investigation.  As Morgan explained;

> *So probably the class time, the ten hours* […] *I also in that block I gave them some time going on with their research,* [..] *so they could ask me for advice at the start and a lot of them did their data collection outside of those hours. For example, the plants; they* [students] *had to water them daily, but that was only five minutes a day. One of the boys did exercises* […] *in his own time. It's hard to make it be ten hours exactly for every student when they're all different. I think maybe ten hours of classroom time* […] *it's going to be more than that for the students*. Morgan (after)

Morgan’s time management approach appeared more flexible than Kerri’s. Kerri found it challenging to assist his large class of students who simultaneously implemented eighteen different IA investigations over a series of lessons. As he explained;

> *With the individual personal engagement aspect and our attempts to individualise the student’s practical work this year in the new* [2016 IA] *course […] put a massive load on me. I do feel responsible for them at least getting some data and so I was faced with eighteen students in the class, for say two to three periods in a row and nearly every student had different problems they faced with the ongoing experiment and collection of data*. Kerri (after)

The tension that Kerri endured during the investigative phase of the IA was audible in the intonations of his speech during his interview, when he recounted the “massive load’’ involved in trouble-shooting experimental issues. Part of this stress was evidently due to his desire to ensure that technical problems were resolved and that all students had sufficient experimental data for analysis – another example of Kerri’s apparent rationalist epistemological stance.

It seemed that Kerri’s approach to managing the IA investigation was that all students had to complete the investigation by the end of three lessons. If this was the case, then Kerri would have understandably been under immense pressure to ensure technical problems and issues relating to the students’ data collection were minimised, so experiments did not need to be repeated. Furthermore, the requirement of the 2016 IA, that students conduct highly diverse, individualised experiments and that eighteen experiments occurred simultaneously in his class, would have significantly added to Kerri's tension during the investigation.

When Morgan was asked about whether she spent much one-on-one time with the students during the experimental phase of the summative IA, she confidently stated:

> *Not really, because when they were doing some in lesson time, there were multiple kids doing stuff at the same time and the ones who weren't were just watering plants every day, I didn't need to help them much with that. They were pretty independent.* Morgan (after)

***PCT 7: Deciding on depth of practical report***

Before implementing the summative IA, both Andrew and Morgan shared concerns about the depth required in the practical report write-up, as follows:

> *I mean what we are looking at is sort of half-way in between the EE*[14] [Extended Essay] *and the old* [2009 IA] *practical report maybe. The exemplars* [sample 2016 IA practical reports viewed at

[14] The Extended Essay is a compulsory, independent 4000 word essay which all IBDP students have to complete as part of a core assessment requirement for the Diploma Program (IBO, 2017).

> IB workshop] *seemed like a smaller thing than what everybody was thinking. It was confusing and a bit worrying* [. …… ] *can't be that much larger than a really decent old formative practical, I guess. The exemplars, to me seemed like a meaty* [detailed] *old syllabus practical*. Morgan (prior)

> *IAs* [2016 IA reports], *I've heard and I can understand, are often thought to be mini EEs. The presenter that we had was trying to allay our fears about that. But it is becoming even more of a detailed research report along the lines of an Extended Essay. I think most people were getting the impression that the one IA* [in 2016 curriculum] *was expected to perhaps be more detailed than, the previous* [2009 IA] *IA.* Andrew (prior)

Morgan was not sufficiently reassured of the depth requirements for the summative IA report at the IB workshop. Her self-efficacy appeared low prior to implementing the 2016 IA. Morgan and Andrew both predicted, prior to the IB's IA workshops, that the 2016 IA practical reports would be less detailed than Extended Essays, but more detailed than the 2009 IA reports. After the IB workshop, both teachers concluded that the IA workshop exemplars were not as detailed as they had expected.

Morgan's self-efficacy was, however, greater after implementing the 2016 IA. As she explained;

> *I think I did quite well in helping them come up with the scope and size of their practical. I guess we'll find out when they come back from the moderator. I think when we* [Morgan and researcher] *talked last time, I said that I felt like it just needed to be like a beefed-up*[15] *old IA, and I think that's sort of about the level that they all go to.* Morgan (after)

Unlike Morgan, Andrew's low self-efficacy concerning depth requirements for practical reports, persisted over the long-term. He learned at the school cluster meeting (attended by moderators) that the 2016 IA was broader and deeper than the 2009 IA version. As Andrew explained;

> *In that old* [2009 IA] *system you had each of these sections, it was marked zero to two. And here* [2016 IA], *you've got sections that are* now marked up to six marks, that they're [moderators] *saying for students who are looking at getting those sixes* [six marks], *then, they are looking at it being broader and deeper than the old IAs*. Andrew (after)

[15] "beefed-up" – slang term that refers to being 'more detailed'

Andrew explained that discussions with several Group 4 IBDP subject teachers and moderators within different contexts, such as formal IBDP Biology workshops, local school cluster meetings and his own school, were professionally enlightening. Andrew's perception following these discussions was that there was an apparent lack of transparency by the IBO concerning IA requirements. According to Andrew, Group 4 IBDP science teachers were not privy to the same assessment information as moderators. Furthermore, Andrew remarked that the IBO provides teachers with less specific detail about assessment compared to the moderators. As he explained;

> *So the other concern, query, was about the* <u>*extra depth*</u> *that they* [moderators] *were looking for. That was sort of being implied, but at times not explicit.*
>
> *This was a criticism that a number of people teaching IB Group 4 subjects have had [….]that the IB will put out guidelines and information and yet information that goes to the moderators, or is given to them, the moderators are specifically told, "This is not for publication. This is not for passing down the chain." And it's secret squirrel stuff that really annoys and frustrates… So it's not just how I feel in Biology, it's about Chemistry teachers and Physics teachers saying, "Okay, well we mark based on our understandings," but then there seems to be this something else that happens amongst*

> *the moderators, and information isn't quite clearly given back why they operate in that way. That's my gut feeling on it*. Andrew (after)

Andrew's perceptions about IA assessment raise serious concerns about assessment transparency within the IBDP Group 4 IA protocol and its potential impact on academic fairness in relation to students' grades.

***PCT 8: Learning a new mark-scheme***

Morgan intended on using the 2016 IA rubric to assess formative practical reports early on in the first year of the program in Year 11. However, she decided at this point in time that her students would find the number of rubric criteria in the 2016 IA mark-scheme difficult to work with. To solve this problem, Morgan tried to create her own 2009/2016 IA hybrid rubric to introduce the students to the 2016 IA mark-scheme, but found modifying the rubric was too difficult. Consequently, she delayed using the 2016 IA rubric for formative assessment purposes with her Year 11 class until later in Term 4. Morgan justified using the 2009 IA rubric for most of the first year of the 2016 IBDP Biology curriculum, because it seemed she found it easier to use and also believed that it would be less threatening to her students. It can be speculated that Morgan's initial reluctance to use the 2016 IA rubric, illustrates her lack of confidence in adapting to the new IA scheme. This is understandable given her status as an ECT with limited teaching experience. As she explained;

> *I thought the new* [2016 IA] *mark-scheme was a bit overwhelming for just a formative practical, like with all* [five] *of those different criteria and I thought, I just I don't think the class I've got is a super strong class and I didn't want to, [….] terrify them too much* [laughs], *because they are a bit terrified about their test scores. I thought if we can build up to it, if I give them a few goes on the simpler rubric* [2009 IA, with three criteria] *and make sure that they're doing everything there, then we can build up to the new one*. Morgan (prior)

By the end of the first year, Morgan had gained a better understanding of the 2016 IA rubric, having trialled it on a few occasions with her class. Once again, successful 'mastery' experience appeared to improve self-efficacy. As Morgan explained;

> *I actually think they're* [criteria] *quite well set out. I do think it's easier to use the scheme* [2016 IA]. Morgan (after)

Kerri was concerned that the 2016 IA marking process would be more subjective than the 2009 IA process, due to the former IA's broader mark-scheme that applied to most assessment criteria. As he explained;

> *I think perhaps as soon as you go to more than 3 or 4 or 5 or 6* [3,4,5 or 6 maximum marks within a mark band], *I think it's going to become more subjective. It* [2009 IA] *is probably going to be easier to agree on, than a 4, 5, 6 level of system, but I am really yet to find out.* Kerri (after)

Despite being the most experienced teacher participant in the current study, in terms of years of teaching, Kerri was the least familiar with the 2016 IA marking scheme. Kerri did, however, appear highly efficacious in his capacity to assess the IA practical reports, even though he had not attended formal IB PD in the new scheme. Additionally, he believed that he would overcome his IA assessment knowledge deficiencies by collaborating with his colleague. Kerri's perception was that he would develop assessment competency through observing and collaborating with his peer – another example of a vicarious self-efficacy source. Kerri's high self-efficacy in relation to IA assessment is evident as follows:

> *They* [summative IA practical report write-ups] *might take three quarters of an hour to an hour each or something. These first few will be much longer […] because that's exactly what we'll do [….] nut out the scheme.* Kerri (after)

***PCT 9: Applying Communication (C) criterion to English as a Second Language students***

The new 'communication' (C) criterion created an ethical dilemma in terms of formative feedback given on ESL students' rough drafts. Prior to IA implementation, Morgan was deeply concerned about one of her ESL student's grammatical difficulties and how extended written explanations might disadvantage his IA practical report grade. As she explained,

> *Two of them have very good English, but one of them, his English is just really bad. I think that probably with report writing it's one of the things that he's got a better chance of sneaking it through, because it's so regimented and structured and even if his English isn't that good and he can get the ideas across, and he has met all of the points, then it's probably ok [ …..] but I'm a bit concerned when he has to do longer writing in the report that will be hard for him.* Morgan (prior)

ESL students constituted fifty percent of Morgan's class and so her apprehension regarding how best to manage assessing the ESL students' reports appeared valid. The C criterion requires that IA reports are well-structured, clear and concisely presented. As Morgan explained;

> *I think the Communication one* [C criterion], *it's going to disadvantage ESL students, whereas before* [2009 IA], *it was, if you*

> *have the science right, then it didn't matter if your English was broken, but now it might actually pull them down on those marks.*
> Morgan (prior)

Morgan initially lacked confidence in determining the extent of formative feedback she was permitted to give to her ESL students in their 2016 IA practical reports. Her overriding uneasiness about academic fairness prompted her to seek advice from the IB coordinator at her school. As Morgan explained;

> *He's* [ESL student] *a native Chinese speaker and his English is just appalling and I was trying to read, I was trying to draft it for the content and I couldn't even read it. The English was just so bad, I couldn't even begin to look at the science [….] and so I said, "Look, what I do in this situation, because I've been told one full draft?" He* [IB Coordinator at Morgan's school] *said in the past he's had feedback where there was a student who, his work was clearly good work, but the English let it down and the feedback from the moderator said, "Why wasn't this clearly ESL student given more guidance on the English?" So, he said, "Absolutely, help* [him with the] *English." I actually went through it once just to get the English in order without changing the content at all and then I actually went through it again looking for the science which I thought, am I*

*allowed to do this? He said, "Absolutely', because they [Morgan's school) have been told off [warned by the IBO] about it before.*

*Morgan* (after)

In other contexts, Morgan had displayed a patently strong commitment to ensuring that the IB guidelines were rigidly followed. However, she recognised that in this situation, her ESL student would be academically disadvantaged if she strictly enacted the IB's IA guidelines. Yung's (2006) study showed that when Biology teachers were faced with the complexity of both teaching and assessing high-stakes tasks, their competing belief paradigms (assessor vs teacher) can create tension which affects their pedagogical approach.

Morgan's question, "Look, what do I do in this situation, because I've been told, one full draft?" indicates that she was undoubtedly struggling to manage her dual roles of assessor and teacher at the time. By accessing her IB coordinator's advice, however, Morgan advanced her understanding of how to apply the IB guidelines to ESL students. Morgan learned that the IB phrase, "one full draft" could be flexibly interpreted. By correcting the ESL student's grammar before formatively assessing the scientific component of the IA draft, Morgan achieved two important goals. Firstly, she facilitated the necessary support the ESL student required from a learning perspective. Secondly, she assisted her student knowing that the IB guidelines were not contravened. Morgan's teaching role in this situation predominated over her assessor role. It is likely that

Morgan's handling of the ESL student's formative feedback was pedagogically transformative for her.

In Morgan's case, verbal/social persuasion by her IB coordinator played a key role in increasing her self-efficacy when assessing ESL students' IA reports. This finding is supported by Milner and Woolfolk Hoy's (2003) study whereby verbal/social persuasion played a significant role in enhancing self-efficacy amongst ECTs until mastery was achieved.

***<u>PCT 10: Providing one opportunity for a summative IA</u>***

Morgan was the only teacher who did not support the 'one-only' IA requirement of the 2016 IA protocol. This view is manifest in the following statement she made during an interview before implementing the 2016 IA:

> *I am a little bit concerned about the new model, that it's one practical. I don't really like it just being just one practical. Because if that one practical is a failure, then there is twenty percent of their mark.* Morgan (prior)

After having implemented the 2016 IA, Morgan indicated that she was still unconvinced of the IB's stipulation of one IA. As she explained;

> *I still would prefer if they had a smaller one and more, or even if they had two, that were each smaller, because there's a lot riding*

*on that one. I mean, like the boy who just his first run (experiments) at it completely didn't work, I mean he got another go. And I guess you take into account that it's their one and only and maybe it's not as strict* [as in the case of the 2009 IA with more than one opportunity to complete an IA]. *I still think twenty percent is a lot for it.* Morgan (after)

# Chapter 5: Conclusion

The current multiple case study presents in-depth accounts of three, Biology teachers' experiences in response to recent assessment reform in the IA practical component of the 2016 IBDP Biology curriculum. This research provides an understanding of the unique professional issues faced by these Biology teachers within Australian schools when implementing pedagogical strategies designed to develop student understanding of practical report writing for the high-stakes summative internal assessment (IA). This chapter briefly revisits the research purpose, summarises the key findings, presents the limitations of the study and finally provides suggestions for future research.

## 5.1 Revisiting the Research Purpose

The current research addressed two main research questions:

1. What pedagogical strategies are IBDP Biology teachers implementing to develop students' understanding of how to write effective practical reports in preparation for the internal assessment (IA)?

2. What are IBDP Biology teachers' perceptions concerning the introduction of the new 2016 IA protocol in practical work?

## 5.2 Summary of Key Findings

This section presents the key findings according to the themes that formed the basis of the two research questions in this study:

1) Pedagogical strategies utilised in implementing the internal assessment (IA).
2) Teachers' perceptions of the 2016 internal assessment (IA) in IBDP Biology.

### 5.2.1 Theme 1: Pedagogical Strategies.

The teachers in this study ensured that the assessment criteria were clearly explained to students before implementing the summative IA. Furthermore, teachers perceived that student learning benefitted from regular participation in a variety of formative practical tasks such as confirmatory, structured- and open-inquiry investigations.

A key finding of this research was that the pedagogical approaches utilised by teachers to assist students with writing practical reports were primarily transmissive and teacher-centred. There was little evidence to suggest that teachers utilised a wide range of student-centred, constructivist approaches following experimental investigations such as those involving self and peer assessment techniques to review formatively assessed practical reports. All three teachers did, however, encourage students to collaborate in small groups during the experimental phase of formative practical investigations – a practice that is supportive of social constructivist principles. Additionally, the teachers did not report using contemporary pedagogies that incorporated scientific explanatory reasoning models, argumentation techniques or strategies designed to develop student metacognition. It is probable that the teachers were neither aware of, nor skilled to instruct students using the aforementioned pedagogies.

The teachers reported that they used pedagogies which facilitated the procedural elements of scientific inquiry and involved the production of scientific evidence. Pedagogical strategies that focused on developing the students' lower-order cognitive abilities such as observational skills, attending to technical aspects of investigations and acquiring mathematical and ICT understandings of data, were commonplace practices amongst teacher participants.

Four scaffolding tools were used by teachers to help students improve their practical report writing skills: (1) partial report writing; (2) authentic, moderator-assessed student exemplar IA reports; (3) scaffolding checklists and (4) formatting tables. Partial report writing and teacher and/or moderator-assessed exemplar practical reports were frequently utilised by the teachers, albeit in diverse ways and in some cases, for different purposes.

Teachers primarily used a range of planned formative feedback strategies and believed that when regularly used they improved the students' practical report writing skills. The most common formative feedback strategies implemented by teachers included writing comments and/or marks indicators in practical reports, face-to-face mini-conferences with individual students and whole class discussions.

### 5.2.2 Theme 2: Perceptions of IA Reform

#### *5.2.2.1 Enabling and Inhibiting Factors – Comparing the 2009 and 2016 IA Protocols*

**Enablers**

Overall, teachers supported the 2016 IA's broader mark-bands for all assessment criteria, except for 'personal engagement' (PE). Teachers perceived that the broader mark-bands increased assessment validity by making it easier for them to differentiate between students' cognitive abilities. The teachers were supportive of most of the 2016 IA rubric criteria and especially favoured the newly introduced PE criterion. Two teachers verified their support of the 2016 IBDP Biology curriculum's single IA requirement, because less work was required by them in terms of planning, implementing and assessing for summative purposes. However, all three teachers agreed that the 2009 IA guideline of submitting the equivalent of two IAs for summative assessment was more academically just for students than the 2016 IA protocol.

