School of Education

Science and Mathematics Education Centre

Developing Effective Formative Assessment Practices

For Students in Year 12 Mathematics A

Melinda Elisabeth Stockwell

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number #SMEC-46-12.

Signed: *Melinda E Stockwell*

Date: 14 July 2017

Abstract

This case study was conducted with students studying Year 12 Mathematics A in an independent school in regional Queensland, Australia. Conducted over one school year, the research aimed to determine whether the implementation of a more comprehensive approach to formative assessment made a difference to students' summative assessment outcomes. Prior to the commencement of the study, formative task achievement was not mirrored in student achievement on summative assessment tasks, which was generally of a lower standard. The research team was made up of the teacher-researcher, who was also Head of the Mathematics Department, and two other teachers who taught the study subject. The factors impacting on formative assessment outcomes were identified in the literature and addressed during the year of the study through the implementation of formative assessment practices that took them into account. The process was iterative in nature.

During the research, the mathematical attributes and the learning experiences to which students were exposed were assessed, as were the impacts on classroom culture, the role and influence of the teacher, and the qualities of the feedback provided to students on formative and summative outcomes.

A mixed-method study, based on a post-positivist paradigm, the study used both quantitative and qualitative methods with a view to providing a substantive resolution to the problematic disconnect between formative and summative assessment outcomes by investigating what practices were effective in promoting student engagement with, and success, in mathematics.

This study identified that the adoption of a more comprehensive model of formative assessment not only increased levels of student engagement and built a more positive classroom culture, but also improved Year 12 summative assessment grades in Mathematics A for most, if not all, students. The influence of the teacher proved to be significant.

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1.1   Introduction

An assessment item can be used in either a formative or a summative assessment process. Formative assessment does not, normally, contribute towards a student's final summative grade; rather, it promotes improved learning outcomes through changes to teaching pedagogy which facilitate better student learning (Andersson & Palm, 2017). Thus, categorisation of the task as formative 'assessment for learning' (Stiggins, 2005) or summative 'assessment of learning' (Keeley, 2015) depends upon the use to which the results are put rather than the characteristics of the task itself.

Research has identified that, although students can make effective use of feedback provided on formative assessment tasks to improve their achievement on formative tasks, the same students fail to achieve comparable success in related summative assessment tasks, leading to the view that success on formative assessment tasks is not a reliable predictor of success on summative assessment tasks (Learning Sciences International, 2016; Smith, 2008; Zhang & Henderson, 2015). This is significant, because students who perform poorly on summative assessment items often receive low exit grades at the end of their schooling, limiting their choices for tertiary study and restricting career options. Bridging the disconnect between formative and summative assessment performance is a high-stakes enterprise, given the consequences for students of poor summative outcomes.

This study explores the extent to which student success in the summative tasks in Mathematics A (a mathematics subject available to students in their final two years of secondary schooling in Queensland, Australia) can be enhanced by incorporating the factors generating a positive formative assessment experience and outcomes into comparable summative assessment tasks.

1.2   Types of assessment: formative and summative

Formative assessment has been recognised as an integral part of the instructional process (Association for Supervision and Curriculum Development [ASCD], 1996; Black, 2010; Black & Wiliam, 2003; McIntosh, 1997) as it informs both the teacher and students about the extent of student understanding (Lesh & Sriraman, 2005), allowing for timely adjustments to be made to the teaching approach before summative assessment take place (Boston, 2002). These adjustments are designed to help students achieve targeted standards-based learning goals within the set time frame (Garrison & Ehringhaus, 2007). Thus, formative assessment has two dimensions: diagnostic - interpreting student contribution in terms of what it reveals about the students' thinking and motivation and providing real-time feedback to both teachers and students (Baroudi, 2007; Boston, 2002; Queensland Curriculum & Assessment Authority [QCAA], 2016) and prognostic - choosing and implementing an appropriate intervention strategy (Black & Wiliam, 2009).

What makes an assessment formative is not the design of a test, technique, or self-evaluation *per se*, but the way it is used. Formative assessment can be loosely categorised into two groups: informal and formal. Informal formative assessment

(Rakoczy, Klieme, Leiß & Blum, 2017; Ruiz- Primo & Furtak, 2007) includes activities such as impromptu question-and-answer sessions, informal discussions and verbal quizzes - day-to-day checking during classroom discussion that monitors progress and student understanding of a specific task (Shirley & Irving, 2015; Tomlinson & Moon, 2014). Formal formative assessment (Yorke, 2003; Yin, Tomita & Shavelson, 2014) can take a number forms such as the submission of drafts for review, systematic use of checklists to monitor student development of knowledge or skills, and verbal presentations (Tomlinson & Moon, 2014). These methods not only monitor student progress, but allow the teacher to identify individual students who require extra support or intervention. Formal formative assessment may also include precise data collection that focuses on specific aspects of the curriculum (McMillan, Venable & Varier, 2013) or diagnostic tests at junctures in the teaching schedule (Decristan, Klieme, Kunter, Hochweber, Büttner, Fauth, Hondrich, Rieser, Hertel & Hardy, 2015). These data assist forward planning and can indicate the teaching and learning strategies that have been most effective in facilitating student learning.

A range of formative assessment practices is used in Mathematics A and these tasks are administered during regular mathematics lessons. The time allocated to each task is, therefore, less than one hour. Due to the time constraints, the questions presented are at a lower level of complexity than those presented in the summative assessment tasks, which benefit from having more time allocated for their completion. Interactions between students and between students and the teacher are commonplace. Students who fail to achieve satisfactory outcomes on these formative assessment tasks are targeted by

the teacher for supporting interventions, such as personal tutoring sessions and/or participation in remedial classes.

The effectiveness of formative assessment is still contested (Black & Wiliam,2009; Ernst, 2014; Havnes, Smith, Dysthe & Ludvigsen, 2012; Sutton, 2010). Although some academics (for example, Kluger and De Nisi, 1996; Shute, Leighton, Jang & Chu, 2016; Thum, Tarasawa, Hegedus, Yun & Bowe, 2015) maintain that formative assessment results in improved learning outcomes; the view is not universally held (for example, Andrade, 2010; Bennett, 2011; Black, 2015; Elwood, 2006; Grosas, Raju, Schuett, Chuck & Millar, 2016).

In particular, the studies of Carrillo-de-la-Peña, Bailles, Caseras, Martínez, Ortet and Pérez (2009), Cooper and Cowie (2010) and Dunn and Mulvenon (2009) suggest that formative diagnostic testing is not a reliable indicator of student learning and understanding.

Summative assessment determines the grade shown on the students' reports at the end of each term/semester/year. In Mathematics A, summative assessment takes the form of a three-hour formal examination at the end of each term and two course work assessments conducted during the year. Summative coursework assessments address one particular topic in depth and include a research component and a rich (real world) task (Aubusson, Burke, Schuck, Kearney & Frischknecht, 2014; Brown, J.P., 2015; Mirza & Hussain, 2014). The summative examination covers all topics studied since the last examination and is held under formal conditions which do not allow for interaction between students or with the teacher. Notes, textbooks and other learning aides cannot be used.

1.3   The Research Problem

The adoption of Popper's (1999) evolutionary approach to problem solving requires that the first step is the identification and definition of the research problem, from which a tentative hypothesis can be framed about the way(s) in which the problem may be solved.

A satisfactory result on a formative assessment task has been assumed by the teacher to indicate that the student has internalised the knowledge and skills associated with the topic which is the basis of the task (Chansarkar & Raut- Roy, 1987). However, approximately one third of students who perform satisfactorily on the formative task fail to achieve a comparable outcome on a related summative assessment task, suggesting that learning demonstrated in one type of task (formative) has not been transferred to the other (summative) type of task; that is, there is no evidence to support the hypothesis that these students have internalised the knowledge and skills associated with these tasks other than at a superficial level (Morgan, 2000). Black and Wiliam (2009) found that more than one third of all formative assessments had a negative impact on learning. They claimed that it is not the formative assessment process itself but the nature, contextualisation, and timing of the feedback that is responsible for the apparent negative effects. Sutton (2010) calls the factors contributing to the lack of transference "roadblocks" to learning.

Several studies (for example, Black & Wiliam, 2009; Gibbs & Simpson, 2005; Sullivan, 2011) maintain that failure to receive appropriate and timely feedback accounts for the discrepancy between results achieved on the formative and summative assessment tasks.

Formative assessment takes place within the teaching cycle and summative assessment traditionally occurs at the end of the teaching cycle, meaning that considerable time has normally elapsed between when a topic was taught and when the summative assessment of that topic takes place.

Attitudinal factors may also impact upon student results (Al Kadri, Al-Moamary, Magzoub, Roberts & van der Vleuten, 2011; Germann, 1988; Harlen & Deakin Crick, 2003). Overconfidence built on strong performance on the formative task may contribute to students not continuing to work at the same level in the lead-up to the summative task (Chiu, 2016; Erat, Haluk & Demirkol, 2016; Sheldrake, 2016) and student 'maths anxiety' has been reported as impacting negatively on student performance in examination situations (Flegg, 2007).

Many students studying mathematics have consistently demonstrated a high level of functional numeracy, despite describing themselves as 'hopeless at mathematics' (Peters, 2012; Tanner & Jones, 2003; Tett & Maclachlan, 2007). There seems to be no shame attached to being weak in mathematics and lack of mathematical ability is often seen as being passed down through the generations, with some parents describing their children as being just like them, "I could never do maths" or "I always struggled with numbers" (Stockwell, 2002).

Despite these preconceptions, some school programs have shown how previously failing students can succeed given a different learning culture (Earl, 2000; Fullan, 2002; Gurr, Drysdale & Mulford, 2005; Hosking & Shield, 2001; Stoll, 2009). Significantly, many 'failing' students consider numeracy skills to be relevant to their lives. When removed

from traditional secondary mathematics classrooms to alternate programs many of these students apply themselves to mathematical tasks and submit assessments of a high standard (Stockwell, 2002).

1.4   Research methodology

1.4.1   Metatheoretical framework

This case study is framed within a post-positivist framework (Baskerville & Wood-Harper, 2016; Gray, 2004; Ryan, 2006), the aim of which is to generate new insights into a problem of practice. It is now recognised that a reliance on quantitative data alone does not allow for the values and beliefs of teachers in the social context of their work to be fully considered (Lakatos, 1976; Quine, 1953; Popper, 1999) and there is a need 'to fuse description-evaluation, fact-value, quantitative-qualitative methods' in a way that will be valuable for the researcher (Aspin, Chapman & Wilkinson, 1994, p. 42). Consequently, post-positivism has been adopted as it allows the researcher to discover in greater detail what students and teachers believe, what they value, and what their attitudes are whilst not ignoring 'scientific enquiry'. The aim is to produce 'warranted assertions' that can be used to improve practice.

1.4.2   Research methodology

The methodology employed by the post-positivist researcher can be described as modified experimental/manipulative or critical multiplism (Glaser & Strauss, 1967; Strauss & Corbin, 1990). Robinson (1992, p.10) says:

Researchers need a methodology which seeks out such questions, reframes them as theory competition, and which seeks to involve practitioners in their adjudication.

The research that emanates from this pragmatic approach involves the collection of data from a range of sources and the testing of these data against a body of existing literature on the subject (Denzin & Lincoln, 2011). The existing theoretical accounts will compete to best explain what the observations and interpretations have revealed.

Grounded theory, as developed by Glaser and Strauss (1967), is an appropriate methodology for this case study as it seeks to identify the central ideas in the data (Dey, 1999) that answer the research question and provide insights and understanding into the processes taking place (Charmaz, 2002). Concepts are identified, then grouped together into categories, from which a core category emerges. An initial hypothesis is formed (constructed) that is subject to further testing and verification by the addition of new data (Hallberg, 2006). The result is a substantive theory (Glaser & Strauss, 1967; Rich, 2012).

1.4.3 Research methods

This case study employs a 'practitioner-as- researcher' model (Cohen, Manion & Morrison, 2013; Denscombe, 2008; Denzin & Lincoln, 2011). The teacher-researcher conducting this case study held the position of Head of the Mathematics Department in the school where this study took place. She had extensive experience of teaching adults and high school students in a range of educational settings, applying a variety of both conservative and innovative teaching and assessment practices. The teacher-researcher

believed that the Mathematics A students in the study had the potential to achieve summative outcomes that were better reflections of their mathematical skills and abilities. The two participant teachers, who taught the study subject at the study school with the teacher-researcher, were invited to be part of the research team based on their understanding of the research problem. They had both indicated and demonstrated an interest in developing a formative assessment program for Mathematics A students which would enable the students to more accurately demonstrate their mathematical skills and knowledge on subsequent summative assessment items.

The inevitable power differential that resulted from the teacher-researcher being the direct supervisor of the other two teachers who took part in this study were recognised and a plan of action was put into place to ensure that these teachers were adequately protected from any adverse effects that may have resulted from them taking part in the case study: both teachers were participating in the case study of their own free will and were free to withdraw from the study at any time without adverse effects impacting on either their role as teachers at the study school or as members of the research team.

Both qualitative and quantitative methods of data collection and analysis are employed (Glaser and Strauss 1967; Punch, 2013). Quantitative methods include collection and analysis of result data generated from the scores students achieved on summative assessment items, while qualitative methods include observations, interviews, questionnaires, focus groups and formative feedback comments. The use of mixed methods enhances the trustworthiness and validity of the research findings. By combining qualitative with quantitative research methods, optimum results from the use

of each method is achieved, while overcoming any of their inherent deficiencies (Denzin & Lincoln, 2011). Triangulation inherent in this research design allows the data to be validated from multiple perspectives.

By drawing on data collected from interviews with students and teachers, the teacher-researcher aims to identify those beliefs and values that these data sources have been least willing to abandon in their talking and thinking, the theories that are embodied in these beliefs and values and the 'touchstone' areas in which agreement appears to exist among and between them. The teacher-researcher's task is to make a choice, to decide which is most plausible. Criteria to be applied to this decision-making process are offered by Evers and Lakomski (1991) and reflect the principles of simplicity, explanatory power, testability, economy, and fit with existing knowledge.

1.5   Research question

The role and functions of both formative and summative assessment, and the implications of these for assessment practice and policy, warrants ongoing attention from educators. Teachers are called upon to engage with research evidence and to participate in research studies related to their classroom practice with the aim of enhancing student achievement (Nolan, 2011; Sutton, 2010). Sutton (2010) concludes that teachers need to not only understand the principles of assessment, but also a commitment to implementing these principles, sometimes at the expense of familiar teaching practices.

A body of research (for example, Brown, G., 2015; Falchikov, 2013; Keeley, 2015) has indicated that certain factors associated with formative assessment are instrumental in

improving learning: providing effective feedback to actively involving students in their own learning, adjusting teaching to consider the results of assessment, recognising the influence assessment has on student motivation and self-esteem and the need for students to self-assess and understand how to improve their performance. Whether these factors and others have the capacity to improve summative outcomes for students of Mathematics A is the focus of this research.

Therefore, the key research question is: Does the implementation of more comprehensive model of formative assessment improve the results achieved by Year 12 students in summative assessment tasks in Mathematics A?

1.6   Significance of the Research

There are several potentially negative consequences for students, and for the school, if there is a significant discrepancy between formative assessment feedback and the evidence of learning provided in summative assessment items. By addressing the desynchrony between formative and summative assessment, there are likely benefits for:

- individual students, as a better summative assessment outcome will, potentially, improve their chances of gaining their first preference of tertiary course or employment;

- the school, by reducing the negative impact of poor summative results on the overall school ranking (a poor score by some students has the capacity to reduce the scores of the entire year twelve cohort (QSA, 2011) - conferring a disadvantage to all students in that year).

This study differs from other studies (Balan, 2012; Brown, Harris & Harnett, 2012; Cooper & Cowie, 2010; Crisp, 2012; Havnes, Smith, Dyshe & Ludvigsen, 2012; Lebler & McWilliam, 2009; McEntarffer, 2012; McGatha, Bush & Rakes, 2009; Peterson & Irving, 2008; Torrance, 2012; Vingsle, 2014; Wiliam, 2010) in that it seeks to identify the 'roadblocks' and barriers that negatively impact upon student achievement in summative assessment by formulating a process of formative assessment that takes these limiting factors into account and applies them in a timely and iterative way in pursuit of improved summative outcomes.

1.7 Overview of the Thesis

The first chapter of this thesis introduces the case study, describes the aim of the study, the research question, its metatheoretical framework, research design and methods.

The second chapter outlines the essential characteristics of formative and summative assessment processes in Mathematics A in Queensland.

The third chapter reviews the literature relating to the research problem.

The fourth chapter describes context and participants of the research and situates the methodology in a post-positivist framework. It describes the methods used and how the data will be analysed.

The fifth chapter presents the results of the study.

The sixth chapter presents a discussion of these results and suggests conclusions, the limitations of the study and possible directions for future research.

Chapter 2   Mathematics A in Queensland

2.1   Introduction

Mathematics A is a Queensland Studies Authority ("the Authority") subject (Queensland Studies Authority (QSA), 2010) available to students in their final two years of secondary schooling. There are two other levels of Mathematics available – Mathematics B and Mathematics C – which are normally studied by more academically able students. Mathematics C (applied mathematics) is only available to high achieving mathematics students who study Mathematics B concurrently.

The selection of either Mathematics A, B or C is based on students' mathematics results in Year 10 and is influenced by their career aspirations. Mathematics A tends to be the subject selected by students who have not previously experienced success in mathematics. Mathematics A Syllabus is sometimes referred to as "real life maths", as its curriculum includes financial mathematics, construction, navigation, networks, statistics, and probability – the mathematics often used in personal and work situations.

Some movement from Mathematics B to Mathematics A takes place during the final two years of schooling, mostly because a student fails to achieve a passing grade (50%) in Mathematics B or has decided on a tertiary course that does not require the higher levels mathematics as a prerequisite. Students who are not able to pass a semester (a semester is made up of two terms in either the first or second half of one academic year) of Mathematics A transfer into the Short Course in Numeracy (QSA, 2013d), a non-Authority subject that does not contribute to the tertiary entrance score.

Mathematics B and C, as well as Mathematics A, contribute to each student's overall position (OP) score for tertiary entrance (QSA, 2011). Mathematics A is the equivalent of Mathematics B and C in terms of the allocation of points for tertiary entrance, although Mathematics A is ineligible as a prerequisite for specific tertiary courses (Mathematics B is the prerequisite for tertiary mathematics and science courses and Mathematics C provides an advantage to students studying engineering or other tertiary mathematics based courses).

The Authority describes Mathematics A (QSA, 2013b, p. 11) thus:

> Mathematics is an integral part of a general education. It can enhance understanding of our world and the quality of our participation in a rapidly changing society. Mathematics A emphasises the development of positive attitudes towards the participant's involvement in mathematics. This development is encouraged using relevant personal and work-related learning experiences. There is also a focus on the development of mathematical knowledge and understanding through investigative and explorative approaches to learning. Mathematics A continues to develop in response to changes in society and, in turn, it influences further societal development.

The Mathematics A Syllabus contains nine core and two elective topics which mostly have a pragmatic theme (mathematics applicable to personal circumstances or to work). Assessment in Mathematics A is school-based and moderated by a series of district and State panels. Schools submit a range of student work portfolios from the Year 11 and 12

cohorts to a district panel each year (QSA, 2013b; 2013e), where work samples are scrutinised by teachers who deliver Mathematics A in several different schools - a process designed to ensure validity and uniformity of grading. During this research, the panel was made up of 23 Mathematics A teachers who, in addition to reviewing the student results achieved on the summative assessments, also scrutinised the marking and grading processes used in each school.

The school in which this study took place mandated that all senior students undertake either Mathematics A or Mathematics B in their final two years of secondary schooling. This imposed an implicit obligation on the school to support less able mathematics students.

2.2   Overall Position (OP) Score for Tertiary Entrance

Results in Authority subjects count in the calculation of Overall Position (OP), the most common selection device used by the tertiary sector in Queensland. The OP Score system (QSA, 2011, 2103c) ranks each school based on the achievement of its Year 12 students: the OP Score is calculated based on a student's achievement on the Queensland Core Skills Test (Wainwright, Wright, Luciano, Montgomery, Geffen & Martin, 2006) and the results obtained in other subjects being studied.

For the purposes of the panel system and for university entrance, Year 11 Mathematics A was considered formative - results from this year did not impact on a student's OP Score (QSA, 2010) – whereas Year 12 was summative, with results contributing to the OP score.

2.3 Pre-case Study Year 12 Formative Assessment

Mathematics A was delivered in every school in Queensland according to the Mathematics A Senior Syllabus 2008 (QSA, 2013b). This Syllabus prescribed the standard and type of questions to be included on summative assessment items conducted in the final two years of Mathematics A. The Syllabus was non-prescriptive in relation to formative assessment. Each school determined whether to include formative assessment processes into their teaching schedule of Mathematics A. Teachers of the subject decided if, when, and how formative assessment in Mathematics A would take place in the school. In practice, most schools delivered some form of formative practice test to students prior to the summative assessment. This was generally supported by formative revision questions prior to the summative examination that were marked by the students. At the school where this study took place formative assessment was an essential component of the Mathematics A program (Figure 1). Compared to other schools in the region, the study school placed a higher priority on, and had developed a reliance on, formative assessment to support students in their studies of senior Mathematics A. Prior to the introduction of the intervention that is the basis of this study, a mid-term formative test was conducted based on the topics studied during the first four weeks of each term. This mid-term formative test was marked by the teacher: students were shown their corrected test and advised of the marks achieved (out of a possible 25). Students were not able to keep the corrected test; rather, they were provided with a clean copy of the test and the correct solutions for use when revising for the summative examination.

Figure 1   Pre-Case Study Formative Assessment Program

Formative Assessment Program
- Draft Progress Check
- Mid-term 1 Topic Test
- Mid-term 2 Topic Test
- Draft Progress Check
- Mid-term 3 Topic Test
- Mid-term 4 Topic Test
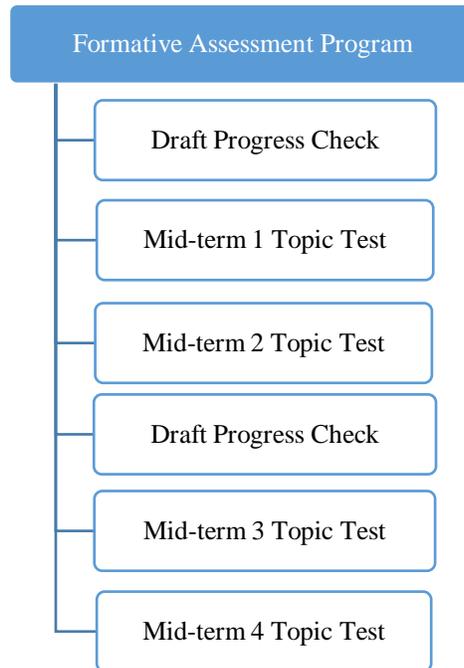
The formative process also supported the summative coursework assignment. Two weeks prior to a summative assignment due date, a progress check was implemented to ensure that students had made satisfactory progress on the summative item (completion of 75% of the knowledge and procedures section and commencement of the first modelling and problem-solving question).

Students who achieved less than 50% on any formative assessment task were targeted for interventionist strategies prior to the summative examination held at the end of the term. The parents of these students were contacted by the teacher prior to the summative examination to discuss strategies for improving the student's performance. This strategy reflects the approach successfully implemented in Finland (Hendrickson, 2012): one-on-

one assistance provided during class or at after-school tutoring sessions. However, this model of intervention has not been shown to consistently improve student outcomes on the summative examination (Mills & McGregor, 2016; Wiliam, Lee, Harrison & Black, 2004).

2.4 Pre-case Study Summative Assessment Processes

2.4.1 Year 11

Summative assessment processes remain unchanged during the case study period from those which operated beforehand. Selected Year 11 assessment results contributed to the student's grade at the end of each semester. These results were reported in a cumulative way – each student's summative assessment results were combined, as directed in the QSA Mathematics A Syllabus (2013b), to produce an A to E grade.

Within each A to E grade there were ten bands (e.g. E1 is the lowest band through to the E10, the highest). Students were ranked to these bands by matching the evidence they provided in their responses to the summative assessment items to the QSA Assessment Criteria for Mathematics A (Appendix A). This process was fully described in the QSA Mathematics A Syllabus (2013b). A pass grade of C in at least one semester of Mathematics A qualified a student to be awarded the Queensland Certificate of Education (QSA, 2013d).

2.4.2 Year 12

In Queensland secondary schools, summative assessment is accorded a high priority and student work is primarily focussed on maximising the OP score (QSA, 2011, 2013c).

School-based assessment in Year 12 Mathematics A included a range of summative assessments as shown in Figure 2 (QSA, 2010), including four formal examinations (held at the end of each term) and two coursework assignments, such as practical reports and extended modelling and problem-solving tasks (administered midway through Terms 1 and 3). The summative items completed during a term contributed to a student's grade at the end of that term. The results from each term were cumulative; that is, the grade achieved by a student in Term 2 was based on the grade received on summative items in both Terms 1 and 2, and so on. The Term 4 report card provided an overall grade representing achievement on all summative items completed over the full school year.

The three-hour summative examination held at the end of each term covered all topics taught since the previous summative examination in two sections: Knowledge and Procedures (KAPS) and Modelling and Problem Solving (MAPS). The KAPS section included 16 - 20 questions that ranged in difficulty from D (lowest) to A (highest) standard questions. To achieve an overall A standard, the student had to score 85% or better (70% to 85% = B; 50% to 70% = C; 25% to 50% =D; less than 25% = E grade). The MAPS section of the examination assessed conceptual skills in four problem-solving areas, each of which was graded according to the QSA Assessment Criteria for Mathematics A (2013b).

The Authority prescribed that teachers assess mathematical skills individually as well as part of a problem-solving activity. These skills were then assessed holistically within a summative assessment task. A Communication and Justification (C&J) grade is assigned

for each summative assessment task (QSA, 2013b), based on the QSA Assessment Criteria for Mathematics A (Appendix A). Consequently, student grades for KAPS, MAPS and C&J accumulated as the year progressed and the QSA Senior Syllabus (2010) provided the criteria for assigning exit scores in Mathematics A.

Figure 2   Pre-Case Study Summative Assessment Program
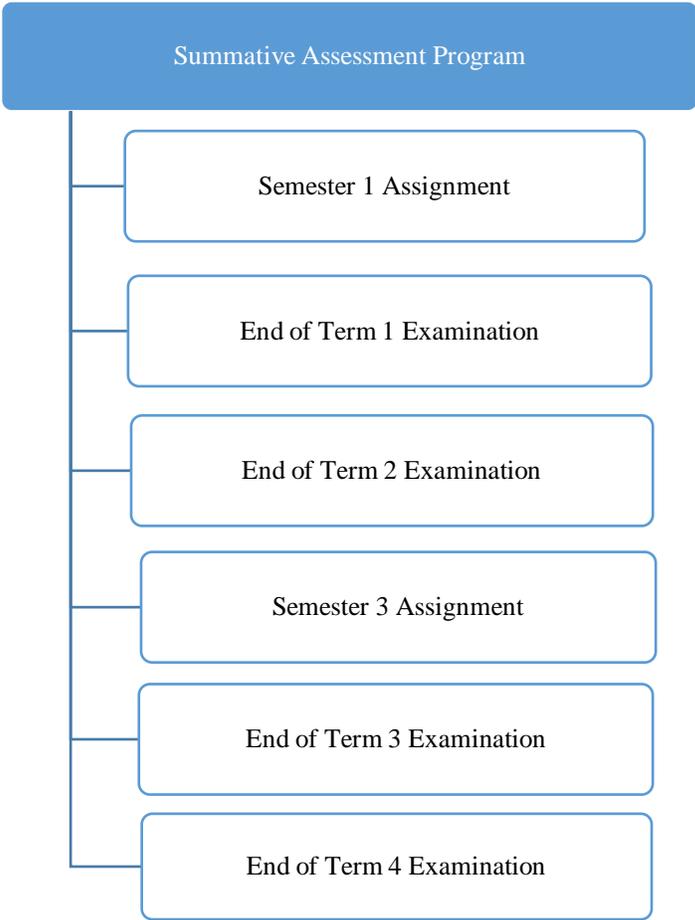
A summative coursework assignment was undertaken in Terms 1 and 3; it included 6 - 10 knowledge and procedures questions and 2 -3 modelling and problem-solving tasks. Both sections included routine questions which were closed and non-routine questions

which contained purposeful, open-ended "rich tasks" (Cooper, Nuyen & Baturo, 2003; Plummer, 1999; Queensland. Department of Education, 2000).

2.4.3   Previous Outcomes in Mathematics A

In previous years the summative outcomes of students in Mathematics A had followed a predictable pattern. Many students experienced a marked drop in grade in Term 1 of their final year, compared to the grade they had achieved at the end of the previous year. This was attributed to the increased rigor of the subject matter and the summative assessment items in the final year of secondary school. In Year 11, a heavy reliance had been placed on informal and formal formative assessment processes which addressed the basic concepts required by students for the final year of Mathematics A. Many students demonstrated increasing mastery of the mathematical skills included in these formative assessment tests and tasks. However, when undertaking summative assessment tasks these same students failed to demonstrate the level of mastery indicated on their formative assessment items. This discrepancy between the students' formative and summative results formed the basis for this study.

Chapter 3   Literature Review

3.1   Introduction

This chapter provides a review of the literature relating to the assessment of student learning, with emphasis on the significant influence of formative assessment in senior school mathematics. The literature suggests that both formative (Irons, 2007) and summative (Norton & O'Connor, 2016) assessment processes are powerful factors influencing intrinsic motivation of students – their desire to learn - and extrinsic motivation – the need to learn. The characteristics, effects of, and influences on formative assessment are presented. Four models of formative assessment are introduced, and the key factors identified by the literature as being crucial to improving formative assessment practice are compared and contrasted.

3.2   Summative Assessment

Morgan (2000) described the primary purpose of assessment in mathematics as the discovery and measurement of the mathematical attributes of individuals. Summative assessment (Norton & O'Connor, 2016; Yan, 2014) investigates student knowledge through short content-based questions and poses modelling and problem-solving questions where mathematical skills are applied to real world problems or mathematical simulations. Summative assessment is designed to capture a snapshot of the student's mathematical skills and applications at a point in time. The student's response is marked, and a grade assigned according to prescribed criteria (QSA, 2010). This grade is taken to

indicate both a student's mathematical ability and their mathematical knowledge at that point in time (Parsi & Darling-Hammond, 2015).

3.3   Formative Assessment

3.3.1   A new direction

Many researchers (Barkley, Cross & Major, 2014; Boaler, 2015; Connell, 1996; Cunningham & Duffy, 1996; Ellis & Berry, 2005; Fry, 2012; Reeves & Okey, 1996; Waddington & Weeth Feinstein, 2016) have challenged the traditional educational approach of memorisation and rote learning, contending that these approaches to teaching do not probe the reasoning behind students' answers. These researchers contend that traditional assessment methods are behaviourist in their approach, focussing on the testing of discrete facts and skills and the provision of marks and grades (Niss,1993). Kilpatrick (1993, p. 44) argued that an alternative vision is necessary: "How can we create a mathematics instruction that helps students to use it better, more rewardingly and more responsibly?"

A new direction in research (Abdal-Haqq, 1998; Black & Wiliam, 2005a; Etengoff, 2016; Gardner & Gardner, 2012; Kolb, 2014; Waddington & Weeth Feinstein; 2016; Wiliam, Lee, Harrison & Black, 2004) investigated whether constructive formative assessment processes based on the work of Piaget (Piaget, Beth & Brousseau, 2014) and Vygotsky (Etengoff, 2016; Vygotsky, 1986) could reliably and accurately demonstrate whether learning had occurred. The result was a move towards a more authentic form of assessment with a focus on conceptual and procedural understanding (Albion, 2014; Goos, Vale & Stillman, 2017; Lesh & Lamon, 2013; Llewellyn, 2012, 2017), rather than

on detailed explanations of concepts. The need for formative assessment processes that probe a student's understanding of mathematical concepts is 'fundamental' according to Ginsburg (2009), while Ziebarth (2004) demanded an approach that identifies the skills which enable students to problem-solve. The researcher concurs with this view.

This enthusiasm for more authentic formative assessment is tempered by the considerable ambiguity evident in the literature purposes (Black, 2015; De Lisle, 2015; Poole, 2016; Rodrigues & Oliveira, 2014; Van der Kleij, Vermeulen, Schildkamp & Eggen, 2015) concerning its definition. Although two primary purposes for formative assessment have been proposed by Nolan (2011) – providing information to teachers about student learning to help them plan or modify instruction and giving feedback to students to help them improve their performance – agreement about its attributed purposes, as well as the best means of achieving them, is not universal (Fisher & Frey, 2015; Vonderwell & Boboc, 2013; Wylie & Lyon, 2015). Ambiguity in definition and purpose is further amplified by divergent classroom practice (Parker & Rennie, 1998).

The term 'formative assessment' has come to take on different meanings in differing situations (Bennett, 2011; Taras, 2007). Despite the divergence in views, Lam (2013) and Shute & Kim (2014) contend that the classification of a task as formative or summative depends not on the nature of the task but on the way the product or outcome is used. In accord with this perspective, Black and Wiliam (1998b, p.140) defined formative assessment as

> …all those activities undertaken by teachers—and by their students in
>
> assessing themselves—that provide information to be used as feedback

to modify teaching and learning activities. Such assessment becomes

formative assessment when the evidence is used to adapt the teaching to

meet student needs.

'Assessment for learning', a term coined by Stiggins (2005), is assessment, therefore,

that broadly reflects upon and responds to information about student learning obtained

through discussion, demonstration and observation in ways that enhance ongoing

learning, (Klenowski, 2009, p. 264). Yet, despite the conviction of Black and Wiliam

(1998b), Klenowski (2009) and others (Ginsburg, 2009; Llewellyn, 2012, 2017;

Shepard, 2007) found little information describing the essential elements of formative

assessment that could be demonstrated to enhance student learning.

3.3.2   Characteristics of effective formative assessment

Nolan (2011) maintained that, to be fully effective, feedback must be provided in

a way and at a time that gives students an opportunity to act on that feedback. Feedback

needs to be structured in such a way that, although it may at times be critical, it

encourages the student to persist and provides necessary information about work quality

and potential strategies for improvement (Butler, 1987; Thorkildsen, Nolen & Fournier,

1994; Wilson & Wineburg, 1993). Nolan (2011) asserted that formative assessment must

be placed within rather than at the end of the learning cycle, to maximise its potential

benefits.

If the goal of improving grades is seen by students to be the main purpose of the

feedback provided and the learning function is underemphasised, its potential to produce

improvement may not be realised (Black, Buoncristiani & Wiliam, 2014). Havnes et al. (2012) maintained that effective feedback must be critical, clear and constructive as student perceptions about the usefulness of feedback is related to the way it is given and the language in which it is delivered. In this case study, this conception of effective feedback is central.

Tong's (2016) study in Malaysia found that not all students have the strategies to effectively collect, organise and use feedback. Brookhart (2017) advocated a slight delay in giving feedback to allow teachers to gain more comprehensive views of student thinking and processing and to enable them to respond in a way that takes cognisance of a student's circumstances and readiness to respond. In mathematics education, Bransford, Brown & Cocking (2000) argue that feedback must address not only topics in which a student has demonstrated poor comprehension, but the level of mathematical reasoning at which point the student stopped engaging with the material, a view mirrored in the work of Hattie and Timperley (2007) which asserts that that appropriate feedback 'can assist students to comprehend, engage and develop effective strategies' to process mathematical information.

To achieve these goals, feedback needs to provide specific and useful advice to the student on areas where s/he is demonstrating poor achievement and suggest ways to address the deficit (Stiggins, 2005). A student's response to formative assessment ideally results in an action plan for both teacher and student, working together to address areas of under-performance (Brown, Harris & Harnett, 2012; Hiebert & Carpenter, 1992). This dictate may challenge well-established teaching practices (Poole, 2016).

Black and Wiliam (1998a) investigated the importance of the perception of students and the role of self-assessment (self- evaluation of the quality attributes of one's own work) in formative practices.

This self-evaluation draws on metacognitive competencies; for example, self-observation, self- judgment, self- reaction, task analysis, self- motivation, and self-control (Brown, G. 2015, p. 4). Self-assessment has been shown to promote self-regulated learning (Andersson & Palm, 2017) and to encourage students to generate their own task or process level feedback (Timmers, Walraven & Veldkamp, 2015). Panadero and Jonsson (2013) found that a student's performance on formative assessment items improved if they self-assessed, but not if they peer-assessed, a response confirmed by G. Brown's study (2015). G. Brown reported that students stated categorically that "You can't assess your friends" but were comfortable with the process of self-assessment, particularly where an absolute system (fixed criteria/standards) was used in preference to a relative system were students work was compared to that of other students. Ramirez (2010) investigated the reason behind a sudden increase in the grades of students in a multiple-choice test. Students who achieved the increased scores were asked to rank the most relevant factors responsible for their improved performance: namely, the availability of a test for self-assessment before the final test; opportunities to attempt similar questions prior to the actual test. In Finland, improved outcomes on the Programme for International Student Assessment (PISA) (Kupiainen, Hautamäki, & Karjalainen, 2009) has been credited by Hendrickson (2012) as being the result of immediate teacher intervention and student self-evaluation.

In a German study (Harks, Rakoczy, Hattie, Besser & Klieme, 2014) it was demonstrated that when students perceived the feedback as useful, it had a positive effect on their level of achievement and interest. Students in the study had been assigned to either process-oriented or a grade-oriented feedback. Results of path analysis showed that process-oriented feedback was perceived as more useful. A similar effect was achieved in a Taiwanese study (Hwang & Chang, 2011) which used a technology (web)-based learning environment to deliver both learning and feedback. Rather than marking answers as right or wrong immediately, the learning system provided hints or supplementary material to the student to help decide whether the answer was correct and complete. Results showed that the approach encouraged student interest and attitude and improved learning achievement.

Black & Wiliam, (1998b), Burke (2014), Rowntree (2015), Schoenfeld (1994), and Watt (2005) concluded that assessment items needed to be critically reviewed to determine exactly what they were assessing. These researchers also reported that the length and timing of assessments impacted on the success of the assessment process, noting that more frequent short tests gave better results than infrequent long ones.

3.3.3 Positive effects of formative assessment

Where positive effects have been observed, the characteristics of formative assessment that produce improved learning outcomes have been proposed. Hendrickson (2012) and Gibbs & Simpson (2005) maintained that when formative assessment practices were strengthened, significant, often substantial, learning gains - in some cases, up to sixty per cent (Wiliam, Lee & Harrison & Black, 2004) – resulted. Formative

assessment, it is claimed, improves the results of low-level achievers more than that of other students, resulting in a reduction in the range of achievement while raising achievement overall (Black & Wiliam, 2009).

Taras (2010b) and others (Black & Wiliam, 2004a, 2009; Peterson & Irving, 2008; Taras, 2007) have described formative assessment as a process arguing that, for formative assessment to be useful, students need to use the feedback they receive in such a way that future learning is enhanced. Taras (2007, p. 3021) states that "The process of formative assessment can only be said to have taken place when feedback has been used to improve the work", that is, it proactively improves learning outcomes (Nicol & MacFarlane-Dick, 2006). Torrance (2012) concludes that the purpose driving the development of a formative assessment model, whether it be critical and creative thinking, improved student grades or assessment of learning, must be at the centre of the process.

Feedback on how a task has been processed by a student and feedback that assists a student to develop skills in self-regulation has been found to be efficacious (Hudesman, Crosby, Ziehmke, Everson, Isaac, Flugman, Zimmerman & Moylan, 2014). Earley, Northcraft, Lee, and Lituchy's (1990) study found that process feedback developed the ability of students to devise their own learning strategies. Savery (2015) further noted that formative assessment and feedback on performance reinforced the self-reflective nature of learning and sharpened a range of metacognitive processing skills, promoting active learning and engaging the learner in higher order thinking.

3.3.4 Challenges in formative assessment

Dunn et al. (2009) found limited empirical evidence to support the efficacy of formative assessment. These researchers maintained that significant improvement in research designs was needed if the impact of formative assessment and evaluation was to be more accurately assessed.

Review of the literature suggests that implementation of a successful formative assessment program is not without its challenges (Bennett, 2011; Gibbs & Simpson, 2005; Grosas et al., 2016; Laveault & Allal, 2016; Rizo, 2013; Shute & Kim, 2014). Feedback has been identified as one of the most critical influences on student learning (Hattie & Timperley, 2007), but it's effect is directly related to the way it is formulated, delivered and framed to involve the learner's active engagement (Nicol, 2010; Shute, 2008).

Hattie and Timperley (2007, p. 86) suggested three major feedback questions must be put to students - Where am I going? How am I going? Where to next? – to foster this engagement, and amplify the benefits of formative feedback, while Cooper & Cowie (2010) advocated, as a strategy to actively engage students, the combination of teacher comments with student responses as a means of prompting a student to seek clarification of any feedback comments s/he did not understand, as shown in Table 1.

Table 1   Promoting Engagement in a Formative Assessment Program

(Adapted from Wiliam, 2007, p. 2)

	Where is the learner going?	Where is the learner right now?	Where to next?
Teacher	Clarifying and sharing learning intentions and criteria for success Setting goals for teaching and learning	Engineering effective classroom discussions, questions, activities, and tasks that elicit evidence of learning Identifying barriers and roadblocks to learning	Providing feedback that moves learners forward Establishing ongoing classroom practices and support systems
Peer	Understanding and sharing learning intentions and criteria for success Providing appropriate feedback	Establishing students as instructional resources for one another Setting up mutually beneficial support systems Developing support systems outside the classroom	
Learner	Clarifying learning intentions and criteria for success Identifying and addressing roadblocks	Making students the owners of their own learning Identifying resources that strengthen learning Establishing behaviours to enhance learning	

A major stumbling block for some students in Cooper and Cowie's (2010) study was the lack of understanding of feedback comments. Sadler (1998) had previously highlighted the need for students to be trained to interpret feedback and make connections between the feedback and the work they produced, and how to use that feedback to improve their work. They need to be schooled in a process of planning, action and reflection (Crookes & Chandler, 2001; Greenwood & Levin, 1998). Cooper and Cowie (2010) also identified that the teachers in their study were surprised by the students' lack of personal insight into their own learning processes.

Thongtawat (1992), in his study of the effectiveness of multiple choice tests compared to tests requiring a short answer response, found that secondary mathematics students who scored poorly on a test sometimes exhibited a good conceptual grasp of the material that the test had covered. Cooper and Cowie (2010, p. 980), maintained, in a similar vein, that "Student performance in the recent national mathematics examinations did not adequately reflect the calibre of the student body".

For formative assessment to be adopted in the wider educational community, sufficient evidence that shows that it has succeeded in improving student learning outcomes is essential (Bennett, 2011). Some studies, for example Torrance (2012), Cooper and Cowie (2010) and Black and Wiliam (1998a) have concluded that formative assessment has failed to improve student outcomes, for several reasons. Firstly, the practice of formative assessment is inherently diverse (Bennett, 2011; Dunn et al., 2009; Falchikov, 2013). This diversity may suggest why formative assessment has resulted in improved learning outcomes in some studies and not others. The Minute Math study (Brookhart, Andolina, Zuza & Furman, 2004) found that formative self-assessment improved rote learning in primary aged children and the study conducted by Clements and Sarama (2008) with pre-school students showed significant mathematical learning improvement through the use of formative assessment, as did Doige's (2012) study of email-based formative assessment. The diversity of formative assessment options has resulted in a range of practices being employed. Some studies (Attali, 2015; Bennett, 2011; Konstantopoulos, Miller & van der Ploeg, 2013; Lawrence, Kaplan & Chernobilsky, 2016; Pang, 2016; Wellington, 2015) found it problematic to measure the effectiveness

of the formative assessment process because the research base was too broad, or the practices implemented were unrelated to the intended outcomes.

Despite the enthusiasm for the purported benefits of feedback on learning, there are some caveats that impact on the extent of its effect. Effective formative assessment practices bring to the forefront the importance of classroom culture, which if perceived by students to be positive, creates an environment in which critical feedback is viewed by students as being constructive and non-judgmental (De Luca, Klinger, Pyper & Woods, 2015). Allen, Gregory, Mikami, Lun, Hamre and Pianta (2013), argue that feedback to students needs to be 'sensitive' and situated within a supportive and positive learning environment - one conducive to success.

> Classrooms characterized by a positive emotional climate, with sensitivity to adolescent needs and perspectives, use of diverse and engaging instructional learning formats, and a focus on analysis and problem solving were associated with higher levels of student achievement (p. 76).

Other studies have demonstrated little or no improvement; for example, Black and Wiliam (2005a, 2009) and Wiliam (2007) concluded that formative assessment used as a benchmark or interim assessment had little or no impact on student achievement, while the study by Maier, Wolf and Randler (2016) found that computer-assisted formative assessment practices can have a zero or negative effect on student achievement. Torrance (2012) described the development of a formative assessment model in a higher education setting in which highly conformative assessment procedures were designed

and developed as instruments for formative assessment, finding that no clear link existed between formative assessment and improved student grades.