**Inhibitors**

In the lead-up to implementing the 2016 IA, the teachers were generally unclear of how to accurately interpret and assess the PE criterion. Additionally, teachers lacked clarity concerning the allocation of class time to the IA and the depth required in practical reports. Two teachers were initially apprehensive about both the 'communication' (C) and 'analysis' (A) criteria, although their concerns diminished upon completion of the summative IA process. Only one teacher disagreed with the IBO's 'one-only' summative practical report guideline for the 2016 IA. All three teachers perceived that the (0-2) mark-band used to assess the 2009 IA criteria was ineffective in accurately differentiating between their students' cognitive capabilities.

#### ***5.2.2.2 Role of Professional Development***

Teacher participants engaged in a variety of both formal (IB and/or school-initiated) and informal (self-initiated by teacher) PD experiences to develop their understanding of 2016 IA curriculum reform initiatives. Two formal PD modes were identified: (1) IBDP Group 4 conference workshops and (2) school-based professional learning communities (PLCs). Three informal PD modes were identified: (1) ad-hoc school-based collaboration and/or mentoring sessions with IBDP science colleagues; (2) OCC website and (3) off-campus school cluster meetings with other teachers and IB moderators from nearby schools.

Teachers perceived that each PD mode had its own unique benefits and constraints. For example, the teachers acknowledged that the IBDP Group 4 IA workshops provided valuable opportunities to share their ideas of IA assessment with workshop leaders and other teachers. Not all teachers' concerns about the IA appeared to be adequately addressed at formal IB workshops. The one-off nature and limited time of IB workshops often resulted in teachers seeking additional expert advice from other sources. For example, the teacher participants found that mentoring by more experienced 'expert' teachers within their own schools was particularly effective, as it was easily accessible during working hours, highly applicable to their local school context and could be sustained long-term.

Significant differences existed between the type, range, accessibility and uptake of non-mandatory PD by teachers. Non-mandatory PD was primarily influenced by personal and school-based contextual factors. Teachers sometimes perceived that the advice provided by their professional networks concerning the 2016 IA at formal IBDP workshops was not always reliable. Furthermore, in some circumstances, teachers perceived that the IBO lacked transparency with respect to some elements of the 2016 IA protocol. In other situations, teachers had either purposefully chosen not to take up, or were unable to access both formal and informal PD activities. In either case, it appeared that teachers missed out on valuable learning opportunities to deepen their understanding of the IA process.

#### *5.2.2.3 Teacher Self-Efficacy*

Despite the teacher participants' extensive academic qualifications and access to several different PD modes, they all admitted to experiencing periods of low self-efficacy whilst planning, implementing and assessing some aspects of the 2016 IA. Low self-efficacy in the current study appeared to be independent of gender, age, teaching experience, type of PD undertaken and school context.

The current study identified ten different Pedagogical Challenge Types (PCTs) in relation to the 2016 IA. These PCTs were experienced by teachers over either a short- or long-term duration. Four PCTs were correlated with a significant decrease in the teachers' self-efficacy over the long-term: (1) understanding the nature and extent of formative feedback for summative IA reports; (2) interpreting and allocating marks to the PE criterion; (3) interpreting data analysis and (4) coping with time-constraints.

It is professionally worrying that teachers experienced low self-efficacy within four areas of the 2016 IA protocol during a prolonged period. Ryder (2015) pointed out that failure of curriculum reform enactment cannot be solely attributed to teachers' personal characteristics. For example, challenges, accompanying curriculum reform often include school-based contextual factors, such as limited time, large class sizes, a busy teacher work schedule and teacher accountability pressures imposed by meeting the requirements of a content-laden, high-stakes curriculum. Such contextual factors may explain why time constraints posed significant challenges for two teachers in this study over the long-term. Furthermore, it is also possible that pre-service training and in-service PD did not appear to adequately prepare teacher participants to meet the pedagogical and assessment literacy demands associated with teaching the academically rigorous IBDP Biology curriculum**.** Alternatively, teachers may have missed out on valuable PD training that may have provided the information needed to effectively address their pedagogical challenges.

The teachers' struggles with the nature and extent of formative feedback may have also been attributed to their own competing belief systems. For example, in this study it appeared that at least one teacher, Morgan, allowed her assessor role to predominate over her teaching role through rigid enactment of the IA assessment guidelines in an attempt to maintain academic fairness. As a consequence of prioritising the assessor role, Morgan's use of a restricted range of scaffolding strategies may have mediated rather than promoted her students' deeper understanding of practical report writing particularly during the first year of the IBDP Biology programme. However, the current study revealed that formal assessment guidelines may be flexibly interpreted. For example, Morgan's discovery that she could legitimately correct an ESL student's grammar in a summative IA report without breaching IB guidelines, is a case in point.

Teachers did not always swiftly resolve the pedagogical challenge types (PCTs) they encountered when implementing the IA. For example, there were several situations in which teachers held inaccurate or at best, partially-accurate understandings of some elements of the IA over several months. In some cases teachers completely misinterpreted the IB's intent of IA criteria outlined at IBDP Group 4 IA workshops and/or accepted inaccurate hearsay advice from their teaching colleagues. Additionally, teachers also relied on prior experiences with the 2009 IA to guide their understanding of the 2016 IA. Although past professional experiences can often be extremely useful in bolstering a teacher's confidence in relation to assessment reform, the current study revealed that this did not always occur.

Overall, this study found that high teaching self-efficacy appeared to be related to the extent to which teachers were able to accurately interpret and implement the IA rubric assessment criteria during both the formative and summative phases of practical work.  Furthermore, the teachers' ability to research, utilise and provide a variety of effective formative feedback strategies, proactively seek accurate professional advice/training concerning the IA protocol from the IBO and experienced IBDP colleagues both within and outside of their own schools before the students implemented the summative IA were key factors in promoting high teacher self-efficacy. Low teacher self-efficacy appeared to be linked to the Biology teachers' misinterpretations of some of the IA assessment descriptors within the assessment criteria, and the nature and extent of formative feedback allowed to be provided to students when assessing summative IA reports. The IBDP Biology teachers in the current study have cited factors such as a lack of transparency with respect to some IA assessment criteria descriptors, as well as insufficient and/or ineffective professional development ( both formal {IB & non-IB}  and informal {IB & non-IB}) as contributing to low teacher self-efficacy whilst implementing the new protocol. Furthermore, personal factors, such as teachers being unfamiliar with the nuances of the new IA, the extent to which they strictly adhered to IB assessment guidelines and personal/ professional time-constraints, also reduced teacher self-efficacy when implementing the reformed 2016 IA.

## 5.3 Limitations

Three limitations were identified as being particularly important in relation to the interpretation of this study's results. Firstly, the current study's transferability to other school contexts was limited due to a small sample size of three teacher participants. In order to counteract some of the perceived disadvantages associated with a small study sample, stratification was used to ensure that important population elements, such as age, gender, teaching experience and school context (i.e. public vs independent, single-sex vs co-educational) were represented. Secondly, although triangulation was achieved through semi-structured interviews, some member-check email correspondence and a small number of formatively assessed practical reports, there was still a heavy reliance upon interview data. The third limitation involved the timing of interviews. Due to logistical reasons, I was unable to interview one of the participants before he implemented the summative 2016 IA. Consequently, data obtained from the third participant's (i.e. Kerry) recount of the pre-implementation phase was considerably retrospective, as it was collected much later after he had implemented the IA with his class. The two other participants' recounts, however, occurred during the pre-implementation phase and reflected a more recent recount.

## 5.4 Implications and Recommendations

### 5.4.1 Educational Practice

Three key recommendations in educational practice have been proposed in light of the current research, with the view of improving IBDP Biology students' understanding of written practical reports in preparation for the summative internal assessment (IA). In developing these recommendations due consideration was attributed to the unique and often complex needs of IBDP Biology teachers who recently implemented, or who may potentially implement the 2016 IBDP Biology IA in the future. Embracement of these recommendations depends upon the unique pedagogical orientations of teachers, diversity of the student cohort and school context. Consequently, it is important to acknowledge that several different professional approaches could be employed to assist teachers to effectively implement the IA.

The first key recommendation emerging from the findings of the current study is that both the IBO and IBDP schools may need to consider how to further enhance transparency in relation to the interpretation and assessment of the IA criteria in Group 4 pure science subjects. For example, the current study's finding that all three teacher participants misinterpreted the PE criterion in a similar way was both unusual and professionally concerning.

The second key recommendation is that IBDP Biology teachers undergo specialist training in contemporary pedagogies that more closely align with the epistemological and constructivist principles of IBDP Biology programme. Although the IBO currently offers professional development (PD) for Group 4 IBDP teachers desiring to become IA workshop leaders and moderators, it does not offer pedagogical training. Schools therefore, may need to play a more central role in both advocating and encouraging PD in contemporary science pedagogies.

The third key recommendation is that schools should provide enriched professional support so that Group 4 IBDP teachers are better able to identify and resolve challenging issues especially prior to and during IA implementation. For example, schools could assist science teachers by appointing a school-based staff member with Group 4 IA expertise. Ideally, this 'Group 4 expert' would have up-to-date IBO recognised training and experience as a Group 4 IA moderator and/or IBO workshop leader. The Group 4 expert could establish an audit of pedagogical and assessment challenges identified by teachers. Additionally, the expert could facilitate connections with off-campus IB moderators to help teachers promptly and effectively resolve challenging issues within the curriculum. Additionally, a regional Group 4 expert could be appointed to a cluster of schools with small faculties. Group 4 experts could also organise targeted, sustained PD for teachers, particularly during assessment reform periods in order to enhance teacher self-efficacy when delivering new curriculum programmes.

Moreover, every effort should be made to ensure teachers can readily access help from Group 4 experts on an 'as needs' basis, preferably in a face-to-face or digital format. Although IBDP Biology online IA workshops are already available for teachers to engage with, IB conferences could be made accessible by Skype in real time or via webinars on the OCC website to encourage more teachers to keep abreast of curriculum innovations and common challenges. Additionally, Group 4 IA experts could establish a locally-based professional learning community (PLC) by holding regular meetings to address common assessment challenges, share best pedagogical practice, examine student learning and engage in informal internal moderation within pure science subjects. Sustained professional support through the establishment of regular PLC meetings for teachers may assist in raising the awareness of online resources (e.g. IB training programmes and social media networks) and encouraging collaborative working relationships within the Group 4 science teaching community.

The success associated with implementing these aforementioned recommendations would ultimately depend on school contexts and staff training needs. If successful, such approaches could minimise the extent to which misinterpretations about curriculum and assessment requirements filter through from the IBO to teachers and from teachers to students, thus maintaining the intended integrity of the curriculum reform.

### 5.4.2 Future Research

The present study focuses on IBDP Biology teachers in high socio-economic, Australian schools. Future research could, therefore, involve examining alternative geographic or socio-economic school contexts. Additionally, new research could also explore the perceptions and pedagogical strategies of teachers implementing the 2016 IA in IBDP Chemistry and Physics. The findings from studies involving IBDP Chemistry and Physics could help determine whether the issues highlighted in the present research resonate with other Group 4 IBDP science teachers.

This research utilised a qualitative, multiple case study approach with a small sample of teachers. Data was primarily collected from teachers' self-reports during a limited number of semi-structured interviews on two separate occasions.[16] Future research could, therefore, incorporate additional data collection instruments such as classroom observations by non-participant researchers and the analysis of students' formatively assessed IA practical reports. Classroom observations would enable researcher/s to verify first-hand, not only the pedagogical strategies teachers use, but also how they are implemented in an authentic school science setting. Research that explores the range of both planned and interactive pedagogical strategies could also be effectively undertaken during classroom observations.

Analysis of Biology students' formative IA reports may enable a deeper insight about the effectiveness of their teachers' formative feedback practices and help determine  the influence of various pedagogies upon student learning outcomes in practical report writing. Other studies could involve interviewing and observing teachers during key phases in implementing both formative and summative IA practical work. Such studies may highlight individual pedagogical and learning challenges associated with practical report writing.

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[16] Two of the teachers were interviewed twice, while the third teacher was interviewed on only one occasion after the implementation of the summative IA.

Future research could also explore the effectiveness of various PD modes with respect to teacher self-efficacy when implementing the 2016 IA for the first time. The present study revealed that IBO staff, such as PD workshop presenters and Group 4 moderators significantly influenced teacher self-efficacy before, during and immediately after IA implementation. Research investigating the perspectives of IB workshop staff concerning teacher self-efficacy in relation to the 2016 IA could also be explored. This latter research could provide baseline data to inform IBDP Group 4 workshop presenters when planning PD for science teachers.

Student perspectives in relation to developing an understanding of practical report writing skills in preparation for the summative IA were outside the scope of the present study. Consequently, student perceptions of the IA could be a beneficial area of future research. For example, several questions could be posed to gain a student-orientated perspective of practical report writing such as: What challenges do students face when writing IA practical reports? What pedagogical strategies implemented by teachers do students find most effective in developing an understanding of practical report writing? Answers to these questions may assist IBDP Group 4 teachers to improve student learning and achievement in IA practical reports.

# Appendices

## Appendix A: 2009 Internal Assessment (IA) Criteria (IBO, 2007, p. 23-24)

Internal assessment criteria

### Design

| Levels/marks | Aspect 1 | Aspect 2 | Aspect 3 |
|---|---|---|---|
| | Defining the problem and selecting variables | Controlling variables | Developing a method for collection of data |
| **Complete/2** | Formulates a focused problem/research question and identifies the relevant variables. | Designs a method for the effective control of the variables. | Develops a method that allows for the collection of sufficient relevant data. |
| **Partial/1** | Formulates a problem/ research question that is incomplete **or** identifies only some relevant variables. | Designs a method that makes some attempt to control the variables. | Develops a method that allows for the collection of insufficient relevant data. |
| **Not at all/0** | Does not identify a problem/research question **and** does not identify any relevant variables. | Designs a method that does not control the variables. | Develops a method that does not allow for any relevant data to be collected. |

### Data collection and processing

| Levels/marks | Aspect 1 | Aspect 2 | Aspect 3 |
|---|---|---|---|
| | Recording raw data | Processing raw data | Presenting processed data |
| **Complete/2** | Records appropriate quantitative and associated qualitative raw data, including units and uncertainties where relevant. | Processes the quantitative raw data correctly. | Presents processed data appropriately and, where relevant, includes errors and uncertainties. |
| **Partial/1** | Records appropriate quantitative and associated qualitative raw data, but with some mistakes or omissions. | Processes quantitative raw data, but with some mistakes and/or omissions. | Presents processed data appropriately, but with some mistakes and/or omissions. |
| **Not at all/0** | Does not record any appropriate quantitative raw data **or** raw data is incomprehensible. | No processing of quantitative raw data is carried out **or** major mistakes are made in processing. | Presents processed data inappropriately **or** incomprehensibly. |

## Conclusion and evaluation

| Levels/marks | Aspect 1 | Aspect 2 | Aspect 3 |
|---|---|---|---|
| | Concluding | Evaluating procedure(s) | Improving the investigation |
| **Complete/2** | States a conclusion, with justification, based on a reasonable interpretation of the data. | Evaluates weaknesses and limitations. | Suggests realistic improvements in respect of identified weaknesses and limitations. |
| **Partial/1** | States a conclusion based on a reasonable interpretation of the data. | Identifies some weaknesses and limitations, but the evaluation is weak or missing. | Suggests only superficial improvements. |
| **Not at all/0** | States no conclusion **or** the conclusion is based on an unreasonable interpretation of the data. | Identifies irrelevant weaknesses and limitations. | Suggests unrealistic improvements. |

## Manipulative skills (assessed summatively)

This criterion addresses objective 5.

| Levels/marks | Aspect 1 | Aspect 2 | Aspect 3 |
|---|---|---|---|
| | Following instructions* | Carrying out techniques | Working safely |
| **Complete/2** | Follows instructions accurately, adapting to new circumstances (seeking assistance when required). | Competent and methodical in the use of a range of techniques and equipment. | Pays attention to safety issues. |
| **Partial/1** | Follows instructions but requires assistance. | Usually competent and methodical in the use of a range of techniques and equipment. | Usually pays attention to safety issues. |
| **Not at all/0** | Rarely follows instructions **or** requires constant supervision. | Rarely competent and methodical in the use of a range of techniques and equipment. | Rarely pays attention to safety issues. |

*Instructions may be in a variety of forms: oral, written worksheets, diagrams, photographs, videos, flow charts, audio tapes, models, computer programs, and so on, and need not originate from the teacher.

See "The group 4 project" section for the personal skills criterion.

**Appendix B: 2016 Internal Assessment (IA) Criteria (IBO, 2014, p. 154-158)**



The tasks include the traditional hands-on practical investigations as in the previous course. The depth of treatment required for hands-on practical investigations is unchanged from the previous internal assessment and will be shown in detail in the teacher support materials. In addition, detailed assessment of specific aspects of hands-on practical work will be assessed in the written papers as detailed in the relevant topic(s) in the "Syllabus content" section of the guide.

The task will have the same assessment criteria for SL and HL. The five assessment criteria are personal engagement, exploration, analysis, evaluation and communication.

# Internal assessment details

## Internal assessment component

**Duration: 10 hours**
**Weighting: 20%**

- Individual investigation.
- This investigation covers assessment objectives 1, 2, 3 and 4.