There are several negative effects associated with formative assessment reported in the literature (for example, Black, Buoncristiani & Wiliam, 2014; Chu, 2014) - loss of confidence and increased anxiety on the part of the students (Black, Buoncristiani & Wiliam, 2014; Nicol & MacFarlane- Dick, 2006; Panadero & Jonsson, 2013) and negative feedback eroding student self-confidence (Black, Buoncristiani & Wiliam, 2014; Nicol & MacFarlane- Dick, 2006; Panadero & Jonsson, 2013).

Black and Wiliam (1998b) identified several inhibiting factors affecting the validity of formative assessment: the predisposition of teachers to assess the amount of work and its presentation rather than quality of what was presented; the willingness to give greater attention to marking rather than on providing advice for improvement; the tendency for feedback to have a managerial focus rather one which helps students to learn more effectively; and, lack of teacher understanding about students' learning needs.

Consequently, Andrade and Cizek (2010) debated whether the anticipated benefits outweighed possible negative effects (Black, Buoncristiani & Wiliam, 2014; Chu, 2014) such as loss of confidence and increased anxiety on the part of the students (Black, Buoncristiani & Wiliam, 2014; Nicol & MacFarlane- Dick, 2006; Panadero & Jonsson, 2013) and negative feedback eroding student self-confidence (Black, Buoncristiani & Wiliam, 2014; Nicol & MacFarlane- Dick, 2006; Panadero & Jonsson, 2013).

3.3.5 Formative assessment in mathematics

Sutton (2010) identified several roadblocks to learning in senior mathematics. Mathematics is often taught in discrete units or blocks. The relative fragmentation of this subject meant that teachers were sometimes unable to correct skills which had not been mastered in one topic before moving on to a new topic. Sutton reported that if different aspects of mathematics that were not clearly related were taught sequentially, teachers often struggled to help students to see the links between feedback on a previously completed assessment item and a new unit of work.

Buxton (1978) asserts that both formative and summative tests encourage rote learning (where information is imprinted in memory) and instrumental understanding (using rules without reason). This theme is taken up by Kieran (1992) who reported that students who failed to conceptualise a mathematical formula often resorted to memorising the procedure. These researchers and others (Blum, Galbraith, Henn & Niss, 2007; Hailikari, Nevgi & Lindblom-Ylänne, 2007; Lederman, 2016; Lesh & Lamon, 2013; Skemp, 1976) suggest that success on a test reliant on memorisation and rote learning would not, necessarily, predict success on an assessment task that probed for deeper relational understanding.

The work of several researchers (Bannister & Linder, 2015; Dixson & Worrell, 2016; Harks, et al., 2014; Wiklund- Hörnqvist, Jonsson & Nyberg, 2014; Wiggins, 2016) has also refuted belief in the value of marking and feedback on summative tests, challenging the presumption these practices will lead to improved learning outcomes on the next unit of work. Skills taught or feedback relating to one unit may not be relevant to subsequent

units of work. Nolan (2011) and Cooper & Cowie 2010) have challenged the assumption that students use what they learn from formative feedback to improve their performance in subsequent tasks. Nolan reported that students found it difficult to relate feedback to subsequent tasks when the new tasks were perceived to be dissimilar to the task eliciting the feedback. This perception also persisted when feedback came from other than the teacher. Peeters, Dochy, Onghena and Struyven (2010) found that peer feedback on one task did not improve student learning on future assessment tasks when this feedback could not change the outcome of the assessment item it addressed. The teachers in Havnes et al.'s study (2012) believed that students ignore written feedback and were only interested in the grade they had achieved. This contradicted student views.

Harlen (2006) raised the issue of the relationship between formative and summative assessment. Adendorff (2007) highlighted the need for reflexivity to enhance rigour in formative assessment practices for senior mathematics.

3.4 Influences on formative assessment

3.4.1 Test theory

Test theory has been traditionally applied to mathematics assessment (Hambleton & Swaminathan, 2013; Wainer & Thissen, 1993). Assessments based on test theory (Lord, 1980; McDonald, 2013) are mostly limited to discrete low level mathematical skills and normally involve a set of questions reflecting the procedural aspects of the topic being tested. The teacher marks each question as correct or incorrect and then assigns a score to each student's work.

McDonald (2013, p. 2) questioned whether, "If one score is sufficient, how accurate is the measure of mathematical knowledge?". Mathematical assessments based on test theory have, therefore, been increasingly criticised. Some researchers (for example, Chansarker & Raut-Roy, 1987; Danielson & Marquez, 2014; Kogan & Laursen, 2014) have expressed concern about this type of assessment process and have demanded closer scrutiny of the methods used to measure achievement in mathematics. The assumptions of test theory are inconsistent with those emerging from cognitive and education psychology that a higher level of formality and rigour to adequately assess comprehension and application of both precrural and conceptual understanding in mathematics is required (McDonald, 2013).

3.4.2 Policy

Black and Wiliam (1998a) suggest that the instructional impact of assessment can be strongly influenced by policy decisions. Schwartz (1990) claims the decisions by authorities, who develop and implement public policy based on what is known and agreed as successful processes in teaching, are not always influenced by what is agreed by educators as best practice in the teaching of a subject such as mathematics. Black and Wiliam (1998b, 2005b) warn that a focus on standards and accountability alone will not provide teachers with the information needed to improve the processes of teaching and learning. Black & Wiliam assert that where authorities pay scant attention to formative assessment processes, making their main preoccupation summative assessment and the recording of data for certification and evaluation, the educational outcomes will be diminished.

There are several examples where policy has pre-empted educational debate: the adoption of ICT in schools has been implemented in Australia with little attention to evidence regarding its impact on student learning (Skryabin, Zhang, Liu & Zhangi, 2015); the incorporation into the Australian Education Act 2013 of the goal for Australia to be in the 'top five' in the Programme for International Student Assessment (PISA) by 2025 is triumph of policy over practice and funding (Masters, 2016). Gorur and Wu (2015) had argued that a more nuanced understanding would point to quite different policy actions in cases such as these.

A national Declaration on Educational Goals for young Australians had two prime goals (Ministerial Council on Education, Employment, Training and Youth Affairs, 2008):

- the promotion of equity and excellence; and
- for all young Australians become successful learners, confident and creative individuals, and active and informed citizens.

At the time that this study took place, the Queensland Government had released an inclusive education policy statement based on the Declaration stating that:

> Education policy in Queensland ensues that schools are supportive and engaging places for all school community members. It builds communities that value, celebrate and respond to diversity. It is underpinned by respectful relationships between learners and school community members. It is supported by collaborative relationships with parents and communities through communication, learning partnerships, participation and consultative decision-making.

Inclusive education means that every day in every classroom, every state

school student is learning and achieving in a safe, supportive, inclusive

and disciplined learning environment. (DEET, 2017).

This statement of policy informed the day-to-day teaching in the mathematics classroom by ensuring that all students were given equal opportunities to learn, to succeed and to achieve their goals. This study was responsive to this policy direction, in that it sought insights into ways to better support underachieving mathematics students and to enable them to achieve improved learning outcomes.

3.4.3 Teacher factors

Teacher knowledge and understanding of mathematics, their reliance on grading, the nature of the learning environment they create, the instructional strategies they employ (including the way they probe for understanding) all impact on formative assessment outcomes in mathematics. An evidence-based study by Heritage, Kim, Vendlinski and Herman (2009) found that clear goals were essential in developing a program of formative assessment. The study concluded that teachers have better skills in some areas than in others; for example, they are 'better at drawing reasonable inferences about student levels of understanding from assessment information than they are at deciding the next instructional steps' (p. 24).

Teacher knowledge and understanding of mathematics

Teachers anxious about their own ability to teach the subject and their understanding of it have been demonstrated to adopt teaching practices characterised by whole class instruction and a substantial reliance on traditional instructional activities

with an over-emphasis on drills, flash cards, and work sheets (Geist, 2015). In addition, their teaching tends to concentrate more on basic skills rather than on concepts, with the impression given to students that there is only one correct way to complete a problem (Gurganus, 2017).

Teachers have been encouraged to use formative assessment processes to evaluate the rigour of their own teaching (Chappuis & Chappuis, 2009). May (2015) reported on his study in which teachers were instructed how to evaluate their practice in relation to how best to instruct and assess formative assessment so that students would be able to develop their mathematics abilities in an optimal manner. This, and the study by Beswick (2014), raised issues of teacher competence in higher level mathematics. Bakx, Baartman and van Schilt-Mol's study (2014) on teaching competence involving eleven senior teachers and seventy students reported weak acceptance by the teachers of the demonstrated competency level of the teachers involved.

The teacher-researcher's experience of working with others with varied mathematical backgrounds and degrees of confidence in their ability to teach the subject confidently, confirmed that teachers of mathematics who lacked confidence in their own mathematical skills placed a heavy reliance on whole class instruction, drills of basic skills and working through examples provided by textbooks. These teachers were anxious and expressed concern when it was suggested that they examine their own pedagogical practice with a view to tailoring teaching strategies and the classroom culture to meet the needs of the learners. The teachers described their focus as 'getting through the work' and 'making it through each lesson'.

Grading of student work

Goldin (1992) observed that the methods used by schools to assess mathematical understanding may have a detrimental effect on meaningful learning (Lesh & Lamon, 2013; Niss, 2013; Rowntree, 2015). Several formative assessment and feedback practices have a potentially negatively impact on student learning. Assigning grades to formative assessment has been associated with minimising the achievement of optimal outcomes. Butler (1988) observed that, when students are assigned a grade for their work, the impact of other feedback is minimised. Kluger and De Nisi (1996) reported that in their study over one-third of 'feedback interventions' had a negative impact on performance. Grading of student work was shown to inhibit student cognitive processes. A similar impact was reported by Elawar & Corno (1985) in which grading resulted in a slowing of student learning and depressed creativity; Butler and Nisan (1986) maintained that it fostered fear of failure and weakened student interest, while Lipnevich and Smith (2009) noted that low grades had a negative on students' sense of self-efficacy and high grades decreased motivation and lessened students' perceived need to improve.

In contrast, non-graded feedback - comments, rubrics, discussion and modelling – has been reported as having a positive and productive effect on the learning process and improving learning outcomes (Irons, 2007; Lipnevich & Smith, 2009; Peeters et al., 2010). Vollmeyer and Rheinberg (2005) noted that learners expecting feedback rather than grades planned their approach to each problem more carefully and used better strategies from the start, strategies based more on identifying the information given about the task and developing a plan of attack than on trying to guess the correct answer.

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A recent study in the Republic of Ireland (O'Mahoney & Heinz, 2016) identified that the grade orientated system of senior mathematics in Ireland has resulted in a grade-centred performance mindset in the students. Despite this, the study identified that most of the participating students found the comment-only method of assessment useful and recognised its benefits in improving their engagement and understanding; comment only marking provided clear goals for students linked to assessment criteria, thus encouraging independent learning and self-assessment. This study showed that students recognised the benefits of task-oriented comment-only feedback. There were differences in perception between students of different abilities: the students who challenged comment-only marking were high achievers who were concerned about their final results. Seeking teachers' reactions to comment-only marking, Ernst (2014) observed that some teachers were disappointed by students ignoring their carefully crafted comments, commenting: "The students didn't even read our supportive comments, which was disheartening", and others reported that while comment-only marking appeared to help students, the gain needed to be balanced against the extra time needed in the teachers already-busy schedule.

Learning environment

While traditional instruction has been mooted as a contributor to poorer learning outcomes in mathematics (Noddings, 2015), so too is the culture of the classroom (Rickards, 2009). The term 'classroom culture' embraces its presiding ethos and characteristics, as well as the way individuals interact with and treat one another (Fisher, den Brok & Rickards, 2006) and the ways in which the teacher organises the educational setting to facilitate learning (Abbott, 2014; Fraser, 2000).

Classroom culture is subject to often unspoken, and frequently unconscious, assumptions about how the teacher and the students are expected to behave and interact (Rickards, Newby & Fisher, 2000). When instruction is provided in a structured, inflexible class which provides little opportunity for questioning or discussion, where the focus is on looking for 'the one right answer' with little or no encouragement for students to reflect on alternative solutions, mathematics learning is impeded (Shields, 2005).

Experiences of learning mathematics in structured, rigid classrooms include little opportunity for debate or discussion, focus on searching for the one right answer, provide limited encouragement to reflect on thinking, foster expectations of a quick answer, and emphasise timed tests (Shields, 2005).

In such classrooms, it is likely that both overt and covert teacher behaviours are implicated in fostering negative attitudes towards mathematics (Breen, 2004). Unrealistic expectations of students, hostility or intimidation of weaker students who are often embarrassed in front of peers when a concept is not understood, giving poor explanations and gender bias often manifest themselves in these circumstances (Shields, 2005).

Teaching practices

Teacher expectations impact the pace at which the lesson proceeds and if the teacher over- or under-estimates student capabilities or holds unrealistic expectations of students there can be numerous long-term effects on a student's construction of identity (Black, 2003; Boaler, 2000). Carefully designed lessons that support eliciting and

building on student thinking can change teachers' beliefs about student learning and change their teaching practices (Seashore, 2015). A willingness and ability to be a self-critical thinker, combined with ongoing self-assessment and monitoring of teaching practice, have been identified as characteristics of a reflective mathematics teacher (Artzt, Armour-Thomas, Curcio & Gurl, 2015).

The efficacy of probing student understanding of mathematics (Byers, 1980; Byers & Herscovics, 1977; Canobi, 2005) has been well demonstrated as critical in promoting better learning outcomes. Limited attendance to, or probing of, students' thinking by the teacher means judgments about their mathematics understanding are more likely to be based on written work, which is often the primary source of students' anxiety (Shields, 2005). Probing questions from the teacher help students to build on what they understand (Artzt, Armour-Thomas, Curcio & Gurl, 2015; White, 2014). Using probing questions to facilitate an augmentation discussion can test whether students can let go of long-held misconceptions which are adversely affecting their learning (Keeley, 2015; Keeley & Tobey, 2016).

Cooper and Cowie (2010) have called on teachers to refine and develop their practice by reflecting on those instances where formative assessment has/has not worked. Teachers in one study reported that they seldom talked to their students to probe their mathematics understanding, being more focussed on determining whether the students understood the process and could repeat the process independently. Probing for understanding during instruction and using formal formative assessment tasks and informal strategies enables teachers to assess understanding of mathematics concepts. Smith and Golding (2017), in

their study of beginning teachers of A level mathematics, found that eliciting student feedback and seeking insights into what their students did/did not know helped new teachers to "Refine teaching goals; consider when and how to introduce rigour; engage with a variety of representations; re-engage as learners; plan and deal flexibly with unusual and unexpected student thinking; differentiate interactions with students, though the depth to which these developed of course varied between teachers" (p. 2).

Reflecting finding from the literature, teachers cited lack of time and a packed curriculum as impeding their efforts to reflect on their own practice and to develop and implement innovative and student-centred teaching strategies, a situation compounded by burgeoning administrative processes and policy-driven professional development relating to issues such as cross-cultural awareness and workplace health and safety (Round, Subban & Sharma, 2016). When teachers are provided with opportunities to engage in professional dialogue and to review their practice, there is a benefit to students and teachers alike (Han & Yang, 2017). These demands are diminishing the opportunity that teachers have to engage in such professional conversations and are eroding time that teachers have available to plan lessons and assessments.

3.4.4   Student factors

Student expectations, their engagement with the subject of mathematics, student levels of frustration and their feelings about mathematics and, all importantly, the anxiety that students experience in the study of mathematics all contribute to the success of formative assessment processes and practices.

Student expectations

Despite critical and creative thinking being enshrined in the Australian Curriculum for Mathematics (Lingard & McGregor, 2014; Sanders, 2016), evidence still points to teachers treating the mathematics curriculum as a body of fixed knowledge to be delivered resulting in students expecting, and relying heavily on, rote learning and recall approaches (Askew, 2013). Challenges from high achieving students and senior students focussed on examination scores for career progression drive the maintenance of traditional methods resulting in pedagogical approaches strongly influenced by exam pressures (O'Mahoney & Heinz, 2016; Stephens, 2014).

Student engagement with mathematics

In education, engagement refers to the degree of attention, curiosity, interest, optimism, and passion that students show when they are in a learning situation. This extends to the level of motivation that they have to learn (Abbott, 2014). Student engagement is pivotal in assuring positive outcomes in mathematics (Bobis, Way, Anderson & Martin, 2015; Lee, 2014; Wilkie, 2016). In several studies (Attard, 2013; Bobis et al., 2016; Brophy, 1999; 2008; Nicol & MacFarlane-Dick, 2006) feedback was shown to increase student motivation and engagement with the learning of mathematics by clarifying how and why learning specific skills and concepts were valuable.

When a student appeared discouraged, disinterested, or disengaged, it has been commonplace to attribute the cause to the student (Afrifa-Yamoah, Cofie, Saeed, Karim & Paul, 2016; Grant, Nutchey, Cooper & English, 2014; Martin, Way, Bobis & Anderson, 2015): their lack of ability, a low level of application to the task, their limited

ability to apply higher order thinking skills, low levels of motivation; the lack of priority placed on mathematics. Although one, or more, of these factors has the potential to negatively impact on student engagement, they may not necessarily be the root cause of the problem (Darling-Hammond, Ancess & Falk, 1995; Gibbs & Simpson, 2004; Nolan, 2011). Other deterrents include language and literacy issues (Grant, Nutchey, Cooper & English, 2014), teacher efficacy beliefs (Bobis et al., 2016), inadequate teaching by non-specialised mathematics teachers (Wilson & Mack, 2014,) mathematics anxiety arising from various causes (Attard, Ingram, Forgasz, Leder & Grootenboer, 2016), a changing youth culture which devalues mathematics (Valero, 2015), and absenteeism (Keegan & Gable, 2016).

Mutual construction of achievement and improvement are needed to enable students to become active participants in the process of classroom assessment and feedback (Tong, 2016). Tong (p.1) noted that "Not all students had the strategies to effectively collect, organize and use feedback. The findings suggest that it is through mutual construction of achievement and improvement that students can become active participants in the process of classroom assessment and feedback".

Pryor and Torrance (1997) suggested that student engagement often depends on the relationship between student and teacher, among peers, and between students and their parent/s. Turner, Christensen, Kackar-Cam, Trucano and Fulmer (2014) reported a direct relationship between teacher motivational support and student engagement which, by implication, demands a conceptualising of student engagement as interpersonal classroom activity. Parental involvement and parental aspirations have been shown to be

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directly related to student academic achievement (Choi, Chang, Kim & Reio, 2015).

Conversely lower overall achievement levels in mathematics have been documented in

students who exhibited negative and disobedient behaviours towards mathematics. This

negative and somewhat pessimistic attitude was found to also predict the quality of the

parent child relationship (Goforth, Noltemeyer, Patton, Bush & Bergen, 2014). Peer

relationships and classroom culture have been shown to have a cumulative effect

(Hornstra, van der Veen, Peetsma & Volman, 2015) on student's attitude to mathematics

and mathematics performance. Peer relationships strengthen through adolescence as

students become more sensitive to peers' perspectives and show increased conformity to

peer influence (Jiang, Song, Lee & Bong, 2014).

Feelings and frustrations in mathematics

Torrance (2012) suggested that although the role of feedback must always be to

inform, the feedback may not always be positive. A low grade or mark and more

extensive forms of feedback contributed most to a negative effect (Korpershoek, Kuyper

& van der Werf, 2015; Schurtz, Pfost, Nagengast, & Artelt, 2014). Reading critical

comments, even when accompanied by advice about how to improve, was found to be as

disconcerting as receiving a poor grade, especially if the critical comments were

unexpected or if the reader disagreed with them (Van De Ridder, Berk, Stokking & Ten

Cate, 2015; Yeager, Purdie-Vaughns, Garcia, Apfel, Brzustoski, Master, Hessert,

Williams & Cohen, 2014). While inflated praise caused students with high self-esteem to

seek out challenges, it was found to have the opposite effect on those with low self-

esteem making them more likely to withdraw to avoid future failure (van Aalderen-

Smeets & van der Molen, 2016). Paradoxically, children with low self-esteem were

more likely to receive inflated praise (Brummelman, Thomas, Orobio de Castro, Overbeek, & Bushman, 2014). Fong and Krause (2014) found that effusive praise can seem trivial to under- and low-achieving students, who respond more positively to mastery and vicarious experiences in the classroom.

Maths anxiety

Providing and receiving feedback is a highly demanding emotional process, impacting on learner identities and notions of self-worth. Goal setting for achievement sets the stage for motivational possibilities that encourage the development of a culture of learned helplessness (Alderman, 2013).

Hadfield and McNeil (1994) identified three factors as major contributors to mathematics anxiety. These included environmental factors, issues relating to the classroom and the perception that mathematics was governed by a set of rigid rules; intellectual factors where the learning style and culture of the classroom reinforced the student's own feelings of self-doubt, and the personality of the individual student engendering feelings of self-doubt, reinforced by a reluctance to ask questions and seek help. Hadfield and McNeil's research found that the influence of these three factors could impact on the learner negatively resulting in the student failing to attempt a question or task thereby failing to submit any response for marking.

A key component of 'learned helplessness' is mathematics anxiety. Maths anxiety, likened to a fear or phobia, produces 'a negative response specific to the learning, or doing, of mathematical activities that interferes with performance' (Whyte, 2009, p. 4). Pradeep (2011) views maths anxiety as 'a sinking feeling, uncertainty and despair' at

doing and understanding mathematics. Traditional mathematics classroom practices (such as imposed authority, public exposure and time deadlines) are the source of anxiety in many students. Miller and Bischel (2004) proposed two forms of anxiety: trait and state. The first form describes an individual's vulnerability to stress in a given situation, while state anxiety is the stress experienced in specific circumstances.

The literature points towards several broad themes related to maths anxiety: student identity (Bartholomew, 2000; Norman, 2006); gender (Devine, Fawcett, Szűcs & Dowker, 2012; Kenney-Benson, Pomerantz, Ryan & Patrick, 2006); student perceptions of mathematics and mathematicians (Mason & Scrivani, 2004; Schoenfeld, 1989); ability grouping (Boaler, 2008; Solomon, 2007); and, the teacher/student relationship (Black, 2003; Solomon, 1998). The work of Fiore (1999) and Vinson (2001) suggests that maths anxiety may be directly influenced by teachers.

Freiberg (2005) and Andrews and Brown (2015) observed that maths anxiety can have various effects on individuals, inducing 'a cognitive, affective, or physical reaction'. For example, a cognitive reaction may involve negative self-talk or avoidance; distrust of ability, fear of looking stupid, and loss of self-esteem resulting in a potential affective response. Physically, students may experience a boost in their heart rate, tenseness, perspiration or nausea. Other researchers confirmed that 'If mathematics makes a student feel anxious … [the learning and teaching of mathematics] will be marked with negative emotions and bodily sensations' (Zambo & Zambo, 2006, p. 15).