## Internal assessment criteria

The new assessment model uses five criteria to assess the final report of the individual investigation with the following raw marks and weightings assigned:

| Personal engagement | Exploration | Analysis | Evaluation | Communication | Total |
|---|---|---|---|---|---|
| 2 (8%) | 6 (25%) | 6 (25%) | 6 (25%) | 4 (17%) | 24 (100%) |

Levels of performance are described using multiple indicators per level. In many cases the indicators occur together in a specific level, but not always. Also, not all indicators are always present. This means that a candidate can demonstrate performances that fit into different levels. To accommodate this, the IB assessment models use markbands and advise examiners and teachers to use a **best-fit approach** in deciding the appropriate mark for a particular criterion.

Teachers should read the guidance on using markbands shown above in the section called "Using assessment criteria for internal assessment" before starting to mark. It is also essential to be fully acquainted with the marking of the exemplars in the teacher support material. The precise meaning of the command terms used in the criteria can be found in the glossary of the subject guides.

### Personal engagement

This criterion assesses the extent to which the student engages with the exploration and makes it their own. Personal engagement may be recognized in different attributes and skills. These could include addressing personal interests or showing evidence of independent thinking, creativity or initiative in the designing, implementation or presentation of the investigation.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1 | **The evidence of personal engagement with the exploration is limited with little independent thinking, initiative or insight.**<br><br>The justification given for choosing the research question and/or the topic under investigation does not demonstrate **personal significance, interest or curiosity.**<br><br>There is little evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation. |
| 2 | **The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative or insight.**<br><br>The justification given for choosing the research question and/or the topic under investigation demonstrates **personal significance, interest or curiosity.**<br><br>There is evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation. |

### Exploration

This criterion assesses the extent to which the student establishes the scientific context for the work, states a clear and focused research question and uses concepts and techniques appropriate to the Diploma Programme level. Where appropriate, this criterion also assesses awareness of safety, environmental, and ethical considerations.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | The topic of the investigation is identified and a research question of some relevance is **stated but it is not focused**.<br><br>The background information provided for the investigation is **superficial** or of limited relevance and does not aid the understanding of the context of the investigation.<br><br>The methodology of the investigation is only appropriate to address the research question to a very limited extent since it takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br><br>The report shows evidence of limited awareness of the significant **safety,** ethical or environmental issues that are **relevant to the methodology of the investigation***. |
| 3–4 | The topic of the investigation is identified and a relevant but not fully focused research question is described.<br><br>The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation.<br><br>The methodology of the investigation is mainly appropriate to address the research question but has limitations since it takes into consideration only some of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br><br>The report shows evidence of some awareness of the significant **safety,** ethical or environmental issues that are **relevant to the methodology of the investigation***. |

| Mark | Descriptor |
|---|---|
| 5–6 | The topic of the investigation is identified and a relevant and fully focused research question is clearly described.<br>The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation.<br>The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br>The report shows evidence of full awareness of the significant **safety,** ethical or environmental issues that are **relevant to the methodology of the investigation***. |

* This indicator should only be applied when appropriate to the investigation. See exemplars in TSM.

### Analysis

This criterion assesses the extent to which the student's report provides evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | The report includes **insufficient relevant** raw data to support a valid conclusion to the research question.<br>Some **basic** data processing is carried out but is either too **inaccurate or too insufficient to lead to a valid** conclusion.<br>The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis.<br>The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete. |
| 3–4 | The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question.<br>Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing.<br>The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis.<br>The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced. |

| Mark | Descriptor |
|---|---|
| 5–6 | The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question.<br><br>Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data.<br><br>The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis.<br><br>The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced. |

### Evaluation

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | A conclusion is **outlined** which is not relevant to the research question or is not supported by the data presented.<br><br>The conclusion makes superficial comparison to the accepted scientific context.<br><br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **outlined** but are restricted to an **account** of **the practical** or **procedural issues** faced.<br><br>The student has **outlined** very few realistic and relevant suggestions for the improvement and extension of the investigation. |
| 3–4 | A conclusion is **described** which is relevant to the research question and supported by the data presented.<br><br>A conclusion is described which makes some relevant comparison to the accepted scientific context.<br><br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **described** and provide evidence of some awareness of the **methodological issues*** involved in establishing the conclusion.<br><br>The student has **described** some realistic and relevant suggestions for the improvement and extension of the investigation. |

| Mark | Descriptor |
|---|---|
| 5–6 | A detailed conclusion is **described and justified** which is entirely relevant to the research question and fully supported by the data presented.<br>A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context.<br>Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the **methodological issues*** involved in establishing the conclusion.<br>The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation. |

*See exemplars in TSM for clarification.

### Communication

This criterion assesses whether the investigation is presented and reported in a way that supports effective communication of the focus, process and outcomes.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | **The presentation of the investigation is unclear, making it difficult to understand the focus, process and outcomes.**<br>The report is not well structured and is unclear: the necessary information on focus, process and outcomes is missing or is presented in an incoherent or disorganized way.<br>The understanding of the focus, process and outcomes of the investigation is obscured by the presence of inappropriate or irrelevant information.<br>There are many errors in the use of subject-specific terminology and conventions*. |
| 3–4 | **The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes**.<br>The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way.<br>The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation.<br>The use of subject-specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding. |

*For example, incorrect/missing labelling of graphs, tables, images; use of units, decimal places. For issues of referencing and citations refer to the "Academic honesty" section.

## Appendix C: IB Learner Profile (IBO, 2017h)

| Attributes of an IB Learner | Description of Attributes |
|---|---|
| 1. Inquirers | We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life. |
| 2. Knowledgeable | We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance. |
| 3. Thinkers | We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned ethical decisions. |
| 4. Communicators | We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups. |
| 5. Principled | We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences. |
| 6. Open-Minded | We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience. |
| 7. Caring | We show empathy, compassion and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us. |
| 8. Risk-Takers | We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change. |
| 9. Balanced | We understand the importance of balancing different aspects of our lives – intellectual, physical and emotional- to achieve well-being for ourselves and others. We recognise our interdependence with other people and with the world in which we live. |
| 10. Reflective | We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development. |

## Appendix D: Sample Nature of Science Theme in 2016 IBDP Biology Syllabus (IBO, 2014, p. 49)

Biology guide

Core

# Topic 3: Genetics 15 hours

**Essential idea:** Every living organism inherits a blueprint for life from its parents.

| 3.1 Genes |
|---|
| **Nature of science:**<br>Developments in scientific research follow improvements in technology—gene sequencers are used for the sequencing of genes. (1.8) |

| | |
|---|---|
| **Understandings:**<br>• A gene is a heritable factor that consists of a length of DNA and influences a specific characteristic.<br>• A gene occupies a specific position on a chromosome.<br>• The various specific forms of a gene are alleles.<br>• Alleles differ from each other by one or only a few bases.<br>• New alleles are formed by mutation.<br>• The genome is the whole of the genetic information of an organism.<br>• The entire base sequence of human genes was sequenced in the Human Genome Project.<br>**Applications and skills:**<br>• Application: The causes of sickle cell anemia, including a base substitution mutation, a change to the base sequence of mRNA transcribed from it and a change to the sequence of a polypeptide in hemoglobin.<br>• Application: Comparison of the number of genes in humans with other species.<br>• Skill: Use of a database to determine differences in the base sequence of a gene in two species. | **International-mindedness:**<br>• Sequencing of the human genome shows that all humans share the vast majority of their base sequences but also that there are many single nucleotide polymorphisms that contribute to human diversity.<br>**Theory of knowledge:**<br>• There is a link between sickle cell anemia and prevalence of malaria. How can we know whether there is a causal link in such cases or simply a correlation?<br>**Aims:**<br>• **Aim 7:** The use of a database to compare DNA base sequences.<br>• **Aim 8:** Ethics of patenting human genes. |

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**Appendix E: 2016 Syllabus Guide SL and HL IBDP Biology (IBO, 2014, p. 25-28)**

Syllabus

# Syllabus content

| | Recommended teaching hours |
|---|---|
| **Core** | **95 hours** |
| **Topic 1: Cell biology** | **15** |
| 1.1 Introduction to cells | |
| 1.2 Ultrastructure of cells | |
| 1.3 Membrane structure | |
| 1.4 Membrane transport | |
| 1.5 The origin of cells | |
| 1.6 Cell division | |
| **Topic 2: Molecular biology** | **21** |
| 2.1 Molecules to metabolism | |
| 2.2 Water | |
| 2.3 Carbohydrates and lipids | |
| 2.4 Proteins | |
| 2.5 Enzymes | |
| 2.6 Structure of DNA and RNA | |
| 2.7 DNA replication, transcription and translation | |
| 2.8 Cell respiration | |
| 2.9 Photosynthesis | |
| **Topic 3: Genetics** | **15** |
| 3.1 Genes | |
| 3.2 Chromosomes | |
| 3.3 Meiosis | |
| 3.4 Inheritance | |
| 3.5 Genetic modification and biotechnology | |

| | Recommended teaching hours |
|---|---|
| **Topic 4: Ecology** | **12** |
| 4.1 Species, communities and ecosystems | |
| 4.2 Energy flow | |
| 4.3 Carbon cycling | |
| 4.4 Climate change | |
| **Topic 5: Evolution and biodiversity** | **12** |
| 5.1 Evidence for evolution | |
| 5.2 Natural selection | |
| 5.3 Classification of biodiversity | |
| 5.4 Cladistics | |
| **Topic 6: Human physiology** | **20** |
| 6.1 Digestion and absorption | |
| 6.2 The blood system | |
| 6.3 Defence against infectious disease | |
| 6.4 Gas exchange | |
| 6.5 Neurons and synapses | |
| 6.6 Hormones, homeostasis and reproduction | |
| **Additional higher level (AHL)** | **60 hours** |
| **Topic 7: Nucleic acids** | **9** |
| 7.1 DNA structure and replication | |
| 7.2 Transcription and gene expression | |
| 7.3 Translation | |
| **Topic 8: Metabolism, cell respiration and photosynthesis** | **14** |
| 8.1 Metabolism | |
| 8.2 Cell respiration | |
| 8.3 Photosynthesis | |
| **Topic 9: Plant biology** | **13** |
| 9.1 Transport in the xylem of plants | |
| 9.2 Transport in the phloem of plants | |

| | Recommended teaching hours |
|---|---|
| 9.3 Growth in plants | |
| 9.4 Reproduction in plants | |
| **Topic 10: Genetics and evolution** | **8** |
| 10.1 Meiosis | |
| 10.2 Inheritance | |
| 10.3 Gene pools and speciation | |
| **Topic 11: Animal physiology** | **16** |
| 11.1 Antibody production and vaccination | |
| 11.2 Movement | |
| 11.3 The kidney and osmoregulation | |
| 11.4 Sexual reproduction | |

## Options 15 hours (SL)/25 hours (HL)

### A: Neurobiology and behaviour

**Core topics**

A.1 Neural development

A.2 The human brain

A.3 Perception of stimuli

**Additional higher level topics**

A.4 Innate and learned behaviour

A.5 Neuropharmacology

A.6 Ethology

### B: Biotechnology and bioinformatics

**Core topics**

B.1 Microbiology: organisms in industry

B.2 Biotechnology in agriculture

B.3 Environmental protection

**Additional higher level topics**

B.4 Medicine

B.5 Bioinformatics

## C: Ecology and conservation

### Core topics

C.1 Species and communities

C.2 Communities and ecosystems

C.3 Impacts of humans on ecosystems

C.4 Conservation of biodiversity

### Additional higher level topics

C.5 Population ecology

C.6 Nitrogen and phosphorus cycles

## D: Human physiology

### Core topics

D.1 Human nutrition

D.2 Digestion

D.3 Functions of the liver

D.4 The heart

### Additional higher level topics

D.5 Hormones and metabolism

D.6 Transport of respiratory gases

**Appendix F: 2016 Group 4 Project Extract (IBO, 2014, p. 161)**

# The group 4 project

The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students from the different group 4 subjects analyse a common topic or problem. The exercise should be a collaborative experience where the emphasis is on the **processes** involved in, rather than the **products of, such an activity.**

**In most cases students in a school would** be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups containing representatives from each of the science subjects. Each group may investigate the same topic or different topics—that is, there may be several group 4 projects in the same school.

Students studying environmental systems and societies are not required to undertake the group 4 project.

## Summary of the group 4 project

The group 4 project is a collaborative activity where students from different group 4 subjects work together on a scientific or technological topic, allowing for concepts and perceptions from across the disciplines to be shared in line with aim 10—that is, to "develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge". The project can be practically or theoretically based. Collaboration between schools in different regions is encouraged.

The group 4 project allows students to appreciate the environmental, social and ethical implications of science and technology. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The choice of scientific or technological topic is open but the project should clearly address aims 7, 8 and 10 of the group 4 subject guides.

Ideally, the project should involve students collaborating with those from other group 4 subjects at all stages. To this end, it is not necessary for the topic chosen to have clearly identifiable separate subject components. However, for logistical reasons, some schools may prefer a separate subject "action" phase (see the following "Project stages" section).

## Project stages

The 10 hours allocated to the group 4 project, which are part of the teaching time set aside for developing the practical scheme of work, can be divided into three stages: planning, action and evaluation.

### Planning

This stage is crucial to the whole exercise and should last about two hours.

- The planning stage could consist of a single session, or two or three shorter ones.
- This stage must involve all group 4 students meeting to "brainstorm" and discuss the central topic, sharing ideas and information.

# Appendix G: Letters of Introduction to School Principals and Teachers

## a) School Principal


Dr Grace Skrzypiec
Lecturer

School of Education
GPO Box 2100
Adelaide SA 5001

Tel: +61 8 8201 5878
Fax: +61 8 8201 3184
Email: Grace.Skrzypiec@flinders.edu.au

CRICOS Provider No. 00114A


EMAIL LETTER OF INTRODUCTION – School Principal

Dear

This email is to introduce Mrs Jacqui Smoler who is a Masters student in the School of Education at Flinders University. She is undertaking research to address the following two questions:

1. What are IBDP Biology teacher perceptions of the 2016 IA protocol?

2. What pedagogical strategies are used by teachers to develop student understanding in preparing written laboratory reports?

She would be most grateful if you would agree to bring this research to the attention of the Science Faculty at your school and consent to the participation of teachers willing to assist in this project by consenting to a 45-60 minute interview and being observed in the classroom teaching on one occasion (early in Term 2) to provide extended responses that will assist in the achievement of the project objectives.

Attached to this email is an ***Information Sheet for Principals*** giving you further information regarding this study and a ***Consent form for Principals*** should your school wish to be involved. Additionally, I have attached the following documents for interested Biology teachers: ***Letter of Introduction for Teachers, Information Sheet for Teachers*** and two ***Consent forms for Teachers.*** Please be assured that any information collected will be treated in the strictest confidence and that no participant will be individually identifiable in the resulting report.

Any queries you may have concerning this project should be directed to me at the address given above or by telephone on (08) 8201 5878, by fax on (08) 8201 3184 or by email Grace.Skrzypiec@flinders.edu.au.

Thank you for giving this request due consideration.

Yours sincerely

Dr Grace Skrzypiec

BSc(Hons), Grad Dip Ed, Med, PhD, Assoc MAPS

Lecturer, School of Education

*This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project Number INSERT PROJECT No. here following approval). For more information regarding ethical approval of the project the Executive Officer of the Committee can be contacted by telephone on (08) 8201 3116, by fax on*

*(08) 8201 2035 or by email human.researchethics@flinders.edu.au*

## b) Teacher Participant

Dr Grace Skrzypiec
Lecturer

School of Education
GPO Box 2100
Adelaide SA 5001

Tel: +61 8 8201 5878
Fax: +61 8 8201 3184
Email: Grace.Skrzypiec@flinders.edu.au

CRICOS Provider No. 00114A

Flinders UNIVERSITY

# EMAIL LETTER OF INTRODUCTION – IBDP Biology Teachers

This email is to introduce Mrs Jacqui Smoler who is a Masters student in the School of Education at Flinders University. She is undertaking research to address the following two questions:

1. What are IBDP Biology teacher perceptions of the 2016 IA protocol?

2. What pedagogical strategies are used by teachers to develop student understanding in preparing written laboratory reports?

She would be most grateful if you would volunteer to assist in this project by consenting to a 45-60 minute interview and allow her to observe one of your Biology lessons (early in Term 2) to provide extended responses that will assist in the achievement of the project objectives.

Attached to this email is an ***Information Sheet for Teachers*** and a ***Consent form for Teachers*** giving you further information regarding this study. Please be assured that any information collected will be treated in the strictest confidence and that no participant will be individually identifiable in the resulting report. After the interview a second Consent form for Teachers will be sent to seek consent for the teacher transcript to be included in the research data.

Any queries you may have concerning this project should be directed to me at the address given above or by telephone on (08) 8201 5878, by fax on (08) 8201 3184 or by email Grace.Skrzypiec@flinders.edu.au.

Thank you for giving this request due consideration.