The interaction between factors contributing to maths anxiety related to the cognitive domain (Leighton, Chu, & Seitz, 2013; Suárez-Pellicioni, Núñez-Peña, & Colomé,

2016) and those related to the affective and physical domains are many and varied. Mutodi and Ngirande (2014) showed that many students have an over-reliance on mathematical procedures, rather than on gaining an understanding of the mathematics concept. When students resort to memorising procedures, rules, and routines without much understanding, the concept is forgotten, and student anxiety increases. O'Connor and Paunonen (2007, p. 984), from their studies of personality predictors of academic performance, concluded that success on written work was more accurately predicted by cognitive ability, what an individual has the potential to accomplish, whereas individual personality traits were found to be a stronger predictor of classroom performance. Individuals suffering from high anxiety have been shown to produce poor maths grades and appear to lack ability – a self-fulfilling prophecy (Ashcraft, 2002; Faust, Ashcraft & Fleck, 1996). This specific context effect is magnified by unrelated life events which trigger events in education (Zopp, 1999). In addition, parents with math anxiety may pass it along to their children (Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015), while teachers with math anxiety pass it along to their students (Fiore, 1999). Finlayson (2014) argues that self-assessment of competencies has the benefit of reducing maths anxiety but recognises that issues of validity need to be addressed using clearly defined criteria (Bakx et al., 2014).

The implications of failure in learning are succinctly described by Covington (1992, p. 4):

> Achievement behaviour in schools can best be understood in terms of attempts by students to maintain a positive self-image. For many students, trying hard is

frightening because a combination of eff ort and failure implies low ability, which is often equated with worthlessness. Thus, many students described as unmotivated are highly motivated — not to learn, but to avoid failure.

Anxiety has a been found to have a negative influence on working memory (Skemp, 1971) suggesting that the reflective activity of intelligence is most easily inhibited by anxiety. Although there is on-going debate (Carey, Hill, Devine & Szücs, 2015; Harari, Vukovic & Bailey, 2013) about the causes of maths anxiety, achievement and performance have been shown to improve when maths anxiety is reduced (Vinson, 2001; Wilbert, 2008). This view is supported by Chinn (2012) who observed that many students give up on mathematics learning by withdrawing from any task that is perceived as likely to result in failure - that is, the consequence of failure in mathematics is an undermining of the confidence of the learner (Engelhardt, 1977). Chinn (2009) had earlier observed that certain aspects and topics in the mathematics curriculum, such as long division, caused similar levels of anxiety for students in all year groups in secondary school, that an anxiety response may be specific to the topic rather than to the learner as an individual.

To reduce anxiety and tension among students, teaching methods need to be modified to include less lecture time, more student-directed approaches characterised by increased discussion and the increased use of cooperative groups that provide students with the chance to exchange ideas, ask questions freely, clarify ideas and express their feelings in a non-threatening environment (Mutodi & Ngirande, 2014). While Nolting (in Boylan,

2011) agrees that maths anxiety is a learned condition, the implication is that it can also be 'unlearned' and, consequently, students can experience success in mathematics.

3.5   Models of formative assessment

Five models of formative assessment emerge from the literature: the collaborative, coursework/assignment, socio-cultural, metacognitive, and the social constructivist models. In practice, formative assessment programs are made up of a combination of these models and strongly influenced by external factors such as the time available to develop and implement the program and the existing culture of the classroom (Decristan et al., 2015).

3.5.1.   Collaborative Model

Ronfeldt, Farmer, McQueen & Grissom (2015) surveyed over 9,000 teachers to investigate existing collaborations in instructional teams and whether these collaborations predicted student achievement. The study reported that teachers and schools that engage in better quality collaboration have better achievement gains in mathematics and reading. The study also found that teacher competency was enhanced when they worked in schools with higher levels of quality collaboration. In support of the adoption of the collaborative model, Torrance (2012, p. 339) claimed that:

> We need to understand our task as one of collaborating with students to bring about learning, to be alert to the generation of unpredictable outcomes and indeed to regard the production of unpredictable and unintended outcomes as an indication of success, not lack of compliance with the programme. We need to make the rules of the game as apparent as possible, but we also need to try to

communicate that we would be happy to see the rules of the game change, if

someone comes up with better ones.

Crossouard (2009) aimed to illuminate the power relations embedded within assessment

practice and the importance of an instructional design that addresses these elements. His

study explicitly investigated the social positioning of teachers and learners, and amongst

learners themselves, finding that an 'activity system' was potentially useful to teachers

in designing classroom activities that support students' critical engagement (Smith,

Sheppard, Johnson & Johnson, 2005) and participation in different communities of

practice. The activity system would include spaces for student agency and divergence

and be framed by rules (or assessment criteria) of the different communities the activity

relates to (Crossouard, p. 1).

In the study by Cajkler, Wood, Norton, Pedder & Xu (2015), the challenges that

inhibited student learning were identified by teachers, who then worked together to

design innovative approaches to address them. They reported that this collaboration

reduced feelings of professional isolation, allowing them to develop a sharper focus on

student learning and more confidence to take risks with their teaching and that the new

approaches that resulted from the collaboration created more opportunities for students

to engage in interactive experiences involving problem-solving and peer teaching in

groups.

Although the efficacy of the collaborative model is supported by these studies, teacher

collaboration in a formative assessment program can be the limited (Miles, 2016) due, in

part, to the time impact of the collaborative process (Seashore, 2015; van den Berg,

Harskamp & Suhre, 2016), the changes in classroom culture that they portend (Clark, 2015; Yee, 2016), power hierarchies among teachers (Chen, May, Klenowski & Kettle, 2014; Laveault & Allal, 2016), and the difficulty of achieving clarification and agreement on clear goals (Hatzipanagos & Rochon, 2014; Ritzema, Deunk, Bosker & van Kuijk, 2016; Yee, 2016).

3.5.2   Coursework Model

Although criticisms have been levelled at the use of coursework for summative assessment purposes (Haugan, Lysebo & Lauvas, 2017; Henderson, Gwynllyw, Hooper & Palipana, 2015; Richardson, 2015), particularly with respect to the difficulty in validating the individuality and authenticity of each student's work, the strength of the use of coursework for formative purposes has been strong (Hudesman et al., 2014; Orsmond & Merry, 2011). Its benefits include coursework taking place in an environment and in a timeframe, that enables quick feedback and encourages peer and self-assessment (Andrade & Brookhart, 2016; Harris & Brown, 2013).

In mathematics education, Hiebert (1986) believed that each student's understanding was evident in extended investigations and assignments (coursework) in ways that were not often seen in traditional classroom interactions which, he argued, tended to focus on procedural rather than conceptual aspects of mathematics. Coursework used for formative assessment purposes enabled the teacher to present the student with novel and complex problems that allowed students to demonstrate conceptual understanding, in addition to procedural competence. Hunt (2005) concurred with this view, maintaining that coursework develops in students the ability to use and apply their mathematics

knowledge, arguing that repeated application of skills to both known and novel problems would enhance a student's understanding of mathematics. It was also a means through which the teacher could challenge and encourage more able students to demonstrate their advanced skill levels. Hernandez-Martinez, Williams, Black, Davis, Pampaka and Wake (2011) noted the success of coursework in promoting learning for lower-achieving students, surmising that this success was due to increased interaction between the student and teacher during coursework tasks and that the longer timeframe for the completion of coursework tasks enabled the student to seek repeated feedback from the teacher or peers and act upon it.

3.5.3   Socio-Cultural Model

Tharp and Gallimore (1988) applied socio-cultural theory when developing the concepts of 'responsive teaching' and 'instructional conversations' in which ongoing interaction between the teacher and student enables the teacher to draw out knowledge that the students has not displayed in class (Veen, Wilt, Kruistum, Oers & Michaels, 2017). Vygotsky (1978) argued that learning takes place in an environment of social interaction in which learners actively participate in constructing meaning and knowledge as they collaborate with their teachers and peers.

Discussion on a topic or question serves to clarify and expand upon the information that had previously been provided, conversations which result in a negotiated understanding of task and quality criteria that can foster a student's mathematical understanding. However, the success of the socio-cultural model relies on the ability and willingness of teachers and students to collaborate as partners in the learning process (Shepard, 2000).

There is evidence to suggest that if students believe they are in the 'right group' they are more likely to succeed, as students place high value on their relationships with classmates when learning mathematics (Boaler, 2000).

When conceived this way, formative assessment is more about reviewing and revising the learning process, as opposed to striving for a correct solution (Niedwiecki, 2011). To improve the learning and metacognitive skills of students (Listiana, Susilo, Suwono & Suarsini, 2016), self-assessment tools must be integrated into the learning process (Baas, Castelijns, Vermeulen, Martens, & Segers, 2015; Boud & Soler, 2016; Dolmans, De Grave, Wolfhagen, & Van Der Vleuten, 2005) and students supported to become self-regulated learners.

The socio-cultural model relies on exposing the thinking strategies being applied to the task - making the cognitive and metacognitive processes explicit to the learner (Baten, Praet & Desoete, 2017; Conley, 2014; Stein, Grover & Henningsen, 1996). The teacher must be able to demonstrate to students the generalizable qualities of mathematical problem-solving and develop in them a general understanding of how future assignments might be approached. Students can, consequently, recognise one activity as similar to or dissimilar from another activity and learn to select tools appropriate to the advancement of a solution (Torrance, 2012).

Pryor and Crossouard (2008) stress that formative assessment should not be presented as a stand-alone task but must be considered in the context of the culture of the classroom and integrated into the learning process (Bennett, 2011). Critically, integrating formative assessment processes may involve a change to the existing classroom culture, a cultural

shift. Teachers may be unsure how to integrate formative assessment into existing practice, may lack the time to explore the options (Robinson, Myran, Strauss & Reed, 2014), and/or be uncomfortable or unfamiliar with data-based decision making (Van der Kleij et al., 2015).

3.5.4   Socio-Constructivist Model

The socio-constructivist model (Roth & Lee, 2007; Yager, 1991) recognises teaching-and-learning to be a joint, collective activity. Goos (2013, p. 18) explains that;

> … learning is conceptualised as participation in social practices that develop teachers' professional identities, and the appropriate unit of analysis is neither the individual nor the social setting but the person...

The socio-constructivist perspective views knowledge and understanding as constructed through interaction, rather than transmitted through instruction (Sriraman & English, 2009). Emphasis is placed on the interaction of teacher and student, student and task, and student and student. It focusses on identifying not only what the learner has (or has not) achieved, but also on what they might achieve with the help of an experienced teacher or collaborating peer (Vygotsky, 1986). Experienced teachers can be more adept at handling negative consequences when lessons do not go as planned (Wright, 2010) although teachers may react differently depending on the circumstances in which feedback is given and elicited. The model demands that learning be scaffolded (Bruner, 1985; Shepard, 2005) and the interactive process of assessment is as much for promoting learning as the provision of feedback to students (Gipps, 1994, 1999).

Socio-constructivist theory is played out in each classroom to a greater or lesser extent every day (Hernandez-Martinez et al., 2011). It is influenced by the culture of the school and productive tensions between teachers' beliefs and goals can be a trigger for development (Goos, 2013). Wright (2015) reports that teachers gain satisfaction from the evidence of positive learning outcomes - such as increased motivation, concentration, and task completion.

3.5.5 The Teacher-Researcher's Theoretical Assumptions

After considering the specific nature of the research problem, the research questions and the previous educational experiences of the students, this case study was informed primarily by the socio-constructivist model. Elements from each of the four modules were trialled in the case study and the outcomes noted when observed. The socio-constructivist model best described the researcher's theoretical assumptions. These assumptions were based on an extensive review of the literature and personal teaching experience, particularly with learners who were challenged by, and had failed to achieve in, traditionally authoritarian teaching cultures.

3.6   Improving formative assessment practice

Black and Wiliam (1998a) categorised the practices of formative assessment into four areas: questioning; peer and self-assessment, marking, and the formative use of summative tests - "going through the examination in class with the students".

3.6.1   Teacher development

When a formative assessment process is developed, or selected, without a clear goal in mind, expected outcomes are unlikely to be achieved (Ertle, Rosenfeld, Presser & Goldstein, 2016; Mertler, 2016; Panadero & Jonsson, 2013; Wiliam, 2014). In

response to the need to be goal-oriented, Torrance and Pryor (2001) proposed a model for formative assessment based on classroom action research (also supported in the work of Antoniou & James, 2014; Carrere, Milesi, Lapyckyj, Ravera, Escher, Miyara, Pita & Añino, 2016; Luckin, Clark, Avramides, Hunter & Oliver, 2017; Mertler, 2016; Nielsen, Sommer, Larsen & Bjørk, 2013; Schoenfeld, 2014). Underpinning an action research program is teacher development that focusses on supporting teachers to embed formative assessment into their instruction and providing them with the skills to better interpret student responses. It demands a special focus on teacher use of effective questioning strategies, the management of peer assessment to identify student errors and misconceptions, and the implementation of instructional strategies to address them (McGatha et al., 2009). The research concluded that a more focused approach to formative assessment processes in professional development programs may yield meaningful results.

3.6.2 Collaboration between teachers

Collaborative research provides a dynamic interconnection between personal, as well as micro (school) and the macro (policy) level factors (Brown, Schildkamp & Hubers, 2016), allowing for the incorporation of external support, the sharing of teacher knowledge and beliefs, professional experimentation, and shared reflection on student reaction to classroom innovations (Cooper & Cowie, 2010).

Collaboration between teachers trying out changes to practice provides advantages for the school, the students and the teachers themselves (Vangrieken, Dochy, Raes & Kyndt, 2015; Yee, 2016). It is especially important in maintaining teachers' commitment to

change over time (Cajkler, Wood, Norton & Pedder, 2014). Collaboration has been identified as essential when integrating new systems and innovations into the culture of a school (Black & Wiliam, 2004b; Clark, 2013). Administrator support is fundamental - the new program must be part of an evolving school improvement program rather than as the special interest project of selected individuals (Campbell, Lieberman, Yashkina, Carrier, Malik & Sohn, 2014) – and premises a commitment to the utilisation of new understandings (Austin & Starkey, 2016; Senge, 2014).

3.6.3   Identifying key strategies

Wiliam (2000a, 2005a) identified five key strategies for improving formative assessment. The first three strategies are: clarifying the assessment task, introducing group work, and providing tasks that generate valid evidence about student progress towards the learning goals. The final two elements are providing feedback that encourages self-directed learning and peer tutoring and assessment. Wiliam's work contributes to essential findings from other studies.

Cooper and Cowie (2010) highlighted the importance of external support, a culture of shared teacher knowledge and beliefs, ongoing professional experimentation, and a commitment to the practice of shared reflection on student responses to classroom innovations. Lebler and McWilliam (Lebler & McWilliam, 2009; McWilliam, 2009) highlighted the importance of aligning curriculum, pedagogy and assessment in building creative capacity in students, maintaining that the provision of an assessment regime that includes self- and peer- assessment, along with assessment by staff, enhances student ability to be self-monitoring and self-directing.

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Several researchers (Brookhart, 2013; Dargusch, 2014; Kobett & Wray, 2017; Seashore, 2015; Walshaw & Anthony, 2008) argue that the use of a self-assessment formative checklist can be of benefit in a senior mathematics formative assessment program as it can provide basic scaffolding for the process of developing a mathematical model for each question. The checklist -presented in the form of a series of steps (Miller & Koesling, 2009) or developed from the language of the standards - helps students adequately address assessment criteria (Burke, 2014) and provides evaluative feedback on formative tasks (Belcher, 2016). Wylie and Lyon (2015) suggest a "pre-flight" checklist to be provided to students as an indicator of quality work.

3.6.4 Limiting the scope

Teachers can reduce the complexity of developing and trialling new formative assessment practices and providing feedback by focusing on a single class or subject area (Nolan, 2011). Black and Wiliam (2004b) suggest beginning with a single formative assessment strategy which allows the teacher to accurately assess the effects of the strategy on student learning and motivation.

3.6.5 Self, peer and co-assessment

The benefits of self-, peer- and co-assessment have been described in many studies (for example, Huba & Freed, 2000; Mills & Glover, 2008; Palchikov & Boud, 1989; Taras, 2010a). Palchikov and Boud (1989) identified eight positive effects for students of these three forms of assessment: increased confidence in their ability to perform; increased self-awareness of the quality of their work; increased ability to reflect on their own behaviour and/or performance; improved performance on

assessments; improved quality of learning output; increased responsibility for their own learning; greater learning autonomy; and, increased satisfaction. Dochy, Segers & Sluijsmans (1999), Peeters et al. (2010) and Peterson & Irving (2008) also stressed the positive effects of self-, peer- and co-assessment, but added a caveat: the effectiveness of peer feedback depended on whether it was perceived to be relevant or justified. Where its relevance and validity for that situation were not apparent to the student, its effect on improving student performance was reduced.

Further support is reflected in the work of Cho and MacArthur (2010) who found that students who received feedback from their peers showed greater improvement in performance than students receiving feedback from the teacher and this finding, perhaps, highlights the high value students place on their relationships with classmates when learning maths (Boaler, 2000). Adediwura (2015) observed that students undergoing peer assessment were no longer ashamed of their mistakes but instead viewed them as a learning process. However, a study in Singapore by Tay and Ng (2015) on online formative assessment stressed the importance of inculcating appropriate values in students, such as that of accountability, to maintain the integrity of the assessment process.

Peer assessment was also found to be positively influenced by training and experience. Sluijsmans, van Merriënboer and van Zundert (2010) reported that trained and experienced peer assessors were most readily accepted by students and the efficacy of their feedback was further enhanced by the development of specific peer feedback formats, through maintaining small group size and allowing sufficient time for revision

and was augmented by providing students with the opportunity to revise their work based on the feedback received from their peers.

Issues of accountability arose with the use of self- and peer- assessment in mathematics (Andrade & Brookhart, 2016; Harris, Brown & Harnett, 2015), concerns which were addressed through the use of rubrics (Panadero & Jonsson, 2013) which provided students with a clear understanding of the constructs to be addressed (Bakx et al., 2014) and through attention being drawn to the correlation between student-directed self- and peer- assessment and teacher's marking of a particular piece of work (Kearney, Perkins & Kennedy-Clark, 2016).

3.7   Summary

The key elements of a comprehensive formative assessment program demand action by the teacher, notably that they recognise the importance of affording students the opportunity to take responsibility for their own learning and to reflect on and review their progress (Cooper & Cowie, 2010). Wiliam (2005a) proposed a model that takes into account those aspects of assessment for learning – formative assessment – that the literature shows to be efficacious: identification of what the learning might achieve in terms of learning goals (Hudesman et al, 2014); the discrepancies between current and desired performance; scaffolding learning; a focus on improvement in learning rather than focussing on grades and avoiding a culture of social comparison; provision of specific and targeted feedback directly related to standards criteria, and learning progressions; the opportunity for students to attach meaning and context to individual skills or mathematical concepts; ensuring understanding is constructed through

interaction rather than direct instruction; appropriate emphasis on interaction between

the teacher and student, students and the task, and between students; provision of

ungraded/unmarked feedback which is contextualised, positive and appropriately timed

and which contains suggested strategies for improvement; providing students with the

opportunity to act on feedback through reflection, and engagement in self-directed

learning.

Chapter 4   A Comprehensive Formative Assessment Program

4.1   Introduction

Instituting cycles of action research, formative assessment practices (Torrance & Pryor, 2001) which were articulated in the literature as fostering improved student learning and which, consequently, promoting improved performance in summative assessments (Wiliam, 2005b) were introduced in each of three classes. Data collection and analysis occurred throughout the year following the implementation of several modified formative assessment instruments.

4.2   Structure of the teaching timetable

The school year was divided into two semesters and each semester was divided into two terms. Terms one, two and three were of approximately equal length (10 weeks) and had equal weighting in the summative assessment process. Term 4 was comprised of only 4 weeks of teaching and one week of assessment. The students were given an interim grade for the whole year at the end of Term 3. This grade could be confirmed or adjusted at the end of Term 4.

During each of the four terms, several formative assessments were scheduled, as outlined below in Figure 3. These formative assessments informed, and culminated in, a summative assessment, normally held at the end of the term.

Figure 3   Formative Assessment Program for Year 12 Mathematics A

TERM ONE

Item 1 Modelling Exercise Week 2

Item 2 Assignment Draft Week 4

Item 3 Topic Test #1 Week 5

TERM TWO

Item 4 Topic Test #2 Week 3

Item 5 Topic Test #3 Week 5

Item 6 Topic Test #4 Week 6

Item 7 Topic Test #5 Week 7

TERM THREE

Item 8 Modelling Exercise Week 1

Item 9 Assignment Draft Week 3

Item 10 Topic Test #6 Week 5

TERM FOUR

Item 11 Topic Test #7 Week 3

Item 12 Modelling Exercise Week 4

4.2.1   Semester 1 Term 1

Modelling Exercise

A detailed examination of the students' responses to summative assignment tasks
undertaken in the previous year was undertaken. This revealed that 72% of the students
had attempted to answer the questions required by the summative assessment task but
that their responses had not been presented in a format that provided sufficient evidence

to support an A, B or C grade in accordance with Authority Assessment Criteria for Mathematics A (QSA, 2013b, 2013e) and "the Criteria" (Appendix A).

This information provided the basis of the first adjustment in the formative assessment program. The first formative assessment task (Appendix B) was a modelling exercise (Bakker, Smit & Wegerif, 2015) like that in the summative assignment, albeit, it was pitched at a C (passing) standard. The wording of the formative assignment questions was the same as the wording of questions in the summative task, although the dataset was different or novel.

Teachers explained to students that they must go above and beyond this C standard model to achieve an A or B grade; that is, they would have to address the A and B standards described in the Criteria. Students were given guidelines to assist them to address the A and B standards which included how to reflect on the model and modify it, how to interpret results, justify the reasonableness of results, make judgements and prepare recommendations.

The modelling exercise incorporated a self-assessment checklist (Butler, 1987) that was provided at the beginning of the activity which students could use to make sure that they had fully completed each task and provided sufficient evidence to support a C standard grade. This checklist (Appendix C) provided students with the opportunity to self-assess to identify areas where they needed to improve. Time was provided at the end of the modelling activity for students to undertake this self-assessment, discuss the task with their peers and ask questions of the teacher. As advocated by Cowie and Cooper (2010),

the checklist included spaces for the students to write a note to the teacher and for the teacher to provide feedback.

Assignment Draft

The second formative assessment item in Term 1 was the preparation of a draft (Herbst & Kosko, 2014) of the summative assignment (Pampaka & Wake, 2011). All students were given a copy of the assignment and a self-assessment checklist (Appendix D) one week before the assignment was due. Students were asked to use this checklist to self-assess both their progress on the summative assignment and the quality of their response. The checklist was later submitted with the summative assignment.

Topic Test 1

A formative assessment topic test was set mid-way through Term 1 covering a single topic. It was completed under exam conditions during a regular mathematics lesson. Ten minutes prior to the end of the test the students were given a formative self-assessment feedback checklist (Appendix E). The checklist guided the students in providing evidence about setting out, justifying of the reasonableness of results, and stating and explaining the relevance of the solution to the problem. When provided with the checklist many students were observed to modify some of their answers. The teacher-reviewed topic (moment in time) test (Fisher & Frey, 2015) which did not include marks or grades (Heinz & O'Mahoney, 2016) and the self-assessment checklist were later returned to students and they were provided with the model answers. Students were then asked to self-assess their work.

To counteract the tendency for the topic tests to give a student an inflated impression about her/his mathematics competency, students were given novel formative assessment tasks prior to the summative examination. These tasks typically included one A and B standard question. The students were allocated one hour to develop their response. Solutions (Núñez-Peña, Bono & Suárez-Pellicioni, 2015) were provided to the students and time allocated for both self- and peer- assessment in which responses were reviewed against the Criteria to determine whether students had provided sufficient evidence to support an A grade.

4.2.2   Semester 1 Term 2

The Term 1 findings informed changes to the formative assessment program for Term 2. In response to student feedback and the themes emerging from the initial analysis of Term 1 data, the topic tests were modified to include questions that represented each of the QSA Criteria standards, aiming to assess evidence of student learning in the same way as the summative assessment examinations (Pinger, Rakoczy, Besser & Klieme, 2016).

Topic Tests 2 - 5

These formative tests did not differ significantly from formative tests used previously in this subject. However, the formative assessment process differed from that used in Term 1.

Ten minutes prior to the end of each test, students were provided with a self-assessment checklist (Appendix F) relating directly to the test. This checklist differed from that provided in Term 1 in that it now provided scaffolding to support the student in

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developing a relevant mathematical model which would enable them to respond to questions on the tests (Panadero, Jonsson & Strijbos, 2016). The checklists scaffolded their thinking through the identification of information provided about the problem to the development of a problem-solving process leading to a solution. The checklists also provided information on the expected conventions of setting out responses so that it addressed the assessment criteria against which the students' work would be assessed.

The students self-assessed their topic test responses and were permitted to modify their responses against a fully worked A standard solution prior to submission of the test (Hudesman et al., 2014). Informal peer review (Shute & Kim, 2014) of their work was also possible. The students then took their topic test home, together with the checklist, for further modification. During the next lesson, each student self-assessed their response against a set of fully worked solutions (Appendix G).

The students submitted their self-assessed response with the checklist to the teacher who assessed each student's work and wrote comments in the comment section of the checklist. As before, no marks or grades were assigned - assessment took the form of ticks, crosses and comments. During the next mathematics lesson, the response and the completed checklist was returned to the student for review; input from the teacher was provided only at the request of the student (Besser, Blum & Klimczak, 2013).

The potential deficits in rigour of the topic tests were addressed (to some extent) by providing, prior to the summative examination, revision questions at an increased level of complexity and a higher degree of difficulty (A and B standard questions) in both Knowledge and Procedures and Modelling and Problem Solving.

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4.2.3 Semester 2 Term 3

Modelling Exercise

In response to student feedback and the themes emerging from the analysis of Term 1 data, in the lesson prior to the formative assessment modelling task, the teacher modelled similar questions to those included on the topic test (Greeno, 1988). This modelling activity involved the whole class. The teacher then elicited suggestions from students prior to writing each step of the solution on the whiteboard. Students were invited to critique this solution to determine whether the response included sufficient evidence to support an A grade.

Scaffolding modelled the process for carrying out the task and provided clear instructions to students (Gipps, 1994; Bruner, 1985) about how to develop a mathematical model to a C standard. Rather than a simulated modelling exercise, the formative assessment process modelled the actual task on the summative assignment. The mathematical attributes and learning experiences being assessed on the formative assessment task were of the same standard and degree of difficulty as those on the summative assignment. However, the formative task did not include an example of an open-ended rich task which students would encounter on the summative assignment to safeguard the integrity of the summative assessment, nor were they provided with a set of precise instructions on how to carry out the modelling task for the same reason.

Students were given with an extensive self-assessment checklist (Appendix H) which linked to the Knowledge and Procedures section of the assignment with the first Modelling and Problem-Solving question. Although this support was more extensive than students had experienced previously, the level of support was considered acceptable

as teacher input was permitted for routine questions on summative assessment items (QSA Mathematics A senior syllabus, 2013b). Subsequent Modelling and Problem-Solving questions were classified as "non-routine", "discriminating questions". No teacher input was allowed (QSA, 2013a; 2013b). Students completed the formative task outside of class time and used the checklist for self- and peer-assessment.

Assignment Draft

Students received a self-assessment checklist presenting the evidence needed to achieve an A standard on the second summative assignment. In addition to the checklist, students were given the opportunity to further monitor their progress or to seek extra help or clarification by meeting with their teacher outside of class time. The completed self-assessment checklist was handed in with the completed summative assignment.

Topic test 6

Topic test 6 incorporated all the elements of formative assessment that the students had requested throughout the year. Short answer questions and problems ranging from D to A standard were included. The emphasis was placed on complete solutions showing all setting out and diagrams to comply with the Criteria (QSA, 2013b). Scaffolding was provided in the form of a self-assessment checklist that addressed all the elements required for a successful outcome on the summative assessment at the end of the term.

To overcome the time constraint of administering the test during a normal mathematics lesson, students could take the test and checklist home to finish in their own time.

4.2.4 Semester 2 Term 4

Student performance was anticipated to be optimised by the end of Term 3, and very little change was expected during the 4-week teaching period of Term 4. Students expressed a high degree of satisfaction with the conduct of formative assessment process in Term 3 and acknowledged that all the modifications they had requested had been incorporated into the program - incorporation of the scaffolding for all standard levels of the modelling task and problem-solving questions and the ability to take formative assessment tests and checklists home for modification prior to submitting them to the teacher.

Topic Test 7

The summative examination in Term 4 covered only four weeks of work so was less rigorous than the final examination in each of the other three terms. The formative test reflected this, in that the problems were less complex – there were more D and C standard questions, with only one B and A standard question included. There was more emphasis on recalling mathematical facts in topic test 7 and less on problem-solving. Nonetheless, a self-assessment checklist was again provided covering setting out conventions and how the Criteria (QSA, 2013b) would be addressed. In line with all other topic tests, it was conducted within class time and students could take their test and self-assessment checklist home for review.

Modelling Exercise

A formative assessment modelling exercise simulating Part B of the summative examination was included into the formative assessment program in Term 4. This was particularly important as the final topic – navigation – involved reading of navigational

maps (Confrey, Gianopulos, McGowan, Shah, & Belcher, 2017), a skill new to the students. The modelling exercise included only Modelling and Problem-Solving questions. Navigational maps of various areas were provided so that students could become familiar with them prior to the summative examination. Once again, a self-assessment checklist provided scaffolding for setting out conventions, how best to address the problem and develop a solution. The students were challenged by the unfamiliar topic of navigation and enthusiastically embraced the formative test and modelling exercise.

Students requested additional problems and applied the self-assessment checklists to these, in effect expanding the formative assessment program throughout the four weeks of Term 4. Due to the shortened teaching time in Term 4, the formative assessment tasks in Term 4 resembled most closely the summative tasks on the Term 4 examination in both subject matter and degree of difficulty.

Chapter 5   Methodology

5.1   Introduction

This chapter begins with a description of the context of the research and its participants.

It then situates the case study within a meta-theoretical framework and the research

approach and methods that derive from that. The research question is introduced and the

research methodology of grounded theory in an action research framework is discussed.

Multiple research methods used in this study, including qualitative and quantitative data

collection and analysis, are described. The rationale system of coding is described, and

the methods employed for data analysis using is explained. The process of coding

including open coding, constant comparison, theoretical sensitivity and pattern matching

is described in detail. The ethical issues involved in the study are addressed.

5.2   The Case Study

The instrumental case study (Grandy, 2010) is in-depth description and analysis of a

bounded system (Brown, 2008) in its real-life context (Merriam, 2009) which can

provide insight into the research question (Anderson, 1998; Punch, 2013). The

instrumental case study focuses on the phenomenon described in the research question

and the case itself is secondary to understanding the phenomenon (Grandy, 2010).

The choice of case implies knowledge of some interesting issue or feature which

identifies and explains the selected unit of analysis (Miles & Huberman, 1994) – that is,

the issues identified as intrinsic to the case (Stake, 2000). A holistic view of the situation

under study is fundamental. An understanding of both the context and the participants is

central. Gialdino (2009) confirmed that "people cannot be known other than in their context, but they cannot be known through their context" (para. 34).

Sample size

The case study approach was adopted in this research because its limited size enabled it to be conducted under conditions controlled by the researcher (Denscombe, 2014; Stake, 2013). Research in a natural setting to change the way in which the researcher interacts in that setting has been attributed to Lewin (1946), who "is credited with coining the term action research to describe work that did not separate the investigation from the action needed to solve the problem" (McFarland & Stansell, 1993, p. 14).

In this case study, a small number of participants - the "case" – is set in the real-world context of a senior mathematics classroom (Yin, 2012). The 'practitioner as researcher' approach (Jones & Stanley, 2008) is central to the case study as it uses the teacher-researcher's subjectivity to provide access to other mathematics teachers in the study (Clark & Sharf, 2007) and to acquire information which has practical application in the solution of the research problem (Greenwood & Levin, 1998; Stringer, 2013). Formative assessment is a relevant topic for a teacher-researcher in a case study approach as it is amenable to investigation within the naturalist setting of their own (and colleagues') classrooms and the implementation of the research findings affords the teacher(s) ownership of the process, ensuring relevance and currency (Brannick & Coghlan, 2007).

The small sample size facilitated a naturalist setting (Guba & Lincoln, 1982) and the convenience of the sample size was determined by the teachers' situation, the time

available, the purpose of the study and the resources available (Patton, 1990). Nolan (2011) and Black and Wiliam (2004b) suggest that a limited sample size has advantages for a case study focusing on formative assessment because the teacher-research brings a pre-understanding of the research problem and the research participants. To address issues which the relatively small sample size raised, case studies around the world where similar research has been undertaken were reviewed to enable factors that could expand the breadth and depth of the study, and thus widen the scope of the research, to be identified and considered for their usefulness in this case study (Hancock & Algozzine, 2015; Stake, 2013).

Teacher as researcher

The closeness of the researcher-teacher to the case produces an invaluable and deep understanding of the context. The case in this study was focused on identifying the factors impacting on the efficacy of formative assessment in Mathematics A informed by the body of research that already existed about formative assessment practices (Baxter & Jack, 2008). The case study sought to build on this body of existing knowledge by augmenting and intensifying understanding of the co-factors in formative assessment.

Choice of methods

The case study approach does not prescribe any specific data collection methods, but rather focuses on holistic description and explanation (Merriam, 1998; Yin, 2006) through which the wholeness, unity and integrity of the case is preserved. No value stance was assumed by the teacher-researcher. Anderson (1998, p. 153) described the case study as follows:

A holistic research method that uses multiple sources of evidence to
analyse or evaluate a specific phenomenon or instance. It often, but not
exclusively, occurs in a natural setting and it may employ qualitative and/
or quantitative methods and measures.

Action research approach

In action research, the research process is cyclical, involving a "non-linear
pattern of planning, acting, observing, and reflecting on the changes in the social
situations" (Noffke & Stevenson, 1995, p. 2), which may blur the distinction between
action and research (Merriam, 2009; Roberts & Owens, 2012). Recognised action
research models, including the work of Kemmis and McTaggart (2005), McNiff and
Whitehead (2002), grounded theory within the action research model proposed by Dick
(2005), and the grounded practice model developed by Walters (2014) informed this
research. The action research model employed is adapted from that proposed by Piggot-
Irvine (2009), as it appeared to best facilitate progression towards a model of improved
formative practice (Figure 4).

Figure 4.   Piggot-Irvine's Action Research Model (2009, p. 7)
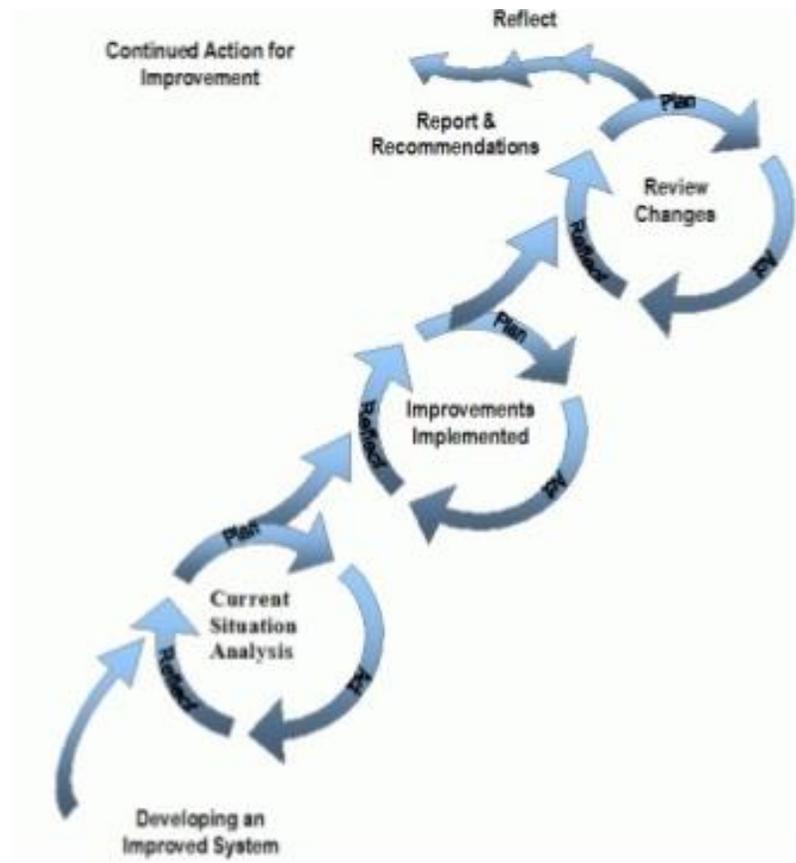
The action research approach adopted in this research aimed to change three things: teacher practice, their understanding of their teaching practices, and the conditions under which they practise (Borg, 1993; Calhoun,1994; Corey, 1953; Freebody, 2003; Kemmis, 2009; Stenhouse, 1975). It was, therefore, conducted as 'participatory research' (Bartlett, & Burton, 2006; Calhoun, 1994; Corey, 1953; Ferrance, 2000; Kemmis & McTaggart, 2000, 2005; Moloney, 2009; Watt & Watt, 1993) as shown in Figure 5. Elements of the Participatory Action Research (PAR) model proposed by Kemmis, McTaggart and Nixon (2013) are an emphasis on collaboration and reciprocal dialogue and learning,

essential components in this research (Gillies, 2016; McNiff & Whitehead, 2002; Mertler, 2008; Zuber-Skerritt, 2003).

Figure 5   Spiral Model of Action Research (Kemmis & McTaggart, 2005, p. 564)
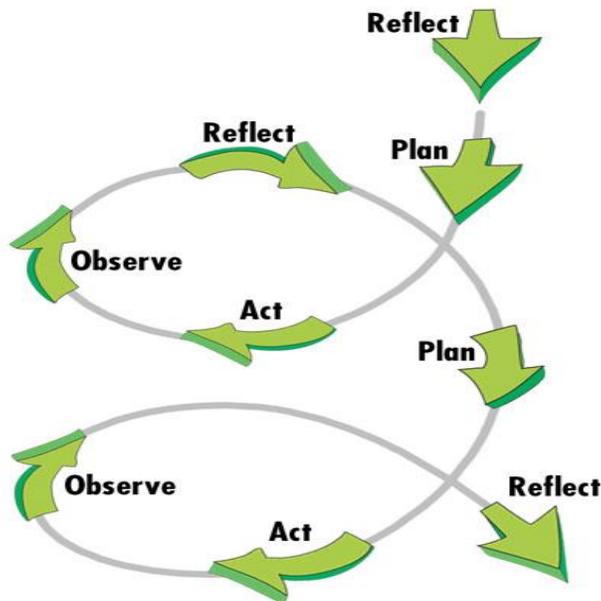
The research of Frydaki and Katsarou (2013) revealed the need to methodologically enrich PAR to illuminate aspects of PAR which often remain - using dialogic studies and post-structural tools, like critical discourse analysis, the teacher-researcher is aided in their analysis of the variety of voices contributing to the research – gaining a better understanding of their ideology and/or the social group represented. The work of Gillies (2016) highlighted the complementary nature of both teacher and student dialogic discourses. Gillies concurred with views of Michaels, O'Connor and Resnick (2008) - it is the recursive nature of these dialogic exchanges that contributes to 'academically

productive talk'. Over the course of this case study, the teacher-researcher and the other two participant teachers reflected, reviewed, re-evaluated and modified their processes at the end of each school term. Each cycle of reflection and planning was followed by a period of classroom experimentation.

5.3   Context and Participants

5.3.1   School

This case study took place in a large independent K-12 school (1038 full-time students) in regional Queensland, Australia.[1] The setting for this case study was, therefore, naturalist rather than interventionist. The school has an academic focus as shown by the range of subjects offered by the study school, and it was understood by teachers, students and parents that most students would articulate to tertiary studies.

The school had an Index of Community Socio-Educational Advantage (ICSEA) that was relatively high (ACARA, 2012). A value on the index corresponds to the average level of educational advantage of the school's student population relative to those of other schools. In 2013, the case study school had a School ICSEA value of 1117 compared to the Average ICSEA value of 1000[2]. ICSEA background information for the school is provided in Table 2.

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[1] Data describing the school and its ICSEA value was obtained from the publicly accessible *Myschool* website (Myschool, 2013) and from the school itself.

[2] The Index of *Community Socio-educational Advantage* (ICSEA) enables meaningful comparisons of *National Assessment Program Literacy and Numeracy* (NAPLAN) test achievement by participants in schools across Australia (ACARA, 2012).

Table 2   ICSEA Background Information (Myschool, 2013)

	Bottom Quarter	Middle Quarters		Top Quarter
School Distribution	2%	14%	31%	52%
Australian Distribution	25%	25%	25%	25%

5.3.2   Student participants

The year 12 Mathematics A cohort (52 students) was selected because the case study could be undertaken under conditions controlled by the teacher-researcher. The requirement for internal validity was addressed by inviting the full cohort of Mathematics A students to participate in the research. Two groups of Mathematics A students - deemed capable students able to undertake senior level mathematics - were streamed into two classes - Classes A and B. These students had demonstrated a range of mathematical abilities in the previous year. A third group - Class C - included students who had previously failed to achieve in mathematics or who had experienced challenges to their schooling related to repeated absences or identified learning difficulties.

Class C was smaller than Classes A and B and lessons were conducted at a slower pace. After the first semester, Class C was split into two groups within the class: one group of five students who continued to fail in Mathematics A undertook the QSA approved Short Course in Numeracy (QSA Short Course, 2013d), a self-directed program comprising four assessment items. The remaining students in Class C continued to work towards achieving a pass in Mathematics A.

The cohort was, therefore, made up of students exhibiting a wide range of abilities. Notably, some students who successfully completed formative assessment tasks, failed to succeed in the summative assignments and examinations (although some were high achievers and at the top of their cohort in other subjects).

5.3.3 Teacher participants

The three teachers (including the teacher-researcher) involved in the case study were specialist mathematics teachers, all of whom committed themselves to participate for the year of the study and to work collaboratively during that time. The three teachers were experienced classroom teachers.

Teacher 1 had been teaching mathematics at the study school for four years. Teacher 2 had come to the school at the beginning of the previous year but had previously taught mathematics at another school for several years. Teacher 3 was a science teacher who had taught at the school for more than ten years, having taught mathematics for the previous four years.

Teacher 1 taught Class A, Teacher B taught Class B, and Teacher 3 taught Class C for the full school year. There were no extended periods of leave when substitute teachers were employed to replace any of the three teachers. Close monitoring of the processes being undertaken by the three teachers involved was undertaken throughout the year, to ensure the consistency of teaching taking place in each class, by conducting regular member checks, peer debriefing, external discussions and by regular checks by academic and workplace supervisors.

This group of three teachers formed a critical community of peers which was subject to scrutiny by other teachers, the school administration and a wider community of peers in the form of the Mathematics A regional moderation panel (QSA, 2013e).

5.3.4 Teacher-researcher

The researcher was, during the conduct of this case study, a mathematics teacher and Head of the Mathematics Faculty at the school – the 'teacher-researcher". The relationship of the teacher-researcher to the study varied between that of observer and participant. The researcher as teacher took the role of participant in her own Mathematics A class; as the researcher, she also observed classes conducted by the other two teachers participating in the case study.

The teacher-researcher's own mathematical journey had been a positive life experience. She had encountered students who had not excelled at mathematics, but who had developed confidence and a belief in their own mathematical ability. She had discovered the power of self-directed study which lead her to believe that success can be achieved outside of the formal educational setting, through independent learning (Zimmerman & Schunk, 2012).

In the case study, the pre-existing relationship between teacher and students meant that participants were familiar with, and may have experienced the teacher, in the research setting (Brannick & Coghlan, 2007; Mercer, 2007), which enabled the teacher-researcher to build rapport more easily with participants than an outside researcher may have been able to do in the finite time prescribed for the study (Mercer, 2007).

The teacher-researcher maintained an action research journal in accordance with guidelines presented by Tripp (1987) and Holly (1989) which allowed her to review assumptions and behaviour and promoted consistency in the translation of the teachers' actions (Holly, 1989; Smith, 2003).

5.4   Meta-theoretical framework

This study is framed within the post-positivist paradigm (DeLuca, Gallivan & Kock, 2008) which was selected because a body of knowledge existed on the research subject about which the teacher-researcher was seeking a greater understanding. Using existing knowledge, together with findings from this study, the teacher-researcher sought to answer the research question. The post-positivist model views the world as "ambiguous, variable and multiple in its realities" (O'Leary, cited in MacKenzie & Knipe, 2006, p. 6). Post-positivism aims to generate or inductively develop a theory or pattern of meanings (Creswell, 2013); because the teacher-researcher sought not only to deepen understanding and construct meaning but to develop a process of prediction and control that would be transferable to other groups and subjects, the paradigm was best suited to this research (Taylor & Medina, 2013).