Yours sincerely

Dr Grace Skrzypiec

BSc(Hons), Grad Dip Ed, Med, PhD, Assoc MAPS

Lecturer, School of Education

*This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project Number INSERT PROJECT No. here following approval). For more information regarding ethical approval of the project the Executive Officer of the Committee can be contacted by telephone on (08) 8201 3116, by fax on*

*(08) 8201 2035 or by email human.researchethics@flinders.edu.au*

# Appendix H: Information Forms for School Principals and Teacher Participant

## a) School Principal

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**Mrs Jacqui Smoler**

School of Education

GPO Box 2100
Adelaide SA 5001

Tel: +61 8 201 2442
Fax: +61 8 8201 3184
Email: smol0016@flinders.edu.au
CRICOS Provider No. 00114A

**INFORMATION SHEET FOR PRINCIPALS**

**Title:** " The influence of IBDP Biology teacher perceptions of the 2016 internal assessment protocol on the pedagogy implemented in developing student skills and understanding in writing laboratory reports".

**Investigators:**
Mrs Jacqui Smoler
School of Education
Flinders University
Email: smol0016@flinders.edu.au
Ph: +61 8 201 2442

**Description of the study:**
This project will examine perceptions that teachers have concerning difficulties faced by students in successfully achieving the internal assessment criteria at the highest level. Additionally, it examines the teaching strategies that classroom teachers use to assist IBDP Biology students to develop their understanding of the rubric descriptors in the preparation of written practical reports which are submitted for assessment. This project is supported by Flinders University, School of Education.

**Purpose of the study:**
This project aims to examine the following questions:

1. What are IBDP Biology teachers' perceptions concerning the introduction of the new 2016 internal assessment protocol?

2. What pedagogical strategies are IBDP Biology teachers implementing to develop student understanding in order to increase student achievement of criteria within the internal assessment of written practical reports?

inspiring achievement

**What will the TEACHERS be asked to do?**
IBDP Biology teachers will be asked to volunteer to participate in a 45-60 minute interview. The interview will examine their perceptions about difficulties students face in achieving the internal assessment criteria within the assessment of written practical reports and the strategies used to develop student understanding to increase achievement of the criteria.

The interview will be audio-taped, using an electronic device and then personally transcribed into a written document by the researcher (Mrs Jacqui Smoler) which teachers will be able to check for accuracy upon completion of the process. Handwritten notes will be taken by the researcher during classroom observations.

**Where will the interviews and classroom observations take place?**
The teacher participant interviews will be conducted in the workplace of the teacher participant in a quiet room after school hours.

**What benefit will my school gain from being involved in this study?**
The sharing of your school's experiences will inform the planning and delivery of future IBDP Biology programs to your students as you will be able to access the outcomes of this project upon its completion.

**Will teachers be identifiable by being involved in this study?**
Names of teachers will not be published. Once the interviews have been transcribed the audio files will be destroyed. Any identifying information will be removed and the transcripts stored on a password protected computer that only the coordinator (Mrs Jacqui Smoler) will have access to. Any comments made will not be linked directly to participants.

**Is there any risk or discomfort to teachers involved in this study?**
The researcher anticipates few risks from your involvement in this study. If you have any concerns regarding anticipated or actual risks or discomforts, please raise them with the researcher.

**How do teachers agree to participate?**
Participation is voluntary. Teachers may refuse to answer any questions and are free to withdraw from the interview without effect or consequences.

**How do school Principal's consent to their teachers participating in the study?**
The *Letter of Introduction to Teachers* and the *Teacher Consent form* accompanying this information sheet are to be given to the Science Coordinator to disseminate to IBDP Biology teaching staff.

If your school agrees to the participation of your IBDP Biology teacher/s in this study, please read the *Principal's consent form* and sign in the appropriate place. **Please then send *one* scanned copy of this consent form to the researcher, (Mrs Jacqui**

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**Smoler) via the following email: smol0016@flinders.edu.au by no later than (date) or give to the researcher on the day of the interview before it commences.**

If the teacher agrees to participate in the *interview* he/she is to read and sign the *Teacher Consent form* provided in the appropriate places and give to the researcher (Mrs Jacqui Smoler) to also sign either in the form of a scanned copy to the following email: smol0016@flinders.edu.au prior to the interview day or on the day of the interview before it commences.

The researcher (Mrs Jacqui Smoler) will contact teacher participants a week after the forms have been sent to the schools to confirm the interview protocol and time. *Please note: Before the interview can take place the School Principal must have already signed the Principal's consent form.*

**How will teachers receive feedback?**
Outcomes from the project will be summarised and given to you by the researcher.

**Thank you for taking the time to read this information sheet and we hope that you will accept our invitation to be involved.**

## b) Teacher Participant

Flinders UNIVERSITY ADELAIDE • AUSTRALIA

**Mrs Jacqui Smoler**

School of Education
GPO Box 2100
Adelaide SA 5001
Tel: +61 8 201 2442
Fax: +61 8 8201 3184
Email: smol0016@flinders.edu.au
CRICOS Provider No. 00114A

**INFORMATION SHEET FOR TEACHER PARTICIPANTS**

**Title:** " The influence of IBDP Biology teacher perceptions of the 2016 internal assessment protocol on the pedagogy implemented in developing student skills and understanding in writing laboratory reports".

**Investigators:**
Mrs Jacqui Smoler
School of Education
Flinders University
Email:smol0016@flinders.edu.au
Ph: 0412 056 774

**Description of the study:**
This project will examine perceptions that teachers have concerning students' successfully achieving the internal assessment criteria at the highest level. Additionally, it examines the teaching strategies that classroom teachers use to assist IBDP Biology students to develop their understanding of the rubric descriptors in the preparation of written practical reports which are submitted for assessment. This project is supported by Flinders University, School of Education.

**Purpose of the study:**
This project aims to examine the following questions:

1. What are IBDP Biology teachers' perceptions concerning the introduction of the new 2016 internal assessment protocol?
2. What pedagogical strategies are IBDP Biology teachers implementing to develop student understanding in order to increase student achievement of criteria within the internal assessment of written practical reports?

inspiring achievement

**What will I be asked to do?**
IBDP Biology teachers will be asked to volunteer to participate in a 45-60 minute interview. The interview will examine teacher perceptions about difficulties students face in achieving the internal assessment criteria within the assessment of written practical reports and the strategies used to develop student understanding to increase achievement of the criteria.

The interview (only) will be audio-taped, using an electronic device and then personally transcribed into a written document by the researcher (Mrs Jacqui Smoler) which you will be able to check for accuracy upon completion of the process.

**Where will the interviews take place?**
The teacher participant interviews will be conducted in the workplace of the teacher participant in a quiet room after school hours.

**What benefit will I gain from being involved in this study?**
The sharing of your experiences will inform the planning and delivery of future IBDP Biology programs to your students as you will be able to access the outcomes of this project upon its completion.

**Will I be identifiable by being involved in this study?**
Names of teachers will not be published. Once the results of the interview have been transcribed the audio file will be destroyed. Any identifying information will be removed and the transcripts stored on a password protected computer that only the researcher (Mrs Jacqui Smoler) will have access to. Your comments will not be linked directly to you.

**Are there any risks or discomforts if I am involved?**
The researcher anticipates few risks from your involvement in this study. If you have any concerns regarding anticipated or actual risks or discomforts, please raise them with the researcher.

**How do I agree to participate?**
Participation is voluntary. You may refuse to answer any questions and you are free to withdraw from the interview without effect or consequences. A consent form accompanies this information sheet. If you agree to participate in the ***interview/classroom observations***, please read and sign the consent form provided in the appropriate places and give to the researcher (Mrs Jacqui Smoler) to also sign either in the form of a scanned copy to the following email: smol0016@flinders.edu.au prior to the interview day or on the day of the interview at **BEFORE** the interview commences.

The researcher (Mrs Jacqui Smoler) will contact teacher participants a week after the forms have been sent to the schools to confirm the interview protocol and time. *Please note: Before the interview/observation can take place the School Principal must have already signed the Principal's Consent form.*

**How will I receive feedback?**
Outcomes from the project will be summarised and given to you by the researcher.

## Appendix I: Consent Forms for School Principals and Teacher Participants

### a) School Principal

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**PRINCIPAL'S CONSENT FORM FOR TEACHER PARTICIPATION IN RESEARCH**

**(CONSENT FORM FOR TEACHER PARTICIPATION IN RESEARCH)**

**(by interview)**

I .............................................................................................................................
being over the age of 18 years hereby consent to participate as requested in the Letter of Introduction and Information Sheet for the research project on "What are IBDP Biology teacher perceptions of the 2016 IA protocol and what strategies are used by teachers to develop student understanding in preparing written laboratory reports?"

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I agree to audio recording of my information and participation.
4. I am aware that I should retain a copy of the Information Sheet for future reference.
5. I understand that:
   - I may not directly benefit from taking part in this research.
   - I am free to withdraw from the project at any time and am free to decline to answer particular questions.
   - While the information gained in this study will be published as explained, I will not be identified, and individual information will remain confidential.
   - I may ask that the recording/observation be stopped at any time, and that I may withdraw at any time from the session or the research without disadvantage.

**Participant's signature** (undertake interview )

**Date................**

6. I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

**Researcher's name: Jacqueline Smoler**

**Researcher's signature........................................Date.........................**

1 | Page

**SCHOOL PRINCIPALS NEED ONLY SIGN THIS FORM ONCE IN THE APPROPRIATE SECTION LISTED BELOW THIS LINE.**

As the Principal of (name of school), I consent to the IBDP Biology teacher/s approached by the researcher in this school to voluntarily participate in an interview process for the purposes of answering the aforementioned research question.

**Principal's signature..............................................Date............................**

2 | Page

## b) Teacher Participant

**CONSENT FORM 1 FOR TEACHER PARTICIPATION IN RESEARCH**
**(by interview)**

I ……………………………………………………………………………………………………………
being over the age of 18 years hereby consent to participate as requested in the Letter of Introduction and Information Sheet for the research project on "What are IBDP Biology teacher perceptions of the 2016 IA protocol and what strategies are used by teachers to develop student understanding in preparing written laboratory reports?"

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I agree to audio recording of my information and participation.
4. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.
5. I understand that:
   - I may not directly benefit from taking part in this research.
   - I am free to withdraw from the project at any time and am free to decline to answer particular questions.
   - While the information gained in this study will be published as explained, I will not be identified, and individual information will remain confidential.
   - I may ask that the recording/observation be stopped at any time, and that I may withdraw at any time from the session or the research without disadvantage.

**Participant's signature** (undertake interview)

**Date……………..**

6. I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

**Researcher's name: Jacqueline Smoler**

**Researcher's signature…………………………………Date…………………..**

1 | Page

**CONSENT FORM 2 FOR USE OF TEACHER INTERVIEW TRANSCRIPT DATA INCLUSION IN RESEARCH**

I ……………………………………………………………………………………………………
being over the age of 18 years hereby consent to participate as requested in the Letter of Introduction and Information Sheet for the research project on "What are IBDP Biology teacher perceptions of the 2016 IA protocol and what strategies are used by teachers to develop student understanding in preparing written laboratory reports?"

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I am aware that I should retain a copy of the Information Sheet for future reference.
4. I understand that:
   - I may not directly benefit from taking part in this research.
   - While the information gained in this study will be published as explained, I will not be identified, and individual information will remain confidential.

**Participant's signature** I, the participant whose signature appears below, have read a transcript of my participation and agree to its use by the researcher as explained.

**Participant's signature………………………………….Date…………………..**

5. I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and that she/he has had the opportunity to review the transcript data and make any necessary modifications to it.

**Researcher's name: Jacqueline Smoler**

**Researcher's signature…………………………………..Date……………………**

**Appendix J: Examples of Audit Trail Documents**

**Exemplar 1 – Extract of case memo**

## M1 Case – based memo June 14th 2016

I really wanted to meet M at her school this time and despite it being the middle of a busy Term 2 she agreed to meeting me at the school. M met me at the front office and ushered me through to her laboratory. After a brief chat with her lab assistants about upcoming practicals- I got the sense that this young teacher had the respect of her lab assistants we set up for the interview on the front lab bench.

## Theoretical/Conceptual Memo

This time I had prepared really specific questions to ask M, many of which related to her recent experience of running the new IA with her current year 12 class. Now was my chance to probe deeper into the actual experience of the new IA.

Question 1 Allocation of 10 hours time for IA

M explained that a two week block of lessons was set aside in which the students could perform their IA prac but it was not a realistic time frame for Biology as some of the experiments needed more time eg plant pracs and exercise prac. At least 2 lessons were spent brainstorming topics for the IA. Exemplars with moderators comments of new IA prac from the OCC were handed out to students who had a look at a really good one and a really bad one. M asked the students to look at the moderator's comments to see how they were marked in order to "get a feel for what they needed to produce". Part of the ten hours was used for research and asking advice of the teacher. A lot of the students did data collection outside of those ten hours. Plants for example had to be watered daily and the students that did exercises did prac in his own time, so the time each student spent on prac was variable. Some students found it really easy to come up with a topic of interest but others needed help in deciding what to do. Overall M was satisfied that the students had managed to find a decent spin on it for personal engagement. One student related his IA to his own garden at home and looking at efficiency of watering – M thought that was fine for IA. It

**Exemplar 2 – Member - Check Email (extract)**

Hi [redacted]

I hope the year has started well for you and that you had a nice relaxing summer break.

I am currently writing up the results and discussion of my thesis and was wondering if you could please answer a few questions, just briefly, that perhaps I should have asked earlier?

Qu 1. When you introduced the new criteria for the summative IA to the Year 11 students for the first time, did you show a Power Point or did you just have the rubric sheet up on an interactive whiteboard? How did you go through the criteria and explain them individually? Rubric sheet on electronic white board. I'd go through each briefly at the start. NEW IA

Qu 2. Can you reveal the range of marks in the IA's or the average score out of ~~20~~ 24%? Marks ranged from 14-24 NEW IA.

Qu 3. Once you marked the formative practicals in the new IA did you provide one on one feedback to some or all of the students? How did you provide the feedback eg one on one chat, whole class discussion, detailed written notes. Notes provided on each submission plus generalised class discussion NEW IA

Qu 4. When marking formative rough drafts did you indicate a mark on the rubric for each criterion as well as a written comment or just a comment only? Comment only NEW & OLD IA.

Qu 5 How did you deal with the students who were struggling with formative IA's in new course and summative IA's in old course? How did you change your teaching to accommodate this? Personalise my approach depending on the student and how they best learnt. NEW IA

Qu 6 How did you assist students who were not putting in enough detailed effort? How did you change your teaching to accommodate this? Gave exemplars and highlighted what was required/missing. OLD IA & NEW IA

Qu7 Did you go to the same trouble of making up or finding checklists to scaffold the student's work in the Old IA as you did in the new IA? If so, why? If not, why? Yes I used scaffolds as this helps students to focus on particular sections. OLD IA

## Exemplar 3 – NVivo: Nodes for Interviews Extract

Nodes

| Name | Sources | References | Created On | Created By | Modified On | Modified By |
|---|---|---|---|---|---|---|
| Accessing Formal and Informal IA Training for IBDP Biology teachers | 5 | 141 | 6/09/2016 8:33 PM | JDS | 8/11/2016 10:21 PM | JDS |
| Collborating with and mentoring by peers in school | 5 | 53 | 15/08/2016 8:50 PM | JDS | 31/08/2016 10:15 PM | JDS |
| Moderating issues | 4 | 36 | 15/08/2016 9:27 PM | JDS | 31/08/2016 10:15 PM | JDS |
| Training issues and the IBO | 5 | 52 | 15/08/2016 9:55 PM | JDS | 31/08/2016 10:15 PM | JDS |
| Affect and Environment | 5 | 96 | 6/09/2016 8:25 PM | JDS | 6/09/2016 8:42 PM | JDS |
| Assessing the strengths and weaknesses of old and new IA protocols in IBDP Biology | 5 | 198 | 6/09/2016 8:36 PM | JDS | 8/11/2016 10:23 PM | JDS |
| Challenging issues and recommendations involved in coping with change in IA | 5 | 97 | 6/09/2016 8:35 PM | JDS | 8/11/2016 10:20 PM | JDS |
| Concerning issues in interpreting criteria and marking with IA rubrics | 5 | 72 | 6/09/2016 8:39 PM | JDS | 8/11/2016 10:29 PM | JDS |
| Creating, locating and providing resources for IA teaching and learning | 5 | 129 | 6/09/2016 8:40 PM | JDS | 8/11/2016 10:10 PM | JDS |
| demonstrating genuine personal engagment in topic | 1 | 1 | 31/08/2016 11:39 AM | JDS | 31/08/2016 10:15 PM | JDS |
| Formatively assessing and providing feedback to students | 0 | 0 | 8/11/2016 10:14 PM | JDS | 8/11/2016 10:14 PM | JDS |
| Perceiving teacher self efficicacy in implementation of 2016 IA | 5 | 91 | 6/09/2016 8:38 PM | JDS | 8/11/2016 10:25 PM | JDS |
| Scaffolding techiques | 5 | 86 | 8/08/2016 8:29 PM | JDS | 6/09/2016 8:26 PM | JDS |
| Teaching strategies | 5 | 588 | 13/08/2016 8:05 PM | JDS | 8/11/2016 10:25 PM | JDS |
| understanding of PE guided by interest and depth of research | 1 | 1 | 31/08/2016 12:26 PM | JDS | 31/08/2016 10:15 PM | JDS |