The teacher-researcher, working in the social domain of the Mathematics A classroom, is the 'scientific re-searcher' of cultural meanings. Thus, when operating out of the post-positivist paradigm, the aim of the researcher is to produce 'warranted assertions' that can be used to assess processes and outcomes by guiding events towards desirable 'ends-in-view' or shared visions (Jones, Torres & Arminio, 2013). The post-positivist researcher appreciates that people place different constructions and meanings on their

experience (Noor, 2008) and acknowledges that the values and perspective of teachers must be given thoughtful consideration and recognition (Anderson, 1998). Punch (2013, p. 158) describes post-positivism as a paradigm that:

> …assumes a relativist view of ontology (multiple realities), a subjectivist view of epistemology (knower and respondent co-create understandings) and a naturalist (in the natural world) set of methodological procedures. The post-positivist criteria are internal and external validity and objectivity.

Punch's (2013) perspective suggests that the post-positivist view of reality accepts there is not a single reality which embodies the way things are and how they work. According to Glaser (2002) this means that theory is a process but can be presented as a momentary product that is still developing.

This research was informed by the ontological assumption on which the post-positivist paradigm rests has a more relativist stance: different enquirers produce different interpretations. Lakatos (1976) posits that, to work one's way out of complex situations, there is a need to establish areas of reasonable surety and other areas to which people can be reconciled. The researcher believes that comparison of different perspectives and ideologies can produce areas of common interest which Lakatos called 'touchstones'. The ontology of post-positivism has been described by Cook and Campbell (1975) as 'critical realism'. Critical in-depth analysis must be applied to this 'reality' to develop an understanding of this perceived reality within the post positivist context.

The epistemology (the relationship between the knower and what was known, the process of knowing) of the post-positivist paradigm (Gialdino, 2009; Patry, 2015) utilises a modified dualist/objectivist view where there is an emphasis on the need for critical conditions and a critical community of peers to guard objectivity (Guba & Lincoln, 1994). Objectivity was safeguarded in this study through the choice of participants, year level, subject and context and the wider community of scholars.

The teacher-researcher recognises that a post-positivist approach has several strengths. Firstly, it has the capacity to overcome formal theory-practice dualism by placing enquiry into a context that admits no division between meaning, fact and value. In this study, the perception of teachers illustrates the key role of construction of meaning and values. Secondly, the touchstone approach is non-protective of norms and axioms. Although this study demonstrates significant levels of agreement with respect to the views teachers have on the efficacy of formative assessment, it raises questions about the stability of these factors. Thirdly, contained within its processes, is a series of checks and balances that confer on post-positivism an evolutionary approach. The testing of questionnaire data through teacher interviews and student focus groups and the semi-longitudinal nature of the study has allowed the findings to emerge, be tested and refined.

5.5   Research Quality

The criteria for judging the quality of an inquiry based on the post-positivist paradigm depends on the realist ontological position (Guba & Lincoln, 1994; Lincoln, Lynham & Guba, 2011). The conventional benchmarks are rigour, internal validity, external validity

or generalisability, reliability and objectivity (Anderson, 1998; Wiersma, 2000; Wolcott, 1997).

Rigour is a key quality measure: the more rigorous a research process, the more trustworthy are the findings - the extent to which the claims of the study are supported by the research design and analysis. This study addressed the need for rigour through its research design (Dick, 1999), methods of data collection, and the qualitative and quantitative analysis of results.

Internal validity is the degree to which variations in an outcome can be attributed to some uncontrolled factor (Fraenkel, Wallen & Hyun, 2012). Without internal validity interpretation of results can be problematic. Threats to internal validity were addressed by identifying students who achieved unexpected outcomes and interviewing students suspected of experiencing an affective event. For example, student maturation - biological or psychological processes that occur with the passage of time - was recognised as occurring as the case study took place over one year. To the extent possible, the tendency for students to score higher in subsequent tests when the series of tests were like one another, was counteracted be using novel questions that had not been trialled with the students.

External validity - the extent to which findings from one study can be generalised – was controlled by the management of threats to external validity through the replication of the formative assessment program and instruments in three senior mathematics classes – A, B and C - at the school. Qualitative student responses and quantitative data from

summative assessments in these classes were used as a check for external validity (Dick, 1999).

Reliability (the extent to which research findings can be replicated) process checks differed from the usual subject level processes that were already in place to ensure consistency of teacher judgement: each of the three classes were taught using the same materials and methods, provided with equal amounts of teaching time and used the same formative and summative processes, and moderation of the summative assessment was carried out by the regional moderation panel for Mathematics A. Prolonged engagement and persistent observation enhanced the reliability of the qualitative data (Guba & Lincoln, 1989).

Objectivity - the extent to which the study is free from researcher bias, motivation, interests, values, prejudices – was a key risk factor. In small case studies, there is potential for contamination by the 'non-disinterested' researcher, the natural setting, the search for qualitative as well as quantitative data, and by the structure of the study. In this case study, objectivity was facilitated by the search for qualitative as well as quantitative data and maintained by peer debriefing, negative case analysis, close monitoring of the process by the three teachers involved (progressive subjectivity), by recording and reviewing the developing constructions and process of change in a professional journal, and, through external discussions and regular process checks by academic and workplace supervisors. External discussions took place regularly with the teacher-researcher's supervisor, with school administration staff, and with peers from other schools teaching the same subject. These discussions established a match between

the constructed realities of the other teachers and students and the realities of the teacher-researcher (Guba & Lincoln, 1989).

5.6 Research Question

Previous formative assessment processes have failed to improve the learning outcomes for the students (Bennett, 2011; Black, 2015; Sadler, 1989). This study investigates the elements of formative assessment processes and practices which have the potential to improve student outcomes in summative assessment, through an iterative process which implements best-practice approaches drawn from the literature (Pinger et al., 2016).

In this case study, the key research question is:

Does the implementation of more comprehensive model of formative assessment improve the results achieved by Year 12 students in summative assessment tasks in Mathematics A?

To investigate the factors involved in the improvement of summative outcomes, it was necessary to establish whether formative assessment items targeted the same levels and types of learning as the summative assessment items and identify the qualities of effective feedback that enabled students to apply mathematical procedural and conceptual understanding to both routine and novel problems in summative assessments.

The similarities and differences in the Mathematics A task sheets and participant responses to formative and summative assessment items were reviewed, together with the way in which teachers questioned and provided feedback to students. The concepts and understandings that were being assessed in the formative assessment tasks and

whether they differed from the mathematical attributes and learning experiences assessed in the summative items were identified. Modifications to existing formative assessment practices were made based on the results of these analyses to propose a re-conceptualised model of formative assessment (Brendefur, Johnson, Thiede, Smith, Strother, Severson, & Beaulieu, 2015).

5.7   Research Methodology

5.7.1   Grounded Theory

What differentiates grounded theory from other qualitative research methods is the philosophical emphasis on how data is generated (Herr & Anderson, 2000, p. 122). Grounded theory, as developed by Glaser and Strauss (1967), focusses on uncovering social relationships and the behaviour of groups where there had been little exploration of the contextual factors - the underlying processes that determine what is happening (Crooks, 2001).

Concepts are the building blocks of grounded theory (Cho & Lee, 2014) – they are the phenomena or central ideas in the data (Dey, 1999) that answer the research question and provide insights and understanding into the processes taking place (Charmaz, 2002). Concepts are identified, then grouped together into categories, from which a core category emerges. An initial hypothesis is formed (constructed) that is subject to further testing and verification by the addition of new data (Hallberg, 2006). The result is a substantive theory (Glaser & Strauss, 1967; Rich, 2012).

Theory generation is grounded in data systematically gathered and analysed (Strauss and Corbin, 1994, p. 273). The theory is developed inductively from the data as opposed to

the traditional approach of theory verification research (Punch, 2013, p. 134). Glaser (1978, p. 93) highlighted that "The generation of theory occurs around a core category. Without a core category, any effort of grounded theory will drift in relevancy and workability". While remaining grounded in the data, the core category is a highly-abstracted category. Most other categories relate to the core. The core category provides the link between the individual variations in the data (Figure 6). The major categories demonstrate how the core category is played out in the everyday lives of participants (Calman, 2012).

Figure 6   Components of Grounded Theory Research (Charmaz, 2006, p. 4)
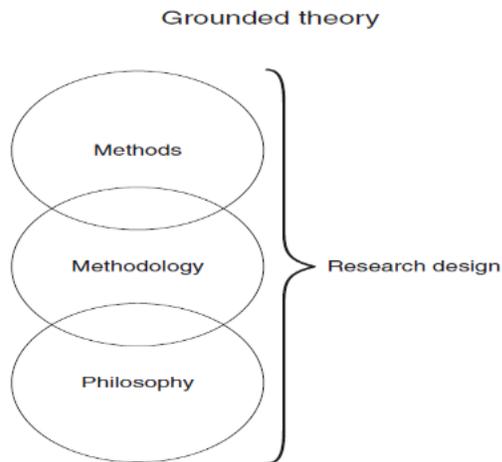
Key features of grounded theory are its iterative study design, theoretical (purposive) sampling, and a cyclical system of analysis. Cycles of simultaneous data collection and analysis, like the cycles of action research, are the key feature of an iterative study design (Kemmis & McTaggart, 2005). Each cycle informs the next cycle of data collection. Guided by the research question, the researcher collects a preliminary set of

data. The second set of data is collected after the analysis of this data and is guided by

the emerging directions of the analysis. Subsequent data collections are guided by

developments that emerge from the analysis (Figure 7).

Figure 7   Constructing Grounded Theory (Charmaz, 2014, p. 19)
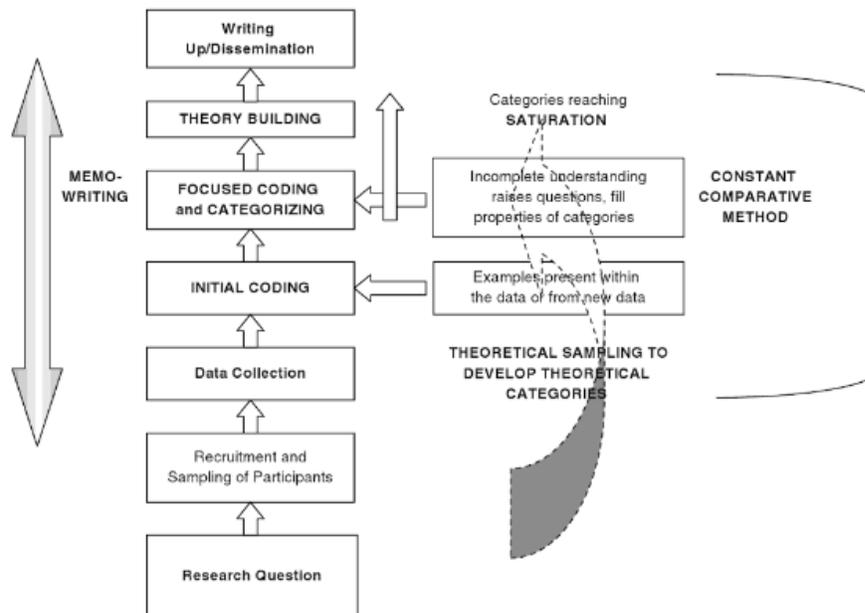
The rigorous application of the data analysis phase of grounded theory results in the

generation of original, justifiable, theory (Strauss & Corbin, 1998). The cycles of

simultaneous data collection and analysis are characteristic of the iterative study design.

The analysis resulting from each cycle informs the next cycle of data collection. Early

themes emerged during the initial data collection and preliminary analysis phase. The

second set of data was collected after the first analysis of data occurred and was guided

by the emerging directions of that initial analysis.

This on-going analysis informs the direction of the next stage of the study and is explicitly aimed at developing theory. (Glaser and Strauss, 1967, p. 45). Glaser and Strauss maintained that theoretical sampling - the process in which data is collected, coded, and analysed, and a consequent decision made about whether more data needs to collected, and where to find it – is the basis of grounded theory.

Grounded theory analysis using constant comparison, checking codes against codes and then checking the codes to the original text, results in an emergent and authentic representation of the data. The codes are then checked against categories and sub-codes, then back to the original text and to the final sub-codes and their dimensions. The next step of the process is to compare categories against each other and, finally, to identify the underlying relationships. This process ensures that the data analysis is grounded in the data (Rich, 2012).

5.7.2   Criticisms of Grounded Theory

One criticism that has been levelled at grounded theory is that it glosses over the meaning contained in respondents' stories as the researcher identifies and classifies codes and defines themes within the data (Conrad, 1990; Reismann, 1990). Strauss and Corbin (1998) suggested that the way to counteract this tendency is by not isolating the variables (in the quest for impartiality), so that valuable layers of complexity remain intact and a richer understanding of the research situation is, consequently, facilitated.

5.8   Research Methods

5.8.1   Multiple methods

The appropriateness of the research methods employed derives from the nature

of the phenomena to be explored. Applying grounded theory in a post-positivist

paradigm, this study used qualitative and quantitative methods of data collection and

analysis (Glaser & Strauss 1967; Punch, 2013). In this case study, a mixture of

quantitative and qualitative methods has been adopted and the substantive assumptions

of the meta-theoretical approach are strongly connected. The aim of employing a range

of data collection methods was to provide a fuller picture of the participant's thinking at

the time each data collection instrument was administered. Using qualitative methods -

questionnaire, ongoing observations, interviews each term, focus groups each term and

when indicated, and regular teacher meetings each fortnight - and quantitative methods

- analysis of summative results; student responses to formative assessment tasks, results

from a summative examination each term and an extended modelling and problem

solving task each semester - allowed the teacher-researcher to generate insights into the

research problem that had not been previously discovered using quantitative methods

alone.

The use of a range of methods aimed to generate confirmatory results, despite

differences in methods of data collection, analysis and interpretation (Harris & Brown,

2010; Villanova, 1984). By using multiple methods, the study hoped to achieve the best

results – provision of plausible explanations about the phenomenon under investigation -

from each while overcoming their unique deficiencies (Bromley, 1986, Cresswell, 2013;

Denzin, 1978; Mathison, 2012) although Mathison (1988) warned about the expectation

of convergence; that is, that the use of multiple data sources would result in a single meaningful solution.

The post-positivist researcher employs a modified experimental/manipulative or critical multiplism (Glaser & Strauss, 1967; Strauss & Corbin, 1990), a form of triangulation used to validate findings in which inherent weaknesses in the research process are negated or minimised by using multiple methods including qualitative and quantitative data collection and analysis (Figueredo, 1993) used in a naturalist setting (Punch, 2013). Triangulation used these multiple forms of overlapping and diverse pieces of evidence to validate findings; to determine the meanings and purposes participants ascribed to their actions (Figueredo, Olderbak, Schlomer, Garcia & Wolf, 2014; Glaser & Strauss, 1967; Strauss & Corbin, 1990).

This study employed three forms of triangulation to increase validity of the findings (Denzin & Lincoln, 2011). Data triangulation: several sampling strategies were undertaken at different times and social situations; investigator triangulation: three teachers with separate classes; methodological triangulation: more than one method employed for gathering data.

Triangulation using qualitative as well as quantitative research counteracted the effects of statistical regression, the tendency for the mean of extreme scores to drift back to the middle. Thus, this multimodal multi-method approach confirmed the validity of convergent findings by cross-checking and allowed for divergent findings to be corroborated or refuted.

To facilitate transferability, this study ensured that sufficient data was provided in enough detail to allow for replication. The division of the student cohort into three classes enabled checks and comparisons to be constantly monitored throughout the year and extraneous variables were controlled to maximise the reliability of results. Quantitative data from summative assessment results was achieved through validation of the summative assessment instruments and marking and grading process by the regional moderation panel for Mathematics A.

To achieve conformability, the study clearly demonstrates that the findings emerge from the data and not from their own predispositions (Shenton, 2004). Experimental mortality occurred if some students exited the school or the Mathematics A class during the study year; these events were noted and incorporated into the outcomes of the study. To be dependable, it was essential that another, independent investigator could replicate the process and decide whether the findings can justifiably be applied to another setting.

5.8.2   Qualitative methods

Qualitative document analysis (Bowen, 2009), student and teacher questionnaires (Fraenkel, Wallen, & Hyun, 2012), focussed (semi-structured) interviews with teachers and students (De Marrais & Lapan, 2004), classroom observation (Merriam, 2009) and student focus groups (Fontana & Frey, 1994) were the qualitative measures adopted in this study. The purported correlation between the questionnaire and the interview was dependent upon the good design of the instruments (Harris & Brown, 2010; Villanova, 1984). Where instrument design is well structured, correlation between the data collected is good and the results will be valid and reliable. Hence, good instrument

design and well-structured interviews carried out by a trained interviewer contributed towards the validity and reliability of the results and the trustworthiness of the findings.

Questionnaire

The student questionnaire (Appendix I) was used to obtain background information about each student, including a description of their learning context and the learning processes they experienced. This information was obtained from the entire cohort at the same time and the teacher-researcher sought to discover the thoughts, feelings and opinions of the students, especially those who were later to be interviewed.

The student questionnaire was distributed in Week 6 of each term which provided sufficient time to enable classroom culture to stabilise prior to collection of data (Wubbels, Levy & Brekelmans, 1997). Its distribution was also timed so that it could be completed by students prior to the first summative examination, to maximise the chance of obtaining answers that were not influenced by perceived "selective sampling" techniques (Uijlings, Van De Sande, Gevers & Smeulders, 2013) or by participants' response to summative results. Participants completed the student questionnaire without collaboration or discussion.

The questionnaire included a series of questions for students to respond to by writing or by marking an answer sheet (Fraenkel, Wallen, & Hyun, 2012, p. 125). It was comprised of questions relating to study habits, homework completion, revision practices, use of a private mathematics tutor, participation in informal study group(s), and use of social media while studying. It also included questions about preparation for the summative assessment task and student response to feedback.

Although the questionnaire lends itself to quantitative data analysis, when used in a mixed method approach most qualitative researchers, including the teacher-researcher in this study - do not statistically manipulate the numeric values; rather, they use their general descriptive properties (Anderson, 1998).

Disadvantages of using a questionnaire are that ambiguous questions cannot be clarified, and the teacher has generally no chance to expand on a question of interest. Questionnaire fatigue and incorrect conversion of answers resulting in data errors are two other reported problems (Jaeger, 1997).

Interview

The interview has been described as a "conversation with a purpose" (Dexter, 1970, p. 136) or a "process in which a researcher and participant engage in a conversation focused on questions related to a research study" (De Marrais & Lapan, 2004, p. 55). The purpose of the interview was to uncover unidentified factors that may have impacted on summative results.

Controlled sampling was used to select the students to be interviewed. Students who were categorised as "contradictory" – those with results in their summative assessment that varied from that predicted by previous formative and summative results in Mathematics A - and those categorised as "inconsistent" – students whose results on formative and summative assessment tasks appeared to contradict each other – were selected for interview. For example, a student who had completed all the formative assessment tasks to a high standard and then failed to achieve a passing grade on the summative examination of the same topic was interviewed with the intent of discovering

why this anomaly had occurred. In this study, 17 students who were identified as "contradictory" and twenty-one students who were identified as "inconsistent" were interviewed.

The interview comprised three structured questions (Appendix J). Students were also asked if there were any other factors that may have impacted on their results. The environment in which the interview was conducted aimed to encourage students to respond openly and honestly. One disadvantage of the interview as a research tool is that it is difficult to record responses in full (Wengraf, 2001). This difficulty was overcome by recording and transcribing the interviews (the transcript of each interview was checked by the student to ensure that it accurately portrayed their views and circumstances), developing the interview questions prior to the interviews taking place, and holding the interviews after the examination period at the end of each term as sufficient time was available for them to be conducted (Merriam, 2009).

Some advantages of the interview over the questionnaire were the better engagement and more complete responses obtained, together with the chance the interview presented to clarify questions, elucidate answers and pick up on non-verbal cues. As only 4% of respondents refused to be interviewed, the data had validity (Brenner, 2006).

Observation

Classroom observations were recorded as transcripts and as entries in the action research journal. Merriam (2009) maintains that observation has two benefits over interviews: it takes place in an appropriate setting and it represents a first-hand encounter with 'the phenomenon of interest' (p. 117).

Kawulich (2005, p. 1) comments that:

> Participant observation involves the researcher's involvement in a variety of activities over an extended period that enables him/her to observe the cultural members in their daily lives and to participate in their activities to facilitate a better understanding of those behaviors and activities.

Observations were conducted in all three classes, based on the guidelines for qualitative research observations documented by Merriam (2009). Observations involved detailed verbal descriptions, direct quotations or the substance of what was said, and the teacher-researcher's reflective comments. Observations were made primarily in a teaching situation, with a focus on the physical setting, the students, activities, interactions, conversations, and small group and informal discussions. Classroom observations documented patterns of student behaviour and changes in this behaviour, classroom interactions, informal discussions and observations of classroom culture. Data was collected from both informal and formal classroom interactions between teacher and student and student and student. Observations were also carried out in other relevant situations, such as pre-examination study sessions, pre- and post-examination discussions with students and examinations. Informal teacher-student and student-student interactions were noted but not necessarily included in the data collection process unless the content was directly relevant to the research question.

As the year progressed, evidence that induction of the participants into a community of practice was taking place was sought: the characteristics of activity and parameters defining community were the focus of observation.

Focus groups

This study followed the *Guidelines for Focus Groups* (Anderson, 1998, Ch. 20, p.200). Focus groups are usually composed of relatively homogenous groups of people aimed at providing information on topics specified by the researcher (Hughes & Dumont, 1993). One of the main advantages of the focus group is the opportunity it presents to observe the group interact on a topic (Morgan, 1998). It is valuable because it can move beyond the level of the individual and provide insights into the cultural knowledge that is shared by group members (Morse & Field, 1995).

The post positivist paradigm holds that there is more than one reality which embodies the way things are and how they work; hence, it was expected that different students would produce varied interpretations. Similarities and differences in students' opinions and experiences become clearer in the focus group, an advance on what a teacher-researcher can infer from statements by individual interviewees. The language and concepts students use to structure their experiences and to think and talk about a designated topic is important information for the researcher (Kitzinger, 1995). Thus, the focus groups examine the cultural knowledge that is shared among group members.

In this case study, the focus group was used to observe group interaction on a specific topic (Morse & Field, 1995), which was either generated by students or by the teacher-researcher. Student involvement was targeted, but voluntary. Although a few (9) students sought to be included, the teacher-researcher sought to include those students whose assignment preparation process and response to assignment questions was weak. The size of the focus groups ranged from five to nine students. Transcripts and

recordings of focus group discussions were made available to students for checking, thus ensuring the validity of the data gathered.