**Exemplar 4 – Sorting of Nvivo Nodes for Interviews Extract**

Aug 8th
5-10pm

## Nodes for Interviews 1A, 2A and 3A

Teaching strengths
Teaching weaknesses
Teaching Resources for Practicals
Doing various practicals formatively in Year 11
Doing all three criteria in same IA prac
Planning for students to practise write-ups of different section in Year 11 new IA
Outlining teacher expectations of each IA section
Explaining what students must be able to think about when preparing prac report
Explaining pedagogy for doing formative prac on Exploration
Explaining pedagogy for doing formative prac on Analysis
Suggesting method for qualitative observations
Teaching approach for practical work
Recommending appropriate support material for students IA
Creating own resources for students
Explaining the focus of formative prac in old IA
Pre reading pedagogy approach
Discussing explicitly requirements of each section of prac
Suggesting design pracs focus related to equipment availability
Introducing expectations and terminology of IA in Year 11
Focusing on specific sections of prac using different pracs in year 11
Providing access to prac in advance for pre reading
Discussing prac with class in advance
Reviewing prac on day before doing
Giving fairly prescriptive pracs in early stages of course
Giving less prescriptive pracs as Year 11 progresses
Referring back to prac once done with explicit expectations of sections
Using class time post prac for students to ask questions about mark allocation to sections
Discussing commonalities in errors & misunderstandings
Doing 3 to 5 pracs a term based on time
Doing one prac per term detailing one particular section
Practising skills and understanding by writing up one section in details per term
Providing regular prac opportunities to build understanding in design
Doing design pracs later in Year 11 old IA
Experiencing designing pracs earlier in year through discussion not always writing
Grouping students in pairs or small groups to discuss and plan design pracs
Discussing design prac early Year 12
Timing design prac in mid term 1 Year 12 old IA
Introducing idea of design pracs to students
Discussing design prac regularly in early Term 12
Encouraging students to approach teacher with question to base design prac
Disallowing double ups of research questions
Suggesting not to do particular pracs
Setting deadlines for submission of research questions
Approving research question
Submission of equipment list and risk assessment
Collating equipment lists for lab tech
Practising formative pracs in Year 11

# Appendix K: Exemplar Interview Protocol

**Interview Protocol: IBDP Biology Teacher**

| | |
|---|---|
| **Time of Interview:** | |
| **Date:** | |
| **Place:** | |
| **Interviewer:** | Ms Jacqui Smoler |
| **Participant Pseudonym:** | |
| **Position of Participant:** | |
| **Project Description:** | The purpose of my study is to investigate the experiences of International Baccalaureate Diploma Program (IBDP) Biology teachers by:<br>1. exploring their perceptions of the new 2016 IA protocol.<br>2. describing the pedagogical strategies they implement to facilitate student understanding in undertaking practical report writing for the purposes of the internal assessment (IA) component of the curriculum with consideration of both the 2009 and 2016 IA protocols. |
| | |
| **Question Number** | **Question** |
| **1** | 1. What do/did you find interesting:<br>a) about the old 2009 version (worth 24%) of the internal assessment (IA) component of IBDP Biology?<br>b) about the new 2016 version (worth 20%)of the IBDP Biology curriculum from the perspective of practical work, which eventually leads to the final production of a major ten hour investigation in Year 12? |
| **2** | Describe in as much detail as possible the pedagogical strategies you have used in a typical lesson (**Year 11 or 12 IBDP Biology? – old 2009 course**) involving explicit instruction of practical report writing skills necessary to promote successful student achievement in each of the following assessment criteria for the internal assessment component:<br>a) Design<br>• Defining problem and selecting variables<br>• Controlling variables<br>• Developing a method for data collection<br>b) Data Collection and Processing<br>• Recording raw data<br>• Processing raw data<br>• Presenting processed data |

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| | c) Conclusion and Evaluation<br>• Concluding<br>• Evaluating procedure<br>• Improving the investigation |
| **3** | What PD have you undertaken for teaching:<br>a) the old 2009 IBDP Biology IA and how has this training helped you to develop student skills in producing successful outcomes in IBDP Biology practical reports?<br>b) the new 2016 IBDP Biology and how has this professional development training helped you to develop student skills in producing successful outcomes in writing formatively assessed Year 11 IBDP Biology practical reports? |
| **4** | How have you managed situations in which a student is consistently underachieving in each of the assessment criteria in the production of IBDP Biology practical reports?<br>a) Design<br>• Defining problem and selecting variables<br>• Controlling variables<br>• Developing a method for data collection<br>b) Data Collection and Processing<br>• Recording raw data<br>• Processing raw data<br>• Presenting processed data<br>c) Conclusion and Evaluation<br>• Concluding<br>• Evaluating procedure<br>• Improving the investigation<br>d) New Year 11 Course |
| **5** | Explain what you think your strengths and weaknesses are in facilitating student practical report writing skills amongst your students in IBDP Biology in<br>a) Year 11? (old course)<br>b) Year 11? (new course)<br>c) Year 12? (old course)<br>d) Year 12? (new course) i.e. predictions for next year? |
| **6** | Describe any challenges/concerns you face/have faced in facilitating student practical report writing skills in a) Year 11 and b) Year 12 IBDP Biology?<br>a)Year 11 (old course)<br>b) Year 11 (new course)<br>c) Year 12 (old course) |

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| **7** | **A new 2016 IA protocol** has been introduced to Year 11 IBDP Biology students this year and will be fully introduced to Year 12 students in 2016. Do you think the introduction of the new protocol has affected the pedagogical strategies that you currently use/have used, to prepare students for successful achievement of the 5 new IA criteria in the Individual Investigation in Year 12?<br><br>If so, could you explain how you have fostered or could foster the development of each of the following five criteria in terms of the students' understandings and skills in preparation for successful achievement in:<br>**a) Personal Engagement**<br>• Significant independent thinking, initiative or insight<br>• Personal significance, interest and curiosity<br>• Personal input and initiative in design, implementation and presentation of investigation.<br><br>**b) Exploration**<br>• Ability to identify a relevant and fully focused research question which is clearly described.<br>• Provide entirely appropriate and relevant background information<br>• Develop highly appropriate methodology which considers, relevance, reliability and sufficiency of collected data.<br>• Develop full awareness of safety, ethical or environmental issues relevant to the methodology of investigation.<br><br>**c) Analysis**<br>• Inclusion of sufficient relevant quantitative and qualitative raw data to support detailed and valid conclusion.<br>• Appropriate, accurate and sufficient data processing<br>• Ability to fully and appropriately consider impact of measurement uncertainty on analysis of data.<br>• Ability to correctly interpret processed data to reach valid and detailed conclusion.<br><br>**d) Evaluation**<br>• Ability to provide a detailed conclusion that is described and justified by considering:<br>1. relevance to research question and fully supported by data<br>2. relevance to accepted scientific context<br>3. considers strengths and weaknesses (such as limitations and sources of error) and provides clear evidence of methodological issues involved<br>4. understanding of realistic and relevant suggestions for improvement and extension of investigation.<br><br>**e) Communication**<br>• Ability to write a well structured and clear report which coherently outlines the focus, process and outcomes of the investigation.<br>• Ability to write a relevant report which is concise and facilitates ready understanding of the focus, process and outcomes of the investigation.<br>• Ability to use subject-specific terminology and conventions in appropriate and correct manner. |

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| **8** | Discuss your understandings of your current IBDP Biology students at this point, in terms of their success in practical report writing skills for formative assessment? For example, are there certain attributes and skills that have been easier than others for the students to achieve? If so, what are they? |
| **9** | Could you provide your opinions on the five 2016 IA criteria and the nature of the associated rubric descriptors, used to assess the summative Individual Investigation compared with those criteria and descriptors used in the 2009 IA? Do you have any worries, concerns? Do you think the new protocol is an improvement on the old? If so, in what ways? |

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## Appendix L: Extract of Assessed Formative Practical Report Work Sample - Morgan

EXPLORATION

This criterion assesses the extent to which the student establishes the scientific context for the work, states a clear and focused research question and uses concepts and techniques appropriate to the DP level. Where appropriate, this criterion also assesses awareness of safety, environmental, and ethical considerations.

| Mark | Descriptor |
|---|---|
| 0 | The student's report does not reach a standard described by the descriptors below. |
| 1–2 | The topic of the investigation is identified and a research question of some relevance is stated but it is not focused.<br><br>The background information provided for the investigation is superficial or of limited relevance and does not aid the understanding of the context of the investigation.<br><br>The methodology of the investigation is only appropriate to address the research question to a very limited extent since it takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br>*Method will not allow collection of any relevant data.*<br>The report shows evidence of limited awareness of the significant safety, ethical or environmental issues that arerelevant to the methodology of the investigation*.<br>*Bacterial safety?* |
| 3–4 | The topic of the investigation is identified and a relevant but not fully focused research question is described.<br><br>The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation.<br><br>The methodology of the investigation is mainly appropriate to address the research question but has limitations since it takes into consideration only some of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br><br>The report shows evidence of some awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation*. |
| 5–6 | The topic of the investigation is identified and a relevant and fully focused research question is clearly described.<br><br>The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation.<br><br>The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.<br><br>The report shows evidence of full awareness of the significant safety, ethical or environmental issues that arerelevant to the methodology of the investigation*. |

* This indicator should only be applied when appropriate to the investigation. See exemplars in TSM.

## Appendix M: Moderator Informed Checklist – Andrew

IBDP Sciences Internal Investigation Headings and Guidance

Research Question

□ The introduction includes an observation that leads to the research question
□ A descriptive yet concise title is given
□ A grammatically correct question about a precise relationship is asked
□ A sufficiently detailed question to stand alone and be self-explanatory is asked
□ A specific measurable dependent variable is included
□ A specific independent variable to be manipulated is included
□ Precise locations, measurements and *Genus species* names are given

Background Information

□ Thinking, initiative or insight for investigating chosen topic is given
□ Justification indicates personal interest, significance or curiosity for chosen design & presentation is given
□ All information is clearly supported with references
□ At least 3 appropriate sources with authors have been used
□ Both Internet and print sources are included
□ There is no plagiarism (this will give a zero)

Hypothesis

□ A grammatically correct answer to the research question is given
□ The hypothesis can be supported through scientific research and reasoning
□ A precise relationship between the independent and dependent variables is predicted
□ The independent and dependent variables are written exactly the same as in the question
□ The hypothesis is given as a scientifically reasonable answer to the research question
□ The hypothesis is clearly justified and supported through a review of scientific literature

Variables

□ All key variables relevant to the experiment are investigated
□ Subheadings of Independent Variable, Dependent Variable and Controlled Variables are given
□ Independent and dependent variables are written exactly the same as in the question
□ A very brief description of how the independent variable is modified is given
□ A very brief description of how the dependent variable is measured is given
□ Controlled variables include all significant variables that could affect the dependent variable
□ A very brief description of why each controlled variable must be kept constant is given

Apparatus

□ [List all equipment used] [include all items, quantities, concentrations, volumes, masses etc., for measuring equipment uncertainties]

Method- manipulation and control of variables

□ An introduction establishes the methodology as a fair test of the hypothesis
□ The modification of procedures from other sources are clearly referenced in APA format
□ All materials are clearly listed with details (type, amount, size, volume, concentration...)
□ Diagrams and/or photographs clearly showing the setup of apparatus is included
□ Diagrams and photographs are referenced using APA or (Drawing/Photograph by Author)
□ What was done and an explanation of why is given for each step
□ How the independent variable was manipulated is clearly described
□ How the listed controlled variables were kept controlled in the experiment is described
□ The use and method of random sampling is described where relevant
□ Comment on possible hazards, environmental, ethical and social impacts of the work, and say how they will dealt with to minimise the impact]

Method- choice of data processing and presentation

□ The introduction establishes the data collected is valid for answering the research question
□ The reliability of the methodology is established through sufficient repetition
□ How the dependent variabl e measurements were taken is precisely explained
□ The number of dependent variable measurements and why this amount is described
□ The size of the increments between each data point and why this was acceptable is described
□ The use of at least 5 repeats to calculate standard deviation for error analysis is explained
□ The inclusion of a sample size of at least 10 is described when the T-test was used
□ The collection of data from any other students or sources is clearly explained and referenced

Data Collection and Analysis: Processing Data (raw including qualitative data and processed data tables)

□ A short introduction is given to establish what data was collected and why it is appropriate
□ Appropriate raw quantitative data is recorded in a clearly designed and drawn table
□ A descriptive title with the variables is given for the data table
□ Column headings include the quantity, units and uncertainties
□ Data is recorded to an appropriate degree of precision and consistent with uncertainties
□ How the uncertainties were determined for measurements is stated below the data table
□ Each data table has a short paragraph establishing its relevance
□ Qualitative data is recorded in the data table or separately as appropriate
□ A short introduction of how the data was processed is given
□ The relevance of this data processing to answer the research question is given
□ Calculations are carried out correctly and allow construction of an appropriate graph
□ Calculations are included in a table of calculations when appropriate
□ Data table from collection is copied and pasted and modified to include calculations
□ Sample calculations are demonstrated for the reader
□ Uncertainties are calculated and explained if necessary

Data Analysis: presenting and describing data (graphs and description of trends)

□ The dependent variable is appropriately graphed against the independent variable
□ Graphs include descriptive titles of the variables and axis are labeled including units
□ Error bars showing the uncertainties are included on the graph for individual data points
□ How uncertainties were determined is stated below the graph and explained if not included
□ Maximum and minimum lines of best fit are drawn if appropriate
□ Each graph has a paragraph discussing the relationship(s) and trends shown – no conclusion

Conclusion

□ An introduction is given (see the 8 step conclusion)
□ A conclusion is clearly stated "In conclusion..."
□ The conclusion given is correct and clearly supported by the interpretation of the data
□ Key data from the analysis is given and trends in the data are discussed
□ The extent to which the hypothesis is supported by the data is explained
□ The variation in results is reported, showing the strength of the conclusion
□ Scientific reasoning is used to show the validity of the relationship
□ How far the conclusion can be generalized is discussed

Evaluation

**Evaluation**
□ The appropriateness of the apparatus in obtaining relevant data is commented on
□ Weaknesses in the methodology are discussed
□ The reliability of the data is commented on
□ The quantity of the data is commented on
□ The precision and accuracy of the data is commented on
□ Outlier data or irregularities in the data are addressed
□ The significance of uncertainties in the trend line is determined

**Suggested Improvements**
□ Where limitations are determined to be significant, specific improvements are proposed
□ Improvements effectively address the limitations (not just to be more careful)
□ Improvements are given which are possible within the context of a school laboratory

**Further Research Questions**
□ At least 2 further research questions are stated with clear independent and dependent variables
□ The research questions are an extension from the conclusion and evaluation
□ A short explanation for ea ch question is given to establish its importance and relevance

References

□ Parenthetical in-text references/citations are given in APA format
□ A Works Cited List with APA formatting is given at the end of the report
□ Sources are written in alphabetical order by author's last name
□ Each source is listed with a hanging indent

Overall Guidance for the Internal Assessment
**Overall Presentation**
□ No spelling or grammar errors are present
□ There are clear headings for each section, with consistent formatting
□ All tables and diagrams have a title and brief description with APA referencing if required.
□ Arial or Times New Roma n font size 12 font is used

**Methodology**
□ A well-organized method ology written in past tense with good paragraph/numbered structure

# References

ACARA. (2012). *Biology Rationale Aims*. Retrieved February 8, 2016, from Australian Curriculum: https://www.australiancurriculum.edu.au/senior-secondary-curriculum/science/biology/rationaleaims/

Allen, C. D., & Penuel, W. R. (2015). Studying teachers' sensemaking to investigate teachers' responses to professional development focused on new standards. *Journal of Teacher Education, 66*(2), 136-149. doi:10.177/00224871145606-46

Alpmen, A. (2016). Affective variables as predictors of biology achievement: A study on 11th grade students. *SHS Web of Conferences*, *26*, p. 01032. doi:http://dx.doi.org/10.1051/shsconf/20162601032

Armstrong, N. A., Wallace, C. S., & Chang, S. (2008). Learning in writing in college biology. *Research in Science Education, 38*, 483-499. doi:10.1007/s11165-007-9062-9

Ary, D., Cheser Jacobs, L., Razevich, A., & Sorensen, C. (2010). *Introduction to research in education* (9th ed.). Belmont, CA: Wadsworth Cengage Learning.

Ausbusson, P., Panizzon, D., & Corrigan, D. (2016). Science education futures: "Great potential. Could do better: Needs to try harder". *Research in Science Education, 46*(2), 203-221. doi:10.1007/s1165-016-9521-2

Ausubel, D. P. (1963). Some psychological considerations in the objectives and design of an elementary-school science program. *Science Education, 47*(3), 278-284. doi:10.1002/sce.3730470314

Bagnall, N. (2005). The International Baccalaureate in Australia and New Zealand in the 21st century. *Change: Transformations in education, 8*(1), 110-123.

Baird, J. R., & White, R. T. (1996). Metacognitive strategies in the classroom. In D. F. Treagust, R. Duit, & B. J. Fraser, *Improving teaching and learning in science* (pp. 190-200). New York: Teachers College Press.

Baker, W. P., Barstack, R., Clark, D., Hull, E., Goodman, B., Kook, J., . . . Lang, M. (2008). Writing-to-learn in the inquiry-science classroom: Effective strategies from middle school science and writing teachers. *Clearing House: A Journal of Educational Strategies, Issues and Ideas, 81*(3), 105-108.

Balgopal, M., & Wallace, A. (2013, March). Writing-to-learn, writing-to-communicate and scientific literacy. *The American Biology Teacher, 75*(3), 170-174. doi:10.1525/abt2013.75.3.5

Bandura, A. (1997). *Self-Efficacy: The exercise of control.* New York: Freeman.

Bennett, C. (2016). Assessment rubrics. *Learning and Teaching, 9*(1), 50-72. doi:10.3167/latiss.2016.090104

Bereiter, C., & Scardamalia, M. (1987). *The psychology of written composition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education, 96*(1), 26-55. doi:10.1002/sce.20286

Biology Education Research Group. (2014). How important is the assessment of practical work? An opinion piece on the new biology A-level from BERG. *Journal of Biological Education, 48*(47), 176-178. doi:10.1080/00219266.2014.956483

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy and Practice, 5*(1), 7-74. doi:10.1080/0969595980050102

Black, P., Harrison, C., Lee, C., Marshall, B., & Wiliam, D. (2004). Working inside the black box: Assessment for learning in the classroom. *Phi Delta Kappan, 86*(1), 8-21. doi:10.1177/003172170408600105

Blonder, R., Benny, N., & Gail Jones, M. (2014). Teaching self-efficacy of science teachers. In R. Evans, J. Luft, & C. Czerniak (Eds.), *The role of science teachers' beliefs in international classrooms* (pp. 3-15). Rotterdam: Sense.

Bloor, D. (1991). *Knowledge and Imagery* (2nd ed.). Chicago, IL: University of Chicago Press.

Bol, L., Stephenson, P. L., O' Connell, A. A., & Nunnery, J. A. (1998). Influence of experience, grade level, and subject area on teachers' assessments practices. *The Journal of Educational Research, 91*(6), 323-330.

Braaten, M., & Windschitl, M. (2011). Working toward a stronger conceptualization of scientific explanation for science education. *Science Education, 95*(4), 639-669. doi:10.1002/sce.20449

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school. *Journal of Research in Science Teaching, 43*(5), 485-499. doi:10.1002/tea.20131

Bruce, C. D., & Ross, J. A. (2008). A model for increasing reform implementation and teacher. *Canadian Journal of Education, 31*(2), 346-370.

Bruner, J. S. (1990). *Acts of meaning.* Cambridge, MA: Harvard University Press.

Bruner, J. S. (1998). What is a narrative fact? *The Annals of the Americal Academy of Political and Social Science, 560*, 17-27.

Burton, E. P., & Frazier, W. M. (2012). Voices from the front lines: Exemplarly science teachers on education reform. *School Science and Mathematics, 112*(3), 179-190. doi:10.1111/j.1949-8594.2011.00131.x

Butler, R. (1987). Task-involving and ego-involving properties of evaluation: Effects of different feedback conditions on motivational perceptions, interest and performance. *Journal of Educational Psychology, 79*(4), 474-482.

Bybee, R. W., Taylor, J. A., Gardner, A., van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. Colorado Springs CO: BSCS.

Cantrell, P., Young, S., & Moore, A. (2003). Factors affecting science teaching self-efficacy of preservice elementary teachers. *Journal of Science Teaching Education, 14*(3), 177-192. doi:10.1023/A:1025974417256

Cavagnetto, A. R. (2010). Argument to foster scientific literacy: A review of argument interventions in K-12 science contexts. *Review of Educational Research, 80*(3), 336-371. doi:10.3/102/0034654310376953

Cavagnetto, A. R., & Hand, B. (2012). The importance of embedding argument within science classrooms. In M. S. Khine, *Perspectives on scientific argumentation* (pp. 39-53). Springer Science and Business Media. doi:10.1007/978-94-007-2470-9-3

Cavagnetto, A. R., Hand, B., & Norton-Meier, L. (2011). Negotiating the inquiry question: A comparison of whole class and small group strategies in grade five science classrooms. *Research in Science Education, 41*, 193-209. doi:10.1007/s11165-009-9152-y

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis.* London: SAGE Publications Ltd.

Choi, A., Hand, B., & Greenbowe, T. (2012). Students' written arguments in genral chemistry laboratory investigations. *Research in Science Education, 43*(5). doi:10.1080/09500693.2011.628344

Clark, I. (2010). Formative assessment: 'There is nothing so practical as a good theory'. *Australian Journal of Education, 54*(3), 341-352. doi:10.1177/000494411005400308

Cohen, D. K., & Hill, H. C. (n.d.). State policy and classroom performance.

Conner , L. N. (2007). Cueing metacognition to improve researching and essay writing in a final year high school biology class. *Research in Science Education*, 1-16. doi:10.1007/s11165-004-3952-x

Conner, L. N. (2014). Students' use of evaluative constructivism: comparative degrees of intentional learning. *International Journal of Qualitative Studies in Education, 27*(4), 472-489. doi:10.1080/09518398.2013.771228

Corbin , J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: SAGE.

Cowie, B., & Bell, B. (1999). A model of formative assessment in science education. *Assessment in Education: Principles, policy and practice, 6*(1), 101-116. doi:10.1080/09695949993026

Creswell, J. W. (2013). *Qualiative Inquiry and Research Design: Choosing Among Five Approaches* (3rd ed.). Thousand Oaks, CA: SAGE.

Cronin-Jones, L. L. (1991). Science teachers and their beliefs on science curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*(3), 235-250. doi:10.1002/tea.3660280305

Cronje, R., Murray, K., Rohlinger, S., & Wellnitz, T. (2013). Using the science writing heuristic to improve undergraduate writing in biology. *International Journal of Science Education, 35*(16), 2718-2731. doi:10.1080/09500693.2011.628344

Crotwell Timmerman, B. E., Strickland, D. C., Johnson, R. L., & Payne, J. R. (2011). Development of a 'universal'rubric for scientific reasoning skills using scientific writing. *Assessment and Evaluation in Higher Education, 36*(5), 509-547. doi:10.1080/0202930903540991

Dangremond Stanton, J., Neider, X. N., Gallegos, I. J., & Clark, N. C. (2015). Differences in metacognitive regulation in introductory biology students: When prompts are not enough. *CBE - Life Sciences Education, 14*, 1-12. doi:10.1187/cbe.14-08-0135

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers' face. *Review of Educational Research, 76*(4), 607-651. doi:10.3102/00346543076004607

Dawson, C. (2007). Prescriptions and proscriptions. The three Ps of scientific writing - past, passive and personal. *Teaching Science, 53*(2), 36-39. Retrieved from Retrieved from https://search-proquest-com.ezproxy.flinders.edu.au/docview/207218732?accountid=10910

Deiner, L. J., Newsome, D., & Samaroo, D. (2012). Directed self-inquiry: A scaffold for teaching laboratory report writing. *Journal of Chemical Education, 89*, 1511-1514. doi:10.102/ed300169g

Denzin, N. K., & Lincoln, Y. S. (2000). *Handbook of Qualitative Research.* Thousand Oaks: SAGE.

Denzin, N. K., & Lincoln, Y. S. (2005). *The SAGE handbook of qualitative research* (Vol. 2nd). Thousand Oaks, California: SAGE.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better concpetualisations and measures. *Educational Researcher, 38*(3), 181-199. doi:10.3102/0013189X08331140

Dogan, S., Pringle, R., & Mesa, J. (2015). The impact of professional learning communities on science teachers' knowledge, practice and student learning: A review. *Professional Development in Education, 42*(4), 569-588. doi:10.1080/19415257.2015.1065899

Doherty, C., Mu, L., & Shield, P. (2009). Planning mobile futures: The border artistry of International Baccalaureate Diploma choosers. *British Journal of Sociology of Education, 30*(6), 757-771. doi:10.1080/041256909903235292

Doppelt, Y., Schunn, C. D., Silk, E. M., Mehalik, M. M., Reynolds, B., & Ward, E. (2009). Evaluating the impact of a facilitated learning community approach to professional development on teacher practice and student achievement. *Research in Science and Technological Education, 27*(3), 339-354. doi:10.1080/02635140903166026

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12. doi:10.3102/0013189X023007005

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287-312. doi:10.1002/(SICI)1098-237X(200005)84:3<287::AID-SCE1>3.0.CO;2-A

Duncan-Howell, J. (2010). Teachers making connections: Online communities as a source of professional learning. *British Journal of Educational Technology, 41*(2), 324-340. doi:10.1111/j.1467-8535.2009.00953.x

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic and social learning goals. *Review of Research in Education, 32*, 268-286. doi:10.3102/0091732X07309371

Duschl, R. A., Shouse, A. W., & Schweingruber, H. A. (2008). What research says about K-8 science learning and teaching. *The Education Digest, 73*(8), 46-50. Retrieved from Retrieved from https://search-proquest-com.ezproxy.flinders.edu.au/docview/218190975?accountid=10910

Ebert, E. K., & Crippen, K. J. (2010). Applying a cognitive-affective model for conceptual change to professional development. *Journal of Science Teacher Education, 21*(8), 371-388. doi:10.1007/s10972-009-9183-2

Ennis, R. H. (1989). Critical thinking and subject specificity: Clarification and needed research. *Educational Researcher, 18*(3), 4-10. doi:10.3102/0013189X018003004

EQI, Education Queensland International. (2017, August 6th). *Queensland academies: Bright minds bright futures.* Retrieved 2017, from https://qa.eq.edu.au/international/

Feldhusen, J. F., & Poelzer, H. G. (1996). An empirical study of the achievement of international baccalaureate students in Biology, Chemistry and Physics in Alberta. *Journal of Secondary Gifted Education, 8*(1), 28-40. doi:10.1177/1932202X9600800104

Fensham, P. J. (2009). The link between policy and practice in science education: The role of research. *Science Education, 93*, 1076-1095. doi:10.1002/sce20349

Fields, E. T., Jurist Levy, A., Karelitz, T. M., Martinez-Gudapakkam, A., & Jablonski, E. (2012). The science of professional development: If you offer professional development in science, will teachers come? More importantly, will it matter if they do? *Phi Delta Kappan, 93*(8), 44-48. doi:10.1177/003172171209300810

Finson, K. D., & Ormsbee, C. K. (1998). Rubrics and their use in inclusive science. *Intervention in School and Clinic, 34*(2), 79-88. doi:10.1177/105345129803400203

First conference of teachers of social studies in international schools: Report. (1962). International school of Geneva August 26 - September 1.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist, 34*(10), 906-911.

Flavell, J. H. (2004). *Theory-of-mind development: Retrospect and prospect* (Vol. 50). Merrill Palmer Q.

Florence, M. K., & Yore, L. D. (2004). Learning to write like a scientist: Coauthoring as an enculturation task. *Journal of Research in Science Teaching, 41*(6), 637-668. doi:10.1002/tea.20015

Flower, L. S., & Hayes, J. L. (1980). The dynamics of composing: Making plans and juggling constraints. In L. W. Gregg, & E. R. Steinberg, *Cognitive processes in writing* (pp. 31-50). Hillsdale, NJ: Erlbaum.

Fontana, A., & Frey, J. (2000). The interview. In N. Denzin, & Y. Lincoln, *Handbook of qualitative research* (2nd ed., pp. 645-672). London: SAGE.

Fontana, J. S. (2004). A methodology for critical science in nursing. *Advances in Nursing Science, 27*(2), 93-101.

Ford, M. (2008). 'Grasp of practice' as a reasoning resource for inquiry and nature of science understanding. *Science and Education, 17*(2), 147-177. doi:DOI 10.1007/s11191-006-9045-7

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). New York: Teachers College Press.

Galbraith, D., & Torrance, M. (1999). *Knowing what to write: Conceptual processes in text production.* Amsterdam, The Netherlands: Amsterdam University Press.

Garbett, D. (2011). Constructivism deconstructed in science teacher education. *Australian Journal of Teacher Education, 36*(6), 36-49. doi:10.14221/ajte2011v36n6.5

Garner, R., & Alexander, P. A. (1989). Metacognition: Answered and unanswered questions. *Educational Psychologist, 24*(2), 143-158. doi:10.1207/s15326985ep2402_2

Gee, J. (1996). *Social linguistics and literacies: Ideology in discourses* (2nd ed.). London: Taylor and Francis.

Gee, J. P. (2004). *Situated Language and Learning : A Critique of Traditional Schooling.* New York: Taylor and Francis.

Gergen, K. (1999). *An invitation to social construction.* Thousand Oaks CA: SAGE.

Gergen, K. J. (1999). *An invitation to social construction.* London: SAGE.

Gibson, S., & Dembo, M. H. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology, 76*(4), 569-582.

Giorka, O. (2009). Teacher or examiner? The tensions between formative and summative assessment in the case of science coursework. *Research in Science Education, 39*, 411-428. doi:10.1007/s11165-008-9086-9

Glaser, B. (1978). *Theoretical sensitivity.* Mill Valley, CA: The Sociology Press.

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research.* Chicago: Aldine.

Goddard, R. D., Woolfolk Hoy, A., & Hoy , W. K. (2000). Collective teacher efficacy: Its meaning, measure and impact on students achievement. *American Educational Research Journal, 37*(2), 479-507. doi:10.3102/00028312037002479

Goodson, I. F. (2003). *Professional knowledge.* Maidenhead: Open University Press.

Granbom, M. (2016). Formative assesment and increased student involvement increase grades in an upper secondary school biology course. *Journal of Biological Education, 50*(2), 185-195. doi:10.1080/00219266.2015.1028572

Grimberg, B. I., & Hand, B. (2009). Cognitive pathways: Analysis of students' written texts for science understanding. *International Journal of Science Education, 31*(4), 503-521. doi:10.1080/09500690701704805

Grotzer, T., & Mittlefehldt, S. (2012). The role of metacognition in students' understanding and transfer of explantory structures in science. In A. Zohar, & Y. J. Dori, *Metacognition in science education: Trends in current research* (pp. 79-99). Springer. doi:10.1007/978-94-007-2132-6_5

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational Communication and Technology Journal, 29*(2), 75-92.

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth Generation Evaluation.* Newbury Park, California: SAGE.

Gunel, M., Hand, B., & McDermott, M. A. (2009). Writing for different audiences: Effects on high-school students; conceptual understanding of biology. *Learning and Instruction*, 354-367. doi:10.1016/j.learninstruc.2008.07.001

Gunes, P., Katircioglu, H., & Yilmaz, M. (2015). The effect of performance based evaluation on preservice biology teachers' achievement and laboratory report writing skills. *Journal of Turkish Science Education, 12*(1), 71-83. doi:10.12973/tused.10134a)

Haigh, M. A., & Anthony, G. J. (2012). Induction and efficacy: A case study of New Zealand newly qualified secondary science teachers. *Journal of Science Teacher Education, 23*, 651-671. doi:10.1007/s10972-012-9285-0

Halliday, M. A., & Martin, J. R. (1993). *Writing science: Literacy and discursive power.* Pittsburgh, PA: University of Pittsburgh Press.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains. *American Psychologist, 53*(9), 449-455.

Hand, B. (2008). *Science inquiry, argument and language: A case for the science writing heuristic.* Rotterdam, Netherlands: Sense.

Hand, B., & Prain, V. (2006). Moving from Border Crossing to Convergence of Perspectives in Language and Science Literacy Research and Practice. *International Journal of Science Education, 28*(2-3), 101-107. doi:10.1080/09500690500336528

Harlen, W., & Crick, R. D. (2003). Testing and motivation for learning. *Assessment in Education: Principles, Policy and Practice, 10*(2), 169-207. doi:10.1080/0969594032000121270

Hasson, E., & Yarden, A. (2012). Separating the research question from the laboratory techniques: Advancing high-school biology teachers' ability to ask research questions†. *Journal of research in science teaching, 49*(10), 1296-1320. doi:10.1002/tea.21058

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement.* Oxon/New York, USA: Routledge.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81-112. doi:10.3102/003465430298487

Havdala, R., & Ashkenazi, G. (2007). Coordination of theory and evidence: Effect of epistemological theories on students' laboratory practice. *Journal of Research in Science Teaching, 44*(8), 1134-1159. doi:10.1002/tea.20215

Hildebrand, G. M. (1996). Writing in/forms science and science learning. *Paper presented at the National Association for Research in Science Teaching.* St Louis, MA.

Hill, I. (2002). *The SACE handbook of research in international education.* (M. Hayden, J. Thompson, & G. Walker, Eds.) New York: Routledge.

Hill, I. (2006). Do International Baccalaureate programs internationalise or globalise? *International Education Journal, 7*(1), 98-108. Retrieved from http://iej.cjb.net

Hodson, D. (1993). Re-thinking old ways: Toward a more critical approach to practical workin school science. *Studies in science education, 22*, 85-142. doi:10.12691/wjce-2-4-1

Hodson, D. (2008). *Towards scientific literacy: A teacher's guide.* Rotterdam, Netherlands: Sense.