Artefacts

Artefacts had been collected throughout the year in the form of student responses to formative and summative assessment tasks. Data obtained from these artefacts and from observations were compared with student responses to the student questionnaire and interview which provided a more complete picture of a student's thinking at the time each instrument was administered.

Teacher meetings

To facilitate dialogue, regular meetings of the three teacher participants were held, to determine and record their reaction to, and interpretation of, events as they unfolded (Torrance, 2012). At the commencement of the year, all teachers were committed to the program and looked forward to the opportunity to engage more fully with a formative assessment program in Mathematics A. As the year progressed and classroom culture evolved into one that was a student-directed autonomous learning culture, Teachers 2 and 3 expressed concerns about loss of power and control in the classroom. Observing that evolution in student behaviour, Teachers 2 and 3 came to recognise that when a classroom culture of self-directed learning develops, and students take control of their own learning journey, unexpected outcomes can emerge.

Research journal

As the data was collected and analysed, different questions began to surface: Emergent themes guided the investigation in new directions. The researcher engaged in

extensive reflection, seeking explanations for causal links between events that would lead to plausible interpretations of information and events. An action research journal was used to record on-going thoughts, ideas for analysis, and early themes. This was done to extend the audit trail from collection through to analysis, to enable a macro view of the direction of the analysis and to guide future researchers to replicate the study (Anderson, 1998). Examples of items included in the audit trail were assessment items; model solutions; assessment criteria and marking schemes; transcripts of student work - including responses to formative and summative assessment tasks; transcripts of interviews; focus groups; classroom discussions; completed questionnaires; completed student feedback forms; the teacher-researcher's professional journal; panel submissions of student work; feedback on grading decisions from district panel meetings; transcripts of teacher meetings; and, discussions and completed teacher feedback forms. Ongoing discussions with other teachers and researchers, the teacher-researcher's doctoral supervisor and school administrators ensured that the audit trail was authentic and adequate. Adherence to the grounded theory research process enabled to the study to justify decisions made as the study progressed and evolved.

5.8.3 Quantitative methods

Quantitative data on the number, type and level of difficulty of questions on formative and summative assessment items and on the number of questions the students attempted was collected and analysed in support of qualitative data from task sheets and student responses to formative assessment items. Student results in the form of marks and grades achieved for each of the summative assessment items were also recorded on

individual student profiles. Student results from each term were tabulated and graphed to show changes in students' summative achievement throughout the year.

This data was recorded and collated to form a developmental profile for each student which allowed the teacher-researcher to assess progress over the year of the study in comparison to Year 11 summative results. The grade a student achieved in Mathematics A at the end of the previous year of study (Year 11) was used as a benchmark for comparison with summative data collected each term in Year 12. The final, exit grade was compared to that student's benchmark grade. All five grades were used to chart student performance over the research period. A 10% improvement in grades, equal to five rungs, was considered to be statistically significant.

5.9   Data Analysis

Qualitative data was generated from the analysis of formative and summative assessment tasks, observations and transcripts of classroom interactions and discussions, teacher-student and student-student interactions, student questionnaires, interviews, focus groups, journals, teacher meetings and artefacts collected over the year (Banfield & Cayago-Gicain, 2006; Willis, 2007).

The formative and summative assessment items were analysed to determine their focus and content, particularly evidence of mathematical knowledge, mathematical reasoning, problem solving and provision of correct solutions. The level of student engagement evidenced by the number of questions addressed on each assessment task was noted and student responses and comments were recorded.

Coding was used to organise the data into descriptive themes that emerged during data collection and analysis phases (Charmaz, 2006; Glaser, 1998; Strauss & Corbin, 1998). Codes were assigned to the data (so that data could be could be easily retrieved) and the data was analysed for emerging themes and trends. The themes were responsive to the research question, sensitive to the data collected, mutually exclusive to each other and conceptually congruent. The data was audited to ensure that it met the quality standards for a qualitative study. Checks were made for internal validity, statistical precision and external validity. To address credibility, the study sought to demonstrate that a true picture of the phenomenon under study was being presented.

The codes were compared, and conceptual labels were used to describe similar codes portraying similar incidents. Each of these groups became a concept. Categories were developed as these conceptual labels were contrasted again and further clustered into a higher and more abstract level known as categories (Strauss & Corbin, 1998).

The coding process for grounded theory analysis recommended by Glaser (1978) and Charmaz (2006, 2014) was employed: the first phase, open coding, aimed to generate initial concepts from the data; the second phase, axial coding, involved the development and linking of concepts into conceptual families; the third phase, selective coding, included the formalising of these relationships into theoretical frameworks; and, the final phase enabled theories to emerge from the saturated categories and themes (Charmaz, 2006, p. 12-13), as shown in Figure 8.

Figure 8   Model of Grounded Theory Analysis (Stockwell, 2013)

Level 4 Theorising
Theories can emerge from saturated categories and themes

Level 3 Selective Coding
Core concept is identified. Previous coding is studied to develop highly refined themes.

Level 2 Axial Coding
Focussed Coding and Category Development Developing and linking of concepts into conceptual families

Level 1 Line by Line Open Coding
Large quanitities of raw data are focussed and labelled.

Initial concepts are generated from the data

Open coding

Open coding was employed at the start of the study (Strauss & Corbin, 1998) to facilitate the discovery of emerging, theoretically relevant categories that could later serve as the basis for theoretical sampling. The analysis begins with as few predetermined ideas as possible, informed by the existing literature and theory, and the teacher-researcher's prior knowledge and experience (Calman, 2012). Where open codes were identified, probing the data enabled the list of open codes to be expanded.

Constant comparison

Grounded theory methodology relies on the constant comparison and interaction of the data. Consequently, each piece of relevant data was continually compared with every other piece of relevant data by questioning in the manner proposed by Glaser (1978) - *What is happening here? Under what conditions does this happen? What is this*

data a study of? What category does this incident indicate? - to identify whether any two pieces of data were similar, to understand the research situation, and to discover the theory implicit in the data. Through this comparison process, the collection, coding, and analysis phases worked in tandem throughout the investigation. Constant comparison involved four stages - comparing incidents applicable to each category, integrating categories and their properties, delimiting the theory and writing the theory (Glaser & Strauss, 1967, p. 105). This allowed the gradual development of the data from the lowest level of abstraction to a higher level of theoretical conception. Theoretical sensitivity, an important component of the data analysis stage, was fostered in the constant comparison phase (Strauss & Corbin, 1998).

Theoretical sensitivity

An understanding of what the participants perceived as being significant and important was developed through immersion in the data. Employing theoretical sensitivity, the important features of the collected data and their meaning - the concepts, categories, properties and their interrelationships – were made accessible (Glaser, 1992; Glaser & Strauss, 1967; Strauss & Corbin, 1998). As theoretical sensitivity increased, certain events that were overlooked in the initial stage of data analysis were recalled, recoded and re-analysed (Strauss & Corbin, 1998).

Pattern matching

The technique of pattern matching was employed where the patterns of relationships observed in one instance were predicted to occur in another (Glaser & Strauss, 1967). While seeking to be responsive to the data and seeking disconfirming evidence, loosely-formed sensitive questions were posed (Corbin & Strauss, 2008).

During the preliminary phase of analysis, questioning was at a basic level. The search for the negative case was employed to explain why some participants exhibited contrary attitudes and less successful outcomes. By seeking out exceptions, the researcher aimed to identify areas of disagreement which required explanations that would lead to a better understanding of what was taking place.

Progressing through to the process of axial coding using constant comparison, emerging themes appeared. When themes not related to the research questions were noted, these were not considered to be of equal importance as those relating directly to the research question and they were not explored further (Merriam, 1998). Theoretical sampling using sensitive questioning and investigating the negative case clustered these emerging themes into higher and more abstract major categories (Figure 9).

Figure 9   Grounded Theory in an Action Research Framework (Dick, 2005, p. 7)
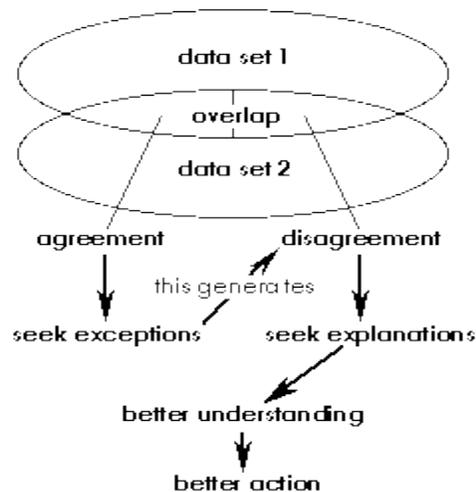
5.10 Theorising

Theory generation depends on progressive verification (Punch, 2013). As the cycles of data collection and analysis progressed, and with continual application of constant comparison and seeking exceptions generating disagreement, themes/key concepts began to emerge (Charmaz, 1995).

To prevent any filtering of data through pre-existing conceptions, the fit between preconceptions and the emerging data was constantly evaluated by looking at the data from multiple angles, making constant comparisons, exploring any possible new directions and building on any feasible ideas (Charmaz, 2006, p. 11). Using this approach there was no need to isolate variables in the quest for impartiality. Valuable layers of complexity could remain intact and facilitated a richer understanding of the research situation as shown in Figure 9.

Major categories were clustered together to form the core category. The core category was a more highly abstracted category but remained grounded in the data, developed so that it accounted for most of the variation of data. Generation of theory occurred around the development of a core category (Calman, 2012). Other categories related to the core category in some way.

5.11 Ethical Considerations

As the action researcher is engaged in diligent inquiry, the methodological, epistemological and ethical considerations of the research are cause for reflection (Herr & Anderson, 2000). Negotiating the multiple, and often contradictory, imperatives and

the different interests and expectations of the various stakeholders presented the teacher-researcher with a challenge.

Ethical principles for conducting this research were followed. Before the study was conducted, ethics approval from Curtin University was sought and gained (Appendix K). All the participants' consent forms, which clarified the purposes and methods of data gathering, how information they provided would be used and how their identities would be protected, were obtained. The participants were also informed in writing that their confidentiality was guaranteed and that they had a right to withdraw from the study at any time. All the participants were also offered the opportunity to further discuss the purposes of the study in person prior to their decision, if required.

As a teaching practitioner, the researcher was keenly aware of the conflictual nature of the ethical issues surrounding research with minors (Clark & Sharf, 2007; Jones & Stanley, 2008). The teacher-researcher had ethical and legal responsibilities towards the subjects who participated in the research (Anderson, 1998, p. 4). Groundwater-Smith and Mockler (2002) suggest that "ethical rigor should be one of the 'three basic tests' of quality educational research, alongside triangulation of data and inter-subjective verification" (p. 4). Specific ethical issues need to be considered when contemplating practice-based research involving schools and the wider community (Jones & Stanley, 2008) in adherence with Program Evaluation Standards (Sanders, 1994).

This set of standards focusses on four requirements of the research: utility, feasibility, propriety, and accuracy. The purpose of the usability standard is to ensure that the study limits the evaluation process to the information needs of the intended users; disruption is

kept to a minimum by applying the three feasibility standards and so making sure that

the research is conducted legally and ethically. The researcher must show due regard for

the welfare of those involved, as well as those affected by its results (Anderson, 1998);

carelessness or inattention to proprietary or private information infringes the

stakeholders' privacy or other rights (Yarborough, 2010, p.122); and communication is

the core of the accuracy standard - it includes trust and authenticity in both

communication and documentation (Yarborough, p. 158).

The impact of the bias integral to the teacher-researcher's status as an insider was

minimised wherever possible: the research purposes, rather than being evaluative of the

participants' practices and beliefs, were deliberately descriptive in nature; focus groups

and interviews, which were guided by open-ended questions, were used to maximise

opportunities for the participants to voice their viewpoints; prior to the commencement

of data analysis transcriptions of the interviews were sent to the participants for

verification, amendment and confirmation; findings were reported using the participants'

own words in order to retain the participants' stance. Identification of sensitive issues

prior to the data collection process sought to minimise the prospect that teacher

participants may be confronted by issues of professional identity in telling stories about

themselves and their teaching.

The possibility of compromise to the study due to issues of power and trust relations

between the participants and the researcher/teacher are acknowledged (Mercer, 2007;

Wengraf, 2001), particularly in relation to the unequal power relationship between the

teacher-researcher and the students. The expectation that the students would be helped

by their involvement in the study or that the outcomes may result in the labeling of participants (Anderson, 1998) was clarified at the beginning of the year and participants were assured that the research would not affect them academically or personally.

A power differential existed between the teacher-researcher, who was also Head of the Mathematics Faculty at the school where this study took place, and the other two teachers involved in the study. The teacher-researcher was the direct supervisor of the two participant teachers. These teachers were fully informed of the scope of the case study and were participating in the case study of their own free will. They were free to withdraw from the study at any time without any adverse effect on their role as teachers or as members of the research team. These teachers understood that they were an integral part of the case study and full participants in the research process. Their considerations, views and feedback were accepted, acknowledged and actioned. They were participants in the research process as professionals, in accordance with the action research guidelines for working with others in organisational and institutional settings (McNiff, 2016).

The potential for students to perceive the teacher-researcher as an authority figure leading to them trying to please for fear of potential negative consequences was also acknowledged (Einarsdottir, 2007), as were the negative consequences in relation to limiting voluntary participation and obtaining honest responses. The teacher-researcher actively sought to build relationality and reciprocity and engage in honest communication with all participants (Hall & Callery, 2001; Mercer, 2007). Confidentiality was built on negotiation and trust. It was obligatory that the teacher-

researcher did not betray a student's or a teacher's confidence, while honestly and accurately reporting findings (Einarsdottir, 2007; Pendlebury & Enslin, 2001).

Appropriate work practices, breaks and workloads avoided an impost on the teacher participants that may have had the potential to compromise the study. As the primary researcher was also the teacher-researcher in the study, care was taken to ensure that objectivity was maintained by peer debriefing, negative case analysis and close monitoring of the process by the three teachers involved. Objectivity was further verified by the submission of portfolios of student work at the beginning and end of the year to the regional monitoring panel for Mathematics A.

Ethical considerations had to include the preservation of the integrity of the summative assessment items in line with guidelines for senior assessment provided by the Queensland Studies Authority (QSA, 2010, 2013b). The range of student responses and grades on the summative assessment items indicated that the integrity of the items had been successfully preserved (Even, 2005; Gibbs & Simpson 2004; González, González, & Bermejo, 2010). This was confirmed through verification of the individuality and authenticity of each student's response by the independent moderation panel for Mathematics A (QSA, 2010, 2013b, 2013e).

Data storage adhered to the procedures set by the School of Education and Curtin University. This study complied with the policies and procedures set by the Queensland College of Teachers (QCT, 2013), the Mathematics A Moderation Panel, and of the school where this study took place.

Chapter 6   Results

6.1   Introduction

This chapter presents the data obtained through an analysis of the quantitative and qualitative data. Data was collected over a full school year.

Quantitative results included a comparison of formative and summative assessment tasks, a comparison of levels of student engagement and the presentation of summative outcomes for each school term showing changes in student grades as the study year progressed. Each student's overall summative result for the year is provided. Qualitative results included data from student self-assessment checklists and student questionnaires, classroom observations and discussions, focus groups, student interviews and teacher meetings.

The coding process is described, and data analysis demonstrated, as the coding process progressed from open coding through cluster codes and on to emergent themes, resulting in a core category.

6.2   Quantitative results

6.2.1   Comparison of formative and summative tasks

The mathematical attributes assessed, complexity and length of question and the standard (D to A) of the questions in formative task sheets were assessed and compared to those in the summative tasks. The results are shown in Table 3 below. This comparison was undertaken to investigate why those students who had previously achieved success on formative assessment tasks failed to achieve on summative

assessment tasks. The teacher-researcher aimed to investigate if these differences this might be due to a variation in the rigor and complexity of questions on formative and summative tasks. Table 3 indicates that Term 1 formative assessment tasks failed to include A and B standard criteria for the knowledge and procedures and the modelling and problem-solving questions. This deficit was remedied as the study progressed and by Term 4 A to D standard criteria were addressed on both formative and summative tasks.

Table 3   Comparison of Attributes of Formative and Summative Assessment Items

Attributes	Formative Assessment	Summative Assessment
Procedural skills		
Logical Setting Out	✔	✔
Labelled Diagram	✔	✔
Formulae	✔	✔
Calculations shown	✔	✔
Solution/Answer	✔	✔
Justification of reasonableness of results	Terms 3 and 4	✔
Knowledge and Procedures		
Scaffolding Provided	Terms 2, 3 and 4	✖
A Standard Questions	Terms 3 and 4	✔
B Standard Questions	Terms 2, 3 and 4	✔
C Standard Questions	Terms 1, 2, 3 and 4	✔
D Standard Questions	Terms 1, 2, 3 and 4	✔
Modelling / Problem Solving		
Scaffolding Provided	Terms 2, 3 and 4	✖
A Standard Questions	Term 4 only	✔
B Standard Questions	Terms 3 and 4	✔
C Standard Questions	Terms 1, 2, 3 and 4	✔
D Standard Questions	Terms 1, 2, 3 and 4	✔
Assessment Criteria Provided	Terms 2, 3 and 4	✔
Assessment Criteria Scaffolded	Terms 3 and 4	✖

The formative and summative assessment tasks were also found to vary in length. This was directly related to the degree of difficulty of the questions. The formative assessment tasks initially included only D and C standard mathematical attributes, in contrast to the summative tasks which assessed D, C, B and A standard tasks on every assessment item. The formative items were modified as the study progressed to include D to A standard questions but were accompanied by a self-assessment checklist that scaffolded the students through the requirements for setting-out and presentation of their responses, and, as the study progressed, for developing the mathematical model required to answer the more complex B and A standard questions. No scaffolding was provided in any of the summative assessment items.

The formative assessment task sheets and student responses were also analysed (Table 4) to assess the demand they placed on the student to provide evidence of procedural skill, mathematical knowledge, mathematical reasoning, problem solving strategies and correct solutions. Scaffolding was not provided for the formative knowledge and procedures and modelling and problem-solving questions during Term 1; consequently, these sections of Table 4 are shown as not available (N/A). By Term 4, scaffolding had been provided for all sections of the assessment items and many of the students were making use of the scaffolding provided for both the knowledge and procedures section and modelling and problem-solving tasks. There was a noticeable increase in students' demonstration of procedural skills as the year progressed. Table 4 shows that students were not only attempting to use these skills but were also demonstrating the correct implementation of the procedural skills required for each task.

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Table 4 Formative Assessment Attributes Attempted & Demonstrated Term 1 & 4

Term	Term 1	Term 4	Term 1	Term 4
Number of students	52	48	52	48
Attributes	**Attempted**		**Demonstrated**	
Procedural skills				
Logical Setting Out	34	44	12	34
Labelled Diagram	8	37	3	17
Formulae	22	38	8	29
Calculations shown	23	47	38	38
Solution/Answer Provided	42	44	5	37
Justification of reasonableness of results	N/A	16	N/A	15
Knowledge and Procedures				
Scaffolding Implemented	N/A	23	N/A	22
A Standard Questions	N/A	27	N/A	8
B Standard Questions	N/A	29	N/A	18
C Standard Questions		45		42
D Standard Questions		47		44
Modelling and Problem Solving				
Scaffolding Implemented	N/A	29	N/A	22
A Standard Questions	N/A	16	N/A	5
B Standard Questions	N/A	27	N/A	11
C Standard Questions	N/A	48	N/A	36
D Standard Questions	N/A	45	N/A	39
Procedural Skills Demonstrated	45	44	23	38
Mathematical Knowledge Demonstrated	47	45	29	41
Mathematical Reasoning Demonstrated	23	34	19	26
Problem Solving Strategies Demonstrated	12	28	8	27
Correct Solutions Provided (>65%)	17	27	4	24

The mid-term formative assessment tasks were assessing the acquisition of mathematical knowledge at the level of the procedural skill required to complete the D and C standard knowledge and procedures questions. The mathematical attributes being assessed were found to be, in the main, specific to each topic. Even though the problems were of a lower degree of difficulty, student responses were often lacking in the required evidence.

For example, most students provided an answer only, while others included some basic calculations only. Only four students (8%) provided the correct setting out and justification needed to support a C grade.

6.2.2 Student engagement and summative outcomes

Using the number of student responses on the self-assessment checklists as a proxy for student engagement in Mathematics A, the researcher categorised the degree of student engagement demonstrated by each student - no engagement, moderate engagement or high engagement. The change in each student's grade from the beginning of the year compared to the end of Term 1 indicated that those students who had engaged with the formative assessment process had improved their grades significantly on the summative assessment items, suggesting that there may be a direct correlation between student engagement with formative assessment tasks and subsequent success on summative assessment items.

6.2.3 Semester 1 Term 1 results

Term 1 results produced unexpected outcomes, in each of the three classes, a substantial number of students either achieved a lower grade than they had at the end of Year 11 or had maintained that grade. Only in Class A did the number of students (11 students or 65%) who achieved a higher grade outstrip those who did not (5 students or 30%). In Class B and C, the number of students whose grade did not improve was disturbingly high. Eleven out of the fifteen students (73%) who were awarded a grade at the end of Year 11 failed to improve on that grade, with most of these students achieving

a lower grade at the end of Term 1. The situation was better in Class C, where nearly half the students (48%) achieved an improved grade.

Class A Teacher 1

Most students in Class A achieved higher marks in Mathematics A than they had previously. At the end of the second topic, students in Class A asked for the formative assessment test to be administered, the results of which are shown in Table 5.

Table 5 Summative Results and Engagement: Class A, Term 1

Student	Start	Finish	Change (rungs)[3]	No. of student responses on self-assessment checklist	Assessed level of engagement (1 low to 5 high)
A1	NIS	C1	-	5	1
A2	C7	B8	+11	14	4
A3	C3	C2	-1	7	2
A4	C5	C7	+2	11	3
A5	A2	A5	+3	18	5
A6	B1	C4	-7	3	1
A7	C3	B2	+9	17	5
A8	C7	B4	+7	18	5
A9	C7	C1	-6	4	1
A10	C9	B1	+2	0	1
A11	C1	C2	+1	19	5
A12	B3	A4	+11	10	3
A13	B2	B6	+4	6	2
A14	C5	B3	+8	18	5
A15	B8	B2	-6	11	3
A16	C3	C3	0	12	4
A17	C5	C6	+1	14	4

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[3] Senior Mathematics subjects are graded using an A to E scale where A is the highest and E is the lowest grade. Each of these grades are divided into 10 rungs with 1 as the lowest and 10 as the highest rung. For example, there is only one rung between a B10 and an A1 grade, but there are five rungs between a B2 and a B7 grade.