Hofstein, A., & Kind, P. M. (2012). Learning in and from science laboratories. In B. J. Fraser, K. Tobin, C. J. Mc Robbie, & B. J. Fraser (Ed.), *Second International Handbook of Science Education* (pp. 189-207). Springer. doi:10.1007/978-1-4020-9041-7_15

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28-54. doi:10.1002/sce.10106

Hohenshell, L. M., & Hand, B. (2006). Writing-to-learn strategies in secondary school cell biology: A mixed method study. *International Journal of Science Education, 28*(2-3), 261-289. doi:10.1080/09500690500336965

Holliday, W. G., Yore, L. D., & Alverman, D. E. (1994). The reading-science learning-writing connection: Breakthroughs, barriers and promises. *Journal of Research in Science Teaching, 31*(9), 877-893. doi:10.1002/tea.3660310905

Houghton, C., Casey, D., & Murphy, K. (2013). Approaches to rigour in qualitative case study research. *Nurse Researcher, 20*(4), 12-17.

Huberman, M. (1989). The professional life cycles of teachers. *Teacher College Record, 91*(1), 31-58.

IBO. (2007). *International Baccalaureate Organisation Diploma Programme Biology Guide: First assessment 2009.* Retrieved from Online Curriculum Centre: http://occ.ibo.org/ibis/occ

IBO. (2010). *Group 4 (experimental sciences) curriculum review: General curriculum review questionnaire analysis.* Retrieved March 20, 2014, from Online Curriculum Centre: http://occ.ibo.org/ibis/occ/Utils/getFile2.cfm?source=/ibis/occ/home/subjectHome.cfm&filename=dp/gr4/d_4_gen4d_crr_1010_1b_e.pdf

IBO. (2012). *Internal assessment in Biology, Chemistry and Physics: Curriculum review report November 2011.* International Baccalaurate Organisation.

IBO. (2014). *International Baccalaureate Organisation Diploma Programme Biology Guide: First assessment 2016.* Retrieved February 10, 2014, from Online Curriculum Centre: http://occ.ibo.org

IBO. (2015). *International Baccalaureate Diploma Programme: Standard level and higher level courses*. Retrieved from International Baccalaureate Organisation: http://www.ibo.org/globalassets/publications/recognition/slhl-brief-en.pdf

IBO. (2017). *International Baccalaureate Organisation.* Retrieved September 13, 2017, from About the IB: Mission: http://www.ibo.org/about-the-ib/mission/

IBO. (2017a). *International Baccalaureate Organisation Diploma Program: A guide to curriculum development.* Retrieved August 6th, 2017, from International Baccalaureate Organisation: http://www.ibo.org//globalassets/publication/recognition/rec4122recogntioncurriculum brief-5web/pdf

IBO. (2017a). *Research*. Retrieved September 13, 2017, from International Baccalaureate Organisation: http://www.ibo.org/research

IBO. (2017b). *International Baccalaureate Organisation diploma program: A guide to curriculum development.* Retrieved August 6th, 2017, from International Baccalaureate Organisation: http://www.ibo.org/globalassets/publications/recognition/rec4122recognitioncurriculum brief-5web.pdf

IBO. (2017c). *Programmes*. Retrieved from International Baccalaureate Organisation: http://www.ibo.org/en.programmes/

IBO. (2017e). *DP authorisation process.* Retrieved August 6th, 2017, from International baccalaureate organisation: http://www.ibo.org/become-an-ib-school/how-to-become-an-ib-school/dp-authorization-process/

IBO. (2017f). *Key facts about the DP.* Retrieved August 6th, 2017, from International Baccalaureate Organisation: http://www.ibo.org/programmes/diploma-programme/what-is-the-dp/key-facts-about-the-dp/

IBO. (2017g). *Assessment fees and services.* Retrieved August 6th, 2017, from International Baccalaureate Organisation: http://www.ibo.org/become-an-ib-school/fees-and-services/assessment-fees-and-services/

IBO. (2017g). *International Baccalaureate Organisation*. Retrieved August 6th, 2017, from Find an IB school: http://www.ibo.org/programmes/find-an-ib-school/

IBO. (2017h). *IB learner profile.* Retrieved August 6th, 2017, from International Baccalaureate Organisation: http://www.ibo.org/contentassets/fd82f70643ef4086b7d3f292cc214962/learner-profile-en.pdf

Johnson, C., Fargo, J., & Kahle, J. B. (2010). The cumulative and residual impact of a systemic reform program on teacher change and student learning in science. *School Science and Mathematics, 110*(3), 144-159. doi:10.1111/j.1949-8594.2010.00017.x

Jokikokko, K. (2009). The role of significant others in the intercultural learning of others. *Journal of research in international education, 8*(2), 142-163. doi:10.1177/1475240909105202

Jonsson, A. (2014). Rubrics as a way of providing transparency in assessment. *Assessment and Evaluation in Higher Education, 39*(7), 840-852. doi:10.1080/02602938.2013.875117

Jonsson, A., & Svingby, G. (2007). The use of scoring rubrics: Reliablity, validity and educational consequences. *Educational Research Review, 9*, 129-144. doi:10.1016/j.edurev.2007.05.002

Jootun, D., McGhee, G., & Marland, G. R. (2009). Reflexivity: Promoting rigour in qualitative research. *Nursing Standard, 23*(23), 42-46.

Katchevich, D., Hofstein, A., & Mamlok-Naaman, R. (2011). Argumentation in the chemistry laboratory: Inquiry and confirmatory experiments. *Research in Science Education, 43*(1), 317-345. doi:10.1007/s11165-011-9267-9

Keys, C. (1999). Revitalising instruction in scientific genres: Connecting knowledge production with writing to learn science. *Science Education, 83*(2), 115-130. doi:10.1002/(SICI)1098-237X(199903)83:2<115::AID-SCE2>3.0.CO;2-Q

Keys, C. W. (2000). Investigating the thinking processes of eighth grade writers during the composition of a scientific laboratory report. *Journal of Research in Science Teaching, 37*(7), 676-690. doi:10.1002/1098-2736

Khine, M. S. (2012). *Advances in nature of science research: Concepts and methodologies.* Bahrain: Springer.

Kishbaugh, T. L., Cessna, S., Horst, S. J., Leaman, L., Flanagan, T., Graber Neufeld, D., & Siderhurst, M. (2012). Measuring beyond content: A rubric bank for assessing skills in authentic research assignments. *Chemistry Education and Research Practice, 13*, 268-276. doi:10.1039/c2rp00023g

Klassen, R., Tze, V., Betts, S., & Gordon, K. (2011). Teacher efficacy research 1998-2009: Signs of progress or unfulfilled promise? *Educational Psychology Review, 23*, 21-43. doi:10.1007/s10648-010-9141-8

Klein, P. (1999). Re-opening inquiry into cognitive processes in writing-to-learn. *11*(3), 203-270. doi:10.1023/A:1021913217147

Klein, P. D., & Rose, M. A. (2010). Teaching argument and explanation to prepare junior students for writing to learn. *Reading Research Quarterly, 45*(4), 433-461. doi:10.1598/RRQ.45.4.4

Koh, K. H. (2011). Improving teachers' assessment literacy through professional development. *Teaching Education, 22*(3), 255-276. doi:10.1080/10476210.2011.593164

Kuhn, D. (1993). Science as argument - implicatoins for teaching and learning scientific thinking. *Science Educator, 77*(3), 319-337. doi:10.1002/sce.3730770306

Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher, 28*(2), 16-26. doi:10.3102/0013189X028002016

Kuhn, T. S. (1996). *The structure of scientific revolutions* (3rd ed.). Chicago, Illinois, USA: The University of Chicago Press.

Kulgemeyer, C., & Schecker, H. (2013). Students explaining science: Assessment of science communication. *Research in Science Education, 43*, 2235-2256. doi:10.1007/S111165-013-93554-1

Lemke , J. L. (1990). *Talking science: Language and learning and values.* Norwood, NJ: Ablex.

Levit, K. E. (2001). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education, 86*(1), 1-22. doi: 10.1002/sce.1042

Lew, L. Y. (2010, Fall). The use of constructivist teaching practices by four new secondary school science teachers: A comparison of new teachers and experienced constructivist teachers. *Science Educator, 19*(2), 10-19. Retrieved from Retrieved from https://search-proquest-com.ezproxy.flinders.edu.au/docview/896626496?accountid=10910

Linn, M. C. (2000). Designing the knowledge integration environment. *International Journal of Science Education, 22*(8), 781-796. doi:10.1080/095006900412275

Lipnevich, A. A., & Smith, J. K. (2009). Effects of differential feedback on students' examination performance. *Journal of Experimental Psychology: Applied, 15*(4), 319-333. doi:10.1037/a0017841.supp

Lipnevich, A. A., McCallen, L. N., Pace Miles, K., & Smith, J. K. (2014). Mind gap! Students' use of exemplars and detailed rubrics as formative assessment. *Instructional Science, 42*, 539-559. doi:10.1007/s11251-013-9299-9

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. (1998). *Designing professional development for teachers of science and mathematics.* Thousand Oaks CA: Corwin Press.

Loughran, J. (1994). Bridging the gap: An analysis of the needs of second-year science teachers. *Science Education, 78*(4), 365-386. doi:10.1002/sce.3730780404

Lucardie, D. (2014). The impact of fun and enjoyment on adults learning. *Procdeia - Social and Behavioural Sciences, 142*, 439-446. doi:10.1016/j.sbspro.2014.07.696

Mageau, T. (2012). Online communities of practice: what works? Four experienced practitioners share what they've learned about community building and collaboration. *The Journal (Technological Horizons in Education), 39*(4), 12. Retrieved September 29th, 2017, from http://go.galegroup.com.ezproxy.flinders.edu.au/ps/i.do?p=EAIM&sw=w&u=flinders&v=2.1&pg=AdvancedSearch&it=static

Martin, J. (2006). *The meaning of the 21st century: A blueprint for ensuring our future.* London, UK: Eden Project Books.

Mc Connell, D. A., Stempien, J. A., Perkins, D., van der Hoeven Kraft, K. J., Vislova, T., Wirth, K. R., . . . Matheney, R. K. (2010). The little engine that could - less prior knowledge but high self-efficacy is equivalent to greater prior knowledge and low self-efficacy. *Geological Society of America, Abstract with Program, 42*(5), 191. doi:10.5408/1.3604028

Mc Neill, K. L. (2008). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education*, 233-268. doi:10.1002/SCE.20294

McCormick, J., & Ayres, P. L. (2009). Teacher self-efficacy and occupational stress: A major Australian curriculum reform revisited. *Journal of Educational Administration, 47*(4), 463-476. doi:10.1108/09578230910967446

McMunn, N., McColskey, W., & Butler, S. (2004). Building teacher capacity in classroom assessment to improve student learning. *International Journal of Educational Policy, Research and Practice, 4*(4), 25-48.

McNeill, K. L. (2008). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education*, 233-268. doi:10.1002/sce.20294

McNeill, K. L., & Krajcik, J. (2007). Instructional strategies to support students writing scientific explanations. In J. Luft, J. Gess-Newsome, & R. Bell (Eds.), *Science as inquiry in the secondary setting.* Washington , DC: National Science Foundation.

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco: Jossey-Bass.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: SAGE.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). Thousand Oaks, CA: SAGE.

Millar, R. (1989). What is scientifi c method and can it be taught? In J. Wellington, *Skills and process in science education* (pp. 44-61). London: Routledge.

Milner, H. R., & Woolfolk Hoy, A. (n.d.). A case study of an African American teachers' self-efficacy, stereotype, threat and persistence. *Teaching and Teacher Education, 19*(2), 263-276. doi:10.1016/S0742-051X(02)00099-9

Miri, B., Ben-Chaim, D., & Zoller, U. (2007). Purposely teaching for the promotion of higher-order thinking skills: A case of critical thinking. *Research Science Education, 37*, 353-369. doi:10.1007/s11165-006-9029-2

Montgomery, K. (2002). Authentic tasks and rubrics: Going beyond traditional assessments in colleage teaching. *College Teaching, 50*(1), 34-40. doi:10.1080/87567550209595870

Monty Jones, W., & Dexter, S. (2014). How teachers learn: The roles of formal, informal and independent learning. *Education Technological Research Development, 62*, 367-384. doi:10.1007/s11423-014-9337-6

Morgan, W., Fraga, D., & Macauley , W. J. (2011). An integrated approach to improve the scientific writing of introductory biology students. *The American Biology Teacher, 73*(3), 149-153. doi:10.1525/abt2011.73.3.6

Mortimer, E., & Scott, P. (2003). *Meaning making in secondary science classrooms.* Berkshire, Great Britain: Mc Graw-Hill Education.

Moyer-Packenham, P. S., Bolyard, J. J., Oh, H., & Irby, N. (2011). Common features of professional development actiivities for mathematics and science teachers. *Professional Development in Education, 37*(4), 571-589. doi:10.1080/19415257.2010.5314597

*My School* . (2017, September 5th). Retrieved from https://www.myschool.edu.au/

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*(4), 317-328. doi:10.1080/0022027870190403

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*, 224-240. doi:10.1002/sce.10066

O Neil, D. K. (2001). Knowing when you've brought them in: Scientific genre knowledge and communities of practice. *Journal of Learning Sciences, 10*(3), 223-264. doi:10.1207/s15327809JLS1003_1

OECD. (2015). *PISA 2015 Draft Science Framework.* Retrieved June 26, 2014, from OECD: https://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framework%20.pdf

Organisation for Economic Co-operation and Development (OECD). (2013). *PISA 2015 Draft Science Framework 2015.* Retrieved March 2013, from https://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framework%20.pdf

Orsmond, P., Merry, S., & Callagjan, A. (2004). Implementation of a formative assessment model incorporating peer and self-assessment. *Innovations in Education and Teaching International, 41*(3), 273-290. doi:10.10802/14703290410001733294

Osborne, J. (2007). Science education for the 21st century. *Eurasia Journal of Mathematics, Science and Technology Education, 3*(3), 173-184. Retrieved from http://www.ejmste.com/Issue-3-2007,2698

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*, 463-466. doi:10.1126/science.1183944

Osborne, J. F., & Patterson, A. (2011). Scientific Argument and Explanation: A Necessary Distinction? *Science Education, 95*(4), 627-638. doi:10.1002/sce.20438

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas about science"should be taught in school science? A Delphi study of the expert community. *Journal of research in science teaching, 40*(7), 692-720. doi:10.1002/tea.101105

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994-1020. doi:10.1002/tea.20035

Pajares, F. M. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332. doi:10.3102/00346543062003307

Palmer, D., Dixon, J., & Archer, J. (2015). Changes in science teaching self-efficacy among primary teacher education students. *Australian Journal of Teacher Education, 40*(12), 27-40. doi:10.14221/ajte.2015v40n12.3

Pandero, E., & Jonsson, A. (2013). The use of scoring rubrics for formative assessment purposes revisted: A review. *Educational Research Review, 9*, 129-144. doi:10.1016/j.edurev.2013.01.002

Pandero, E., & Romero, M. (2014). To rubric or not to rubric? The effects of self-assessment on self-regulation, performance and self-efficacy. *Assessment in Education: Principles, Policy and Practice, 21*(2), 133-148. doi:10.1080/0969594X.2013.877872

Patton , M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, California: SAGE.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: SAGE.

Patton, M. Q. (2015). *Qualitative research and evaluation methods* (4th ed.). Los Angeles: SAGE.

Peker, D., & Wallace, A. (2011). Characterising high school students' written explanations in biology laboratories. *Research in Science Education, 41*, 169-191. doi:10.1007/s11165-009-9151-z

Pendergast, D., & Main, K. (2016). Teacher self-efficacy and junior secondary. In S. Garvis, & D. Pendergast (Eds.), *Asia-Pacific Perspectives on Self-Efficacy* (pp. 103-113). Rotterdam: Sense.

Pereira, H. (2012). Rigour in phenomenological research: Reflections of a novice nurse researcher. *Nurse Researcher, 19*(3), 16-16. Retrieved from http://nurseresearcher.rcnpublishing.co.uk.ezproxy.flinders.edu.au/

Piaget, J. (1964). Cognitive development in children: Piaget development and learning. *Journal of Research in Science Teaching, Part 1: 2*(3), 176-186. doi:10.1002/tea.3660020306

Pintrich, P. R. (2000). Educational psychology at the millennium: A look back and a look forward. *Educational Psychologist*, 221-226. doi:10.1207/S15326985EP3504_01

Pintrich, P. R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory into Practice, 41*(4), 219-225. doi:10.1207/s15430421tip4104_3

Pintrich, P. R. (2002). The role of metacognitive knowledge in learning,teaching and assessing. *Theory Practice, 41*, 219-225.

Popham, W. J. (1997). What's wrong and what's right - with rubrics. *Educational Leadership, 55*(2), 72-75.

Popper, K. R. (1980). *The logic of scientific discovery.* London, UK: Hutchinson.

Porter, R., Guarienti, K., Brydon, B., Robb, J., Royston, A., Painter, H., . . . Smith, M. H. (2010). Writing better lab reports. *Science Teacher, 77*(1), 43-48. Retrieved from https://search-proquest-com.ezproxy.flinders.edu.au/docview/214624332?accountid=10910

Punch, K., & Oanacea, A. (2014). *Introduction to research methods in education* (Vol. 2nd). London: SAGE.

Rennie, L. J., Goodrum, D., & Hackling, M. (2001). Science teaching and learning in Australian schools. *Research in science education, 31*(4), 455-498. doi:10.1023/A:1013171905815

Richter, D., Kunter, M., Klusmann, U., Ludtke, O., & Baumert, J. (2011). Professional development across the teaching career: Teachers' uptake of formal and informal learning opportunities. *Teaching and Teacher Education, 27*, 116-126. doi:10.1016/j.tate.2010.07.008

Ritchie, J., & Lewis, J. (2009). *Qualitative research practice: A guide for social science students and researchers.* London: SAGE.

Rivard, L. P., & Straw, S. B. (2000). The effect of talk and writing on learning science: An exploratory study. *Science Education, 84*(5), 566-593. doi:10.1002/1098-237X(200009)84:5<566::AID-SCE2>3.0.CO;2-U

Ross, J. A. (1998). The antecedents and consequences of teacher efficacy. In J. Brophu (Ed.), *Advances in research on teaching* (Vol. 7, pp. 49-73). JAI Press.

Roth, W.-M. (2005). Ethnomethodology and the R/Evolution of science. *Canadian Journal of Science, Mathematics and Technology Education, 5*(2), 185-198. doi:10.1080/14926150509556652

Ruiz-Primo, M. A., & Furtak, E. M. (2007). Exploring teachers' informal formative assessment practices and students' understanding in the context of scientific inquiry. *Journal of research in science teaching, 44*(1), 57-84. doi:10.1002/tea.20163

Ruiz-Primo, M. A., Li, M., Tsai, S. P., & Schneider, J. (2010). Testing one premise of scientific inquiry in science classrooms: Examining students' scientific explanations and student learning. *47*(5), 583-608. doi:10.1002/tea.20356

Ryan-Nicholls, K. D., & Will, C. I. (2009). Rigour in qualitative research: Mechanisms for control. *Nurse Researcher, 16*(3), 70-85.

Ryder, J. (2015). Being professional: Accountability and authority in teachers' responses to science curriculum reform. *Studies in Science Education, 51*(1), 87-120. doi:10.1080/03057267.2014.1001629

Ryder, J., & Banner, I. (2013). School teachers' experiences of science curriculum reform. *International Journal of Science Education, 35*(3), 490-514. doi:10.11080/09500693.2012.665195

Sadler , D. R. (2010). Beyond feedback: developing student capability in complex appraisal. *Assessment and Evaluation in Higher Education, 35*(5), 535-550. doi:10.1080/02602930903541015

Sadler, D. R. (1987). Specifying and promulgating achievement standards. *Oxford Review of Education, 13*(2), 191-209. doi:10.1080/0305498870130207

Sadler, D. R. (2009). "Indeterminacy in the use of preset criteria for assessment and grading". *Assessment and Evaluation in Higher Education, 34*(2), 159-179. doi:10.1080/02602930801956059

Saka, Y., Southerland, S. A., & Golden, B. (2009). Enactment of reform in induction: Changes in beginning teachers ' self-efficacy beliefs and pedagogical discontentment. *Paper at the annual meeting of the National Association for Research in Science Teaching.* Garden Grove CA.

Sampson, V., & Blanchard, M. R. (2012). Science teachers and scientific argumentation: Trends in views and practices. *Journal of Research in Science Teaching, 49*, 1122-1148. doi:10.1002/tea.21037

Sampson, V., & Gleim, L. (2009). Argument-driven inquiry to promote the understanding of important concepts and practices in biology. *The American Biology Teacher, 71*(8), 465-472.

Sampson, V., Grooms, J., & Walker, J. P. (2011). Argument-driven inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: An exploratory study. *Science Education, 95*, 217-257. doi:10.1002/sce.20421

Sandelowski, M. (1986). The problem of rigour in qualitative research. *Advances in Nursing Science, 8*(3), 27-37.

Sandoval, W. A., & Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction, 23*(1), 23-55. doi:10.1207/s1532690xci2301-2

Savage, G. (2014). Reconstituting "The public" through national reform: A reflection on the development of the common core standards. *Journal of curriculum and pedagogy, 11*(1), 40-43. doi:10.1080/15505170.2014.908435

Sbraini, A., Carter, S. M., Wendell Evans, R., & Blinkhorn, A. (2011). How to do a grounded theory study: A worked example of a study of dental practices. *BMC Medical Research Methodology, 11*(128), 1-10. doi:10.1186/1471-2288-11-128

Schraw, G., & Moshman, D. (1995). Metacogntive theories. *Educational Psychology Review, 7*(4), 351-371. doi:10.1007/BF02212307

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. *Research in Science Education, 36*, 111-139. doi:10.1007/s11165-005-3917-8

Schwab, J. J. (1962). The teaching of science as enquiry. In P. F. Brandwein (Ed.). Cambridge, MA: Harvard University Press.

Seimears, M. C., Graves, E., Schroyer, G. M., & Staver, J. (2012). How constructivist-based teaching influences students learning science. *The Educational Forum*, 265-271. doi:10.1080/00131725.2012.653092

Settlage, J., Southerland, S. A., Smith, L. K., & Ceglie, R. (2009). Constructing doubt-free teaching self: Self-efficacy, teacher identity, and science instruction within diverse settings. *Journal of Research in Science Teaching, 46*(1), 102-125. doi:10.1002/tea.20268

Skamp, K., & Preston, C. (2015). Teaching primary science constructively. In K. Skamp, *Teaching primary science constructively* (5th ed., pp. 1-54). Melbourne: Cengage Learning.

Southerland, S. A., Nadelson, L., Sowell, S., Saka, Y., Kahveci, M., & Granger, E. M. (2012). Measuring one aspect of teachers' affective states: Development of the science teachers' pedagogical discontentment scale. *School Science and Mathematics, 112*(8), 483-494. doi:DOI: 10.1111/j.1949-8594.2012.00168.x

Spanier, B. B. (1992). Encountering biological sciences: Ideology, language and learning. In A. Herrington, & C. Moran, *Writing, teaching and learning in the disciplines* (pp. 193-212). New York: Modern Language Association of America.

Spillane, J. P. (1999). External reform initiatives and teachers' efforts to reconstruct their practice: The mediating role of teachers' zones of enactment. *Journal of Curriculum Studies, 31*(2), 143-175. doi:10.1080/002202799183205

Staer, H., Goodrum, D., & Hackling, M. (1998). High school laboratory work in Western Australia: Openess to inquiry. *Research in Science Education, 28*(2), 219-228. doi:10.1007/BF02462906

Stake, R. (2003). Case study. In N. K. Denzin, & Y. S. Lincoln (Eds.), *Strategies of qualitative inquiry.* London: SAGE.

Stake, R. E. (1994). Case studies. In N. K. Denzin, & Y. S. Lincoln, *Handbook of qualitative research* (pp. 236-247). Thousand Oaks, California: SAGE.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, California: SAGE.

Stake, R. E. (1995). *The Art of Case Study Research* (1st ed.). Thousand Oaks, CA: SAGE.

Stiggins, R. J. (1991). Assessment literacy. *Phi Delta Kappan, 72*(7), 534-539. doi:10.120404455

Stiggins, R. J. (1995). Assessment literacy for the 21st century. *Phi Delta Kappan, 77*(3), 238-245. Retrieved from Retrieved from http://www.jstor.org/stable/20405538

Strauss, A., & Corbin, J. (1998). *Basics of qualiatative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks, California: SAGE.

Svendsen, B. (2016). Teachers' experience from a school-based collaborative teacher professional development programme: reported impact on professional development. *Teacher Development, 20*(3), 313-328. doi:10.1080/13664530.2016.1149512

Swanson, H. L. (1990). Influence of metacognitive knowledge and aptitude on problem solving. *Journal of Educational Psychology, 82*, 306-314. doi:10.1037/0022-0663.82.2.306

Taber, K. S. (2010). Paying lip-service to research? The adoption of a constructivist perspective to inform science teaching in the English curriculum context. *The Curriculum Journal, 21*(1), 25-45. doi:10.1080/095585170903558299

Talanquer, V., Tomanek, D., & Novodvorsky, I. (2013). Assessing students' understanding of inquiry: What do prospective science teachers notice? *Journal of Research in Science Teaching, 50*(2), 189-208. doi:10.1002/tea.21074

Tang, K.-S. (2016). Constructing scientific explanations through premise-reasoning-outcome (PRO): An exploratory study to scaffold students in structuring written explanations. *International Journal of Science Education, 38*(9), 1415-1440. doi:10.1080/09500693.2016.1192309

Tang, X., Coffey, J. E., Elby, A., & Levin, D. M. (2010). The scientific method and scientific inquiry: Tensions in teaching and learning. *Science Education, 94*(1), 29-47. doi:10.1002/sce.20366

Tang, X., Coffey, J., & Levin, D. M. (2015). Reconsidering the use of scoring rubrics in biology instruction. *The American Biology Teacher, 77*(9), 669-675. doi:10.1525/abt2015.77.9.4

Thomas, G. (2011). *How to do your case study: A guide for students and researchers.* London: SAGE.

Tierney, B., & Dorroh, J. (2004). How to learn to write science. (2nd). Arlington, Virginia, USA: NSTA Press.

Tobin, K. (2012). Sociocultural perspectives on science education. In B. J. Fraser, K. Tobin, & C. J. McRobbie, *Second International Handbook of Science Education* (Vol. 24, pp. 3-17). New York, NY: Springer.

Tobin, K., & McRobbie, C. J. (1996). Cultural myths as constraints to enact science curriculum. *Science Education, 80*(2), 223-241. doi:10.1002/(SICI)1098-237X(199604)80:2<223::AID-SCE6>3.0.CO;2-I

Torrance, H. (2007). Assessment as learning? How the use of explicit learning objectives, assessment criteria and feedback in post-secondary education and training can come to dominate learning. *Assessment in Education, 14*(3), 281-294. doi:10.1080/09695940701591867

Toulmin, S. E. (1958). *The Uses of Argument.* Cambridge: Cambridge University Press.

Towndrow, P. A., Tan, A., Yung, B., & Cohen, L. (2010). Science teachers' professional development and changes in science practical assessment practices: What are the issues? *Research in Science Education, 40*, 117-132. doi:10.1007/s11165-008-9103-z

Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring student's self-efficacy, sense of beloning and science identity. *CBE-Life Sciences Education, 13*, 6-15. doi:10.1187/cbe.13-120241

Trumbull, D. J. (1999). *The New Science Teacher: Cultivating good practice.* New York: Teachers College Press.

Trust, T., Krutka, D. G., & Carpenter, J. P. (2016). "Together we are better': Professional learning networks for teachers. *Computers and Education, 102*, 15-34. doi:10.1016/j.compedu.2016.06.007

Tschannen-Moran, M., & Woolfolk Hoy, A. (2001). Teaching efficacy: Capturing an elusive construct. *Teaching and Teacher Education, 17*(7), 783-805. doi:10.1016/S0742-051X(01)00036-1

Tschannen-Moran, M., Woolfolk Hoy, A., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research, 68*(2), 202-248. doi:10.3102/00346543068002202

Tytler, R. (2004). Constructivist views on teaching and learning. In G. Venville, & V. Dawson, *Art of Teaching Science* (pp. 18-33). Crows Nest, NSW: Allen and Unwin.

Tytler, R., Symington, D., Darby, L., Malcolm, C., & Kirkwood, V. (2011). Discourse communities: A framework from which to consider professional development for rural teachers of science and mathematics. *Teaching and Teacher Education, 27*, 871-879. doi:10.1016/j.tate.2011.02.002

Usher, E. L., & Pajares, F. (2008). Self-efficacy for self-regulated learning. *Educational and Psychological Measurement,, 68*(3), 443-463. doi:10.1177/0013164407308475

van Driel, J. H., Meirink, J. A., van, V., & Zwart, R. C. (2012). Current trends and missing links in studies on teacher professional development in science education: A review of design features and quality of research. *Studies in Science Education, 48*(2), 129-160. doi:10.1080/03057267.2012.738020

van Opstal, M. T., & Daubenmire, P. L. (2015). Extending students' practice of metacognitive regulation skills with the science writing heuristic. *International Journal of Science Education, 37*(7), 1089-1112. doi:10.1080/09500693.2015.1019385

Veel, R. (1997). Learning how to mean-scientifically spealing: Apprenticeship into scientific discourse in the secondary school. In F. Christie , & J. R. Martin, *Genre and institutions: Social process in the workplace and school* (pp. 161-195). London: Cassell.

Velthuis, C., Fisser, P., & Pieters, J. (2015). Collaborative curriculum design to increase science teaching self-efficacy: A case study. *The Journal of Educational Research, 108*(3), 217-225. doi:10.1080/00220671.2013.878299

Vukmann, K. B. (2005). Developmental differences in metacognition and thier connections with cognitive development in adulthood. *Journal of Adult Development, 12*, 211-221. doi:10.1007/s10804-005-7089-6

Vygotsky, L. S. (1978). The prehistory of written language. In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.), *Mind and society: the development of higher psychological process* (pp. 105-119). Cambridge, MA: Harvard University Press.

Walker, J. P., & Sampson, V. (2013). Learning to argue and arguing to learn: Argument-driven inquiry as a way to help undergraduate chemistry students learn how to construct arguments and engage in argumentation during a laboratory course. *Journal of Research in Science Teaching, 50*(5), 561-596. doi:10.1002/tea.21082

Wallace , C. S. (2004). Framing new research in science literacy and language use: Authenticity, multiple discourses, and the "third space". *Journal of Research in Science Teaching, 41*(9), 936-960.

Wallace, C. (2004). Framing new researchin science literacy and language use: Authenticity, multiple discourses and the "third space". *Science Education, 88*(6), 901-914. doi:10.1002/sce.20024

Wallace, C. (2011). Authoritarian science curriculum standards as barriers to teaching and learning: An intepretation of personal experience. *Science education, 96*(2), 291-310. doi:10.1002/sce.20470

Wallace, C. S., & Kang, N. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching, 41*(9), 936-960. doi:10.1002/tea.20032

Wallace, C., Hand, B., & Prain, V. (2004). *Writing and learning in the science classroom* (1st ed.). New York: Springer. doi:DOI 10.1007/978-1-4020-2018-6

Washburn, E., & Cavagnetto, A. (2013). Using argument as a tool for integrating science and literacy. *Reading Teacher, 67*(2), 127-136. doi:10.1002/TRTR.1181

Wellington, J., & Osborne, J. (2001). *Language and Literacy in science education.* Philadelphia: Open University Press.

Westbroek, H., Janssen, F., & Doyle, W. (2016). Perfectly reasonable in a practical world: Understanding chemistry teacher responses to a change proposal. *Research in science education, 46*(1), 1-21. doi:10.1007/s11165-016-9560-8

Wheatley, K. F. (2002). The potential benefits of teacher efficacy doubts for educational reform. *Teaching and Teacher Education, 18*(1), 5-22. doi:10.1016/S0742-051X(01)00047-6

Whitehead, D., & Murphy, F. (2014). "Mind your language" High school students write laboratory reports. *Journal of Adolescent and Adult Literacy, 57*(6), 492-502. doi:10.1002/jaal.272

Wieviorka, M. (1992). 'Case studies: History or sociology?'. In C. C. Ragin, & H. S. Becker (Eds.), *What is a case? Exploring the foundations of social inquiry.* New York: Cambridge University Press.

Wilkinson, V., & Hayden, M. (2010). The international baccalaureate diploma and student attitudes: An exploratory study. *Journal of research in international education, 9*(1), 85-96. doi:10.1177/1475240909358529

Wilson, S. M. (2013). Professional development for science teachers. *Science, 340*, 310-313. doi:10.1126/science.1230725

Wollenschlager, M., Hattie, J., Nachts, N., Moller, J., & Harms, U. (2016). What makes rubrics effective in teacher-feedback? Transparency of learning goals is not enough. *Contemporary Educational Psychology, 44-45*, 1-11. doi:10.1016/j.cedpsych.2015.11003

Wood, D. (2015). Improvement of students' scientific writing in a middle-years science classroom (unpublished Master's thesis). *Curtin University, Western Australia*.

Yin, R. K. (2003). *Case study research: Designs and methods* (3rd ed.). Thousand Oaks, CA: SAGE.

Yin, R. K. (2012). *Applications of Case Study Research* (1st ed.). Thousand Oaks: SAGE.

Yore, L. D. (2010). Foundations of scientific, mathematical and technological literacies - common themes and theoretical frameworks. In L. D. Yore, E. Van der Flier-Keller, D. D. Blades, T. W. Pelton, & D. B. Zandvliet, *Pacific CRYSTALl Centre for Science, Mathematics and Technology Literacy* (pp. 23-44). Rotterdam, Netherlands: Sense.

Yung, B. (2001). Three views of fairness in a school-based assessment scheme of practical work in biology. *International journal of science education, 23*(10), 985-1005. doi:10.1080/09500690010017129

Yung, B. (2006). Looking across the cases: A preliminary analysis. In B. Yung (Ed.), *Assessment reform in science fairness and fear* (Vol. 31, pp. 151-163). Netherlands: Springer.

Zhang, M., Parker, J., Koehler, M. J., & Eberhardt, J. (2015). Understanding inservice science teachers' needs for professional development. *Journa of Science Teacher Education, 26*(5), 471-496. doi:10.1007/s10972-015-9433-4

Zimmerman, B. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*(1), 82-91. doi:10.1006/ceps.1999.1016

Zohar, A., & Barzalai, S. (2013). A review of research on metacognition in science education: current and future directions. *Studies in Science Education, 49*(2), 121-169. doi:10.1080/03057267.2013.847261