Amongst the students who had achieved an improved grade, there was a discernible movement from C to B standard grades, with one student moving from B to A standard. There was also a discernible upward movement of more than four rungs for each A standard student in this class. Eight of the seventeen students (47%) were assessed as having a 4 or 5 (high) degree of engagement. Seven (41%) of these students showed an improvement in grade. This improvement ranged from 1 rung to 11 rungs. There was no evidence that improvement was due to a low(er) starting grade. One student retained the same grade over the first term. Six of the students (35%) were assessed as demonstrating engagement levels of 1 (lowest) of 2. Of these students, three (18%) decreased in grade over the term, two increased their grade (12%). One student was new to the subject and had no benchmark grade to use for comparison.

Class B Teacher 2

Only four students (24%) improved their grade, while eight (48%) students went down in grade and three students (18%) stayed at the same level (Table 6).

Table 6   Summative Results and Engagement: Class B, Term 1

Student	Start	Finish	Change (rungs)	No. of student responses on self-assessment checklist	Assessed level of engagement
B1	B3	B2	-1	10	3
B2	C2	C4	+2	7	2
B3	C6	D8	-8	3	1
B4	D5	D5	0	7	2
B5	B8	B7	-1	12	3
B6	C3	D7	-6	3	1
B7	NIS	C7	-	11	3
B8	C3	D7	-6	3	1
B9	B2	C10	-3	5	2
B10	B1	B1	0	13	3
B11	C7	C7	0	11	3
B12	C1	E8	-13	2	1
B13	C4	D4	-10	5	2
B14	C3	C5	+2	12	4
B15	C6	C9	+3	15	4
B16	NIS	C3	-	18	5
B17	B1	B3	+2	9	3

NIS =Not in Subject

The finding that eight students had achieved a lower grade than they had at the end of Year 11 was not only unexpected but was of considerable concern as there appeared to be no external factors that would account for the drop in achievement. The students also evinced surprise at their poor results when interviewed. The teacher of Class B believed the result achieved in Term 1 more accurately reflected these students' mathematical ability and their attitude to the subject than had the grade they achieved at the end of Year 11.

Three of the seventeen students (18%) were assessed as having a 4 or 5 (high) degree of engagement. Two (12%) of these students showed an improvement in grade. One was

new to the subject and had no benchmark grade. This improvement ranged from 2 to 3 rungs. Eight of the students (48%) were assessed as demonstrating engagement levels of 1 (lowest) or 2. Of these students, six (36%) decreased in grade over the term by between 3 and 13 rungs and one student (6%) increased in grade by two rungs. One student (6%) retained the same grade over the term.

Class C Teacher 3

Class C's grades at the end of Term 1 (Table 7) showed that six students (42%) had improved their grade, seven students (50%) achieved a lower grade than at the start of the year, and one student (7%) retained the same grade. Students in Class C worked at a lower level than those in the other classes. The results from this class were also of concern, particularly as students C6 and C10 had both regressed 10 rungs, or one full grade. Interviews with these students revealed a general dissatisfaction with the teacher and they were concerned that they were not receiving the same learning materials as students in the other two classes. There were no reported external factors involved. However, it was noted that four of these students (28%) demonstrated behaviour problems in other classes, according to other subject teachers.

Table 7   Summative Results and Engagement: Class C, Term 1

Student	Start	Finish	Change (rungs)	No. of student responses on self-assessment checklist	Assessed level of engagement
C1	C1	D5	-6	5	2
C2	E7	E7	0	0	1
C3	D5	D3	-2	4	2
C4	C1	C3	+2	9	3
C5	C1	C5	+4	11	3
C6	C4	D4	-10	1	1
C7	C6	C2	-4	12	3
C8	D1	D4	+3	7	2
C9	C5	C1	-4	9	3
C10	C2	D2	-10	0	1
C11	D10	D6	-4	1	1
C12	E10	D3	+3	4	2
C13	E4	E5	+1	3	2
C14	C1	C3	+2	14	4

One out of fourteen students (7%) was assessed as having a 4 or 5 (high) degree of engagement. This student increased in grade by two rungs, retaining a C (passing) grade. Nine of the students (63%) were assessed as demonstrating engagement levels of 1 (lowest) or 2. Of these students, five (35%) decreased in grade over the term by between 2 and 10 rungs; three students (21%) increased their grade one by 1 to 3 rungs. One student (7%) retained the same grade over the term. It should be noted that students in Class C were provided with limited access to the formative assessment checklists and processes during Term 1, meaning that levels of engagement were more regulated than voluntary. All five (36%) of the students demonstrating a moderate to high degree of engagement with the assessment checklists retained their C (passing) grade over a range of +/- 4 rungs.

6.2.4   Semester 1 Term 2 results

Class A Teacher 1

The students' grade awarded in Term 2 indicated an overall improvement in results when compared to that achieved in Term 1, although several students achieved a grade lower than they had achieved in Term 1 (Table 8). Students were reported as not in subject (NIS) if they had been enrolled in a different subject during that term. This usually applied to students who had initially enrolled in Mathematics B and found the subject too difficult or students who had not been enrolled at the study school during the term.

Table 8   Summative Results: Class A, Term 2

Student	Start	Term 1	Term 2	Change (rungs) T1 to T2	Change (rungs) Start to T2
A1	NIS	C1	C6	+5	+5
A2	C7	B8	B1	-7	+4
A3	C3	C2	C4	+2	+1
A4	C5	C7	C7	0	+2
A5	A2	A5	A8	+3	+6
A6	B1	C4	B3	+9	+2
A7	C3	B2	C10	-3	+7
A8	C7	B4	B2	-2	+5
A9	C7	C1	C3	+2	-4
A10	C9	B1	B6	+5	+7
A11	C1	C1	C3	+2	+2
A12	B3	A4	A6	+2	+13
A13	B2	B6	B8	+2	+6
A14	C5	B3	B3	0	+8
A15	B8	B2	B3	+1	-5
A16	C3	C3	C4	+1	+1
A17	C5	C6	B2	+6	+7

Twelve of the seventeen students (72%) in the class improved their overall grade from Term 1 to Term 2 with two students (12%) moving from a C to a B grade. The five grades were each divided into ten rungs to allow for a more accurate comparison of student achievement within the grade. Ten students (60%), while remaining in the same grade level, improved their rung position. The anomalous cases involved one student who had maintained the same grade and four students (24%) who achieved a lower grade (one student was 7 rungs lower).

Class B Teacher 2

Nine students out of seventeen students (54%) had improved their grade, by between one and seven rungs. Two students (12%) showed no change in grade and six students (36%) scored lower than they had at the end of Term 1. Two students had recently entered the subject and had no benchmark grade for comparison (Table 9).

Table 9   Summative results: Class B, Term 2

Student	Start	Term 1	Term 2	Change (rungs) T1 to T2	Change (rungs) Start to T2
B1	B3	B2	B3	+1	0
B2	C2	C4	C2	-2	0
B3	C6	D8	C4	+6	-2
B4	D5	D5	D5	0	0
B5	B8	B7	A3	+6	+5
B6	C3	D7	C3	+6	0
B7	NIS	C7	C7	0	0
B8	C3	D7	C3	+6	0
B9	B2	B2	B1	-1	-1
B10	B1	B1	B2	+1	+1
B11	C7	C7	C6	-1	-1
B12	C1	E8	D4	+6	-7
B13	C4	D4	D3	-1	-9
B14	C3	C5	C6	+1	+3
B15	C6	C9	C7	-2	+1
B16	NIS	C3	C10	+7	-
B17	B1	B3	B4	+1	+3
B18	NIS	NIS	C5	-	-

Class C Teacher 3

In Class C, five students (35%) out of nine improved their grade – one student (7%) moved from an E to a D grade increasing by 8 rungs, while another student (7%) achieved a lower grade than had been achieved at the end of Term 1 (decreasing by 2 rungs). Four students (28%) remained at the same level. Of the nine students who remained in the class from the beginning of the year, 5 students (35%) had increased

their grade, three (21%) had shown no gain on their Year 11 grade, while one student

had regressed a full ten rungs from a C4 to a D4 at the end of Term 2 (Table 10).

Table 10   Summative Results: Class C, Term 2

Student	Start	Term 1	Term 2	Change (rungs) T1 to T2	Change (rungs) Start to T2
C1	C1	D5	D5	0	-6
C2	E7	E7	NIS	-	-
C3	D5	C3	NIS	-	-
C4	C1	C3	C3	0	+2
C5	C1	C5	C3	-2	+2
C6	C4	D4	D4	0	-10
C7	C6	C2	C6	+4	0
C8	D1	D4	NIS	-	-
C9	C5	C1	C5	+4	0
C10	C2	D2	C2	+10	0
C11	D10	D6	C3	+7	+4
C12	E10	D3	NIS	-	-
C13	E4	E5	D2	+8	+8
C14	C1	C3	C3	0	+2

6.2.5   Semester 2 Term 3 results

Class A Teacher 1

Seven students (42%) had improved from Term 2 to Term 3, with one student

achieving a 7-rung improvement. The other six students had more modest gains of

between 1 and 4 rungs. Three students (18%) showed no improvement in grade and

seven students (42%) achieved a lower score, dropping by between one and three rungs.

There were also three notable instances of improvement in grade, relative to the starting grade: two students improved by a full grade or more (Table 11).

Table 11   Summative Results: Class A, Term 3

Student	Start	Term 1	Term 2	Term 3	Change (rungs) T2 to T3	Change (rungs) Start to T3
A1	NIS	C1	C6	B3	+7	-
A2	C7	B8	B1	C7	-4	0
A3	C3	C2	C4	C4	0	+1
A4	C5	C7	C7	C8	+1	+3
A5	A2	A5	A8	A7	-1	+5
A6	B1	C4	B3	B2	-1	+1
A7	C3	B2	C10	C10	0	+7
A8	C7	B4	B2	C8	-4	+1
A9	C7	C1	C3	C3	0	-4
A10	C9	B1	B6	B9	+3	+10
A11	C1	C1	C3	C4	+1	+3
A12	B3	A4	A6	A5	-1	+12
A13	B2	B6	B8	B9	+1	+7
A14	C5	B3	B3	B2	-1	+7
A15	B8	B2	B3	B4	+1	-4
A16	C3	C3	C4	C8	+4	+5
A17	C5	C6	B2	C9	-3	+4

Class B Teacher 2

In Class B, eight students (48%) improved their performance between Terms 2 and 3, with the largest gain being 7 rungs. Three students (18%) maintained their Term 2 grade and seven students (42%) achieved a lower grade, in one case by 10 rungs (Table 12).

Table 12   Summative Results: Class B, Term 3

Student	Start	Term 1	Term 2	Term 3	Change (rungs) T2 to T3	Change (rungs) Start to T3
B1	B3	B2	B3	B7	+4	+4
B2	C2	C4	C2	D8	-10	-4
B3	C6	D8	C4	C4	0	-2
B4	D5	D5	D5	C2	+7	+7
B5	B8	B7	A3	B8	-5	0
B6	C3	D7	C3	C3	0	0
B7	NIS	C7	C7	B2	+5	+5
B8	C3	D7	C3	C2	-1	-1
B9	B2	B2	B1	B6	+5	+4
B10	B1	B1	B2	B1	-1	0
B11	C7	C7	C6	C4	-2	-3
B12	C1	E8	D4	D5	+1	-6
B13	C4	D4	D3	D10	+7	-5
B14	C3	C5	C6	C5	-1	+2
B15	C6	C9	C7	C7	0	+1
B16	NIS	C3	C10	B3	+4	+10
B17	B1	B3	B4	B8	+4	+7
B18	NIS	NIS	C5	C3	-2	-2

Class C Teacher 3

Four students withdrew from the Mathematics A class at the end of Term 1 and the

cohort for this class in Terms 2 and 3 was 10 students. Of these, four students (40%)

increased their grade, with one student achieving an 8-rung improvement. Three students

(30%) demonstrated no improvement in grade and three students (30%) achieved a

lower grade than they did in Term 2 (Table 13). When Term 3 results are compared with

the start grade, six students (60%) had achieved a grade higher than that which they commenced the year with, with one student demonstrating a 10-rung improvement. One student, despite achieving an improved grade in Term 3 in comparison to Term 2, was still 7 rungs lower than the grade achieved at the end of Year 11.

Table 13   Summative Results: Class C, Term 3

Student	Start	Term 1	Term 2	Term 3	Change (rungs) T2 to T3	Change (rungs) Start to T3
C1	C1	D5	D5	C3	+8	+2
C2	E7	E7	NIS	-	-	-
C3	D5	C3	NIS	-	-	-
C4	C1	C3	C3	C1	-2	0
C5	C1	C5	C3	C6	+3	+5
C6	C4	D4	D4	D7	+3	-7
C7	C6	C2	C6	C5	-1	-1
C8	D1	D4	NIS	-	-	-
C9	C5	C1	C5	C6	-1	+1
C10	C2	D2	C2	C2	0	0
C11	D10	D6	C3	C3	0	+4
C12	E10	D3	NIS	-	-	-
C13	E4	E5	D2	D4	+2	+10
C14	C1	C3	C3	C3	0	+2

6.2.6   Semester 2 Term 4 results

The Term 4 results showed little change from Term 3. It was a shorter term than the other three and included only one topic. Changes in grade between Terms 3 and Term 4 are normally anticipated to be 3 rungs or less. Where a change involves more than 3 rungs, or involves a movement to a higher grade, for example a C to a B grade,

special permission from the regional panel chair is required to confirm the grade allocated.

Class A Teacher 1

From Term 3 to Term 4 there was only one grade change in Class A with Teacher 1, one student moving up one rung (Table 14). The percentage of students remaining in Mathematics A who had demonstrated improvement was 82.4%. An interview with those students who had experienced a drop in their grade revealed that one of the students had a mathematical learning difficulty and had found the increasing complexity of the work too difficult to cope with. The other student had experienced a serious family upheaval event which had seriously interfered with all her studies.

Table 14 Full Year Summative Results: Class A

Student	Start	Term 1	Term 2	Term 3	Term 4	Change (rungs) T3 to T4	Change (rungs) Start to End
A1	NIS	C1	C6	B3	B3	0	+12
A2	C7	B8	B1	C7	C7	0	0
A3	C3	C2	C4	C4	C4	0	+1
A4	C5	C7	C7	C8	C8	0	+3
A5	A2	A5	A8	A7	A7	0	+5
A6	B1	C4	B3	B2	B3	+1	+2
A7	C3	B2	C10	C10	C10	0	+7
A8	C7	B4	B2	C8	C8	0	+1
A9	C7	C1	C3	C3	C3	0	-4
A10	C9	B1	B6	B9	B9	0	+10
A11	C1	C1	C3	C4	C4	0	+3
A12	B3	A4	A6	A5	A5	0	+12
A13	B2	B6	B8	B9	B9	0	+7
A14	C5	B3	B3	B2	B2	0	+7
A15	B8	B2	B3	B4	B4	0	-4
A16	C3	C3	C4	C8	C8	0	+5
A17	C5	C6	B2	C9	C9	0	+4

Legend

   grade showed mostly consistent improvement term-on-term

   grade remained largely unchanged each term

   grade showed considerable variation between terms (+/-2 rungs)

Class B Teacher 2

Class B with Teacher 2 showed minor movement from Term 3 to Term 4. Three

students (18%) moved up by up to three rungs and one student moved down by one rung

(Table 15). The percentage of students remaining in Mathematics A who had

demonstrated improvement was 43.75%. Student interviews with the students who had

gone down in grade revealed that these students blamed a change of teacher. They

claimed that their Year 11 teacher had been highly supportive, whereas Teacher 2 was assessed by the students as having a *laissez faire* attitude and as being unwilling to provide extra help or support materials outside of the set class times.

Table 15   Full Year Summative Results: Class B

Student	Start	Term 1	Term 2	Term 3	Term 4	Change (rungs) T3 to T4	Change (rungs) Start to End
B1	B3	B2	B3	B7	B7	0	+4
B2	C2	C4	C2	D8	D5	-3	-7
B3	C6	D8	C4	C4	C4	0	-2
B4	D5	D5	D5	C2	C3	+1	+8
B5	B8	B7	A3	B8	B8	0	0
B6	C3	D7	C3	C3	C3	0	0
B7	-	C7	C7	B2	B2	0	-
B8	C3	D7	C3	C2	C2	0	-1
B9	B2	B2	B1	B6	B6	0	+4
B10	B1	B1	B2	B1	B1	0	0
B11	C7	C7	C6	C4	C4	0	-3
B12	C1	E8	D4	D5	D8	+3	-3
B13	C4	D4	D3	D10	C1	+2	-3
B14	C3	C5	C6	C5	C5	0	+2
B15	C6	C9	C7	C7	C7	0	+1
B16	NIS	C3	C10	B3	B3	0	+10
B17	B1	B3	B4	B8	B8	0	+7
B18	NIS	NIS	C5	C3	C3	0	-

Legend

▇ grade showed mostly consistent improvement term-on-term

▇ grade remained largely unchanged each term

▇ grade showed considerable variation between terms (+/-2 rungs)

135

Class C Teacher 3

Over the full year, one student had increased their achievement by a full grade (10 rungs), one by 5 rungs, one by four rungs and two by one rung. Not all students finished with a gain in grade, with one student regressing by 7 rungs from a C4 to a D7 (Table 16). The percentage of students remaining in Mathematics A who had demonstrated improvement was 60%. Of the students who changed out of Mathematics A after Term 1, two had shown an improved grade at the time of departure, one student's grade remained the same and one student's grade dropped to a lower grade.

Table 16   Full Year Summative Results: Class C

Student	Start	Term 1	Term 2	Term 3	Term 4	Change (rungs) T3 to T4	Change (rungs) Start to End
C1	C1	D5	D5	C3	C2	-1	**+1**
C2	E7	E7	NIS	-	-	-	-
C3	C5	C3	NIS	-	-	-	-
C4	C1	C3	C3	C1	C1	0	0
C5	C1	C5	C3	C6	C6	0	**+5**
C6	C4	D4	D4	D7	D7	0	-7
C7	C6	C2	C6	C5	C5	0	-1
C8	D1	D4	NIS	-	-	-	-
C9	C5	C1	C5	C6	C6	0	**+1**
C10	C2	D2	C2	C2	C1	-1	-1
C11	D10	D6	C3	C3	C2	-1	**+4**
C12	E10	D3	NIS	-	-	-	-
C13	E4	E5	D2	D4	D4	0	**+10**
C14	C1	C3	C3	C3	C3	0	**+2**

Legend

■ grade showed mostly consistent improvement term-on-term

■ grade remained largely unchanged each term

■ grade showed considerable variation between terms (+/-2 rungs)

Interviews with two of the remaining students who had decreased in grade showed increasing disengagement with the education process at several levels (C6 and C7), while the third student (C10) was angry about the dictatorial attitude of the teacher, saying that he wanted to take control of his own learning without constant criticism from the teacher.

6.2.7   End of year results

By the end of Year 12, several students had demonstrated an improvement on the final grade that they had achieved in Year 11. When the entire cohort of students participating in the study was considered, sixty two percent (62%) had shown an improvement in their grade for Mathematics A relative to the commencing grade. After review of student folios and comparing the folios to the QSA Criteria and to the work of other students in the region, all the grades allocated to students in this study were supported by the regional moderation panel.

There was considerable variation between the three classes in the percentage of students who demonstrated improvement: Class A had the highest number (82.4%), followed by Class C (60%) and Class B (43.75%). As Classes A and B were comprised of students assumed to have equal average ability with respect to mathematics, this result is notable.

What these broad results do not highlight is the marked diversity in the performance of students in the three classes. While it is acknowledged that trends in the cohort rather than individual performance is central to this study, and reliance on changes to individual performance is not a reliable indicator of efficacy, in the context of this study

with its focus on the use of a more diverse range of formative process to support learning outcomes in summative assessment, the performance of some students, particularly those whose performance failed to improve, is notable.

When the Term 1-4 grades are considered, the students fall into three broad groups: those whose summative grade showed mostly consistent improvement term-on-term, those whose grade remained largely unchanged each term, and those who grade showed considerable variation (+/-2 rungs) between terms. When taking into account students who had left Mathematics A (n=4), 62% (28/48) of all students fell into the ongoing improvement category. The remaining 17 students (38%) either demonstrated little or no improvement in achievement or had grades that varied (+/- 3 rungs) between terms, despite the implementation of the revised formative assessment program.

6.3   Qualitative results

Key concepts emerging from grounded theory findings were identified from each of the data sources.

6.3.1   Student self-assessment checklists

Overall, student response to the feedback checklist was positive - all but two students actively engaged with the formative self-assessment feedback checklist. The students believed that the formative assessment process provided with the formative modelling task described exactly what they needed to do to complete the summative assignment correctly; it helped them to begin each question, prompting them to check whether their setting out provided sufficient evidence to support the grade against which it was being measured (C grade).

Class A Teacher 1

Teacher 1 was the teacher-researcher and the teacher of Class A. Class A appeared to demonstrate a direct relationship between engagement on the formative assessment tasks and improved summative grade. Eight of the seventeen students (47%) were assessed as having a 4 or 5 (high) degree of engagement. Seven (41%) of these students showed an improvement in grade. This improvement ranged from 1 rung to 11 rungs. One student (A12) who engaged at a moderate level with the formative assessment tasks improved their grade by 11 rungs from B3 to A4. This student explained that they had not previously understood the concept of addressing the criteria for Mathematics A in order to achieve a higher grade. They had previously been focussed on providing the correct answer whereas the formative assessment tasks, focussed on providing evidence to meet the A standard criteria, had come as a revelation to them. As they had previously been able to respond to the summative tasks by arriving at the correct answer, this new knowledge and awareness of the importance of providing sufficient evidence had been sufficient to enable them to increase their grade significantly. Of the students who engaged with the formative assessment tasks to a higher degree (4 or 5), two students (A11 and A16) showed little (1 rung) or no improvement from the benchmark grade. These students had both been diagnosed with learning difficulties in mathematics during previous years. They were both delighted and surprised to receive a passing grade in year 12 Mathematics A in Term 1 as year 12 was at a higher level of difficulty that year 11 for Mathematics A. Student A15 engaged at a moderate level with the formative assessment tasks, but decreased in grade by 6 rungs. This student had not understood the concept of formative assessment tasks addressing

only the D, C and some B standard questions, leaving the student to respond to the higher-level B and A standard tasks independently. Student A15 had responded to the summative questions based on the formative assessment self-assessment tasks and left the higher-level questions blank, thereby limiting the grade he could achieve on the summative task. This issue was addressed in Terms 2, 3 and 4 by modifying the formative assessment tasks to include the questions of a higher level of complexity (B to A standard questions).

Class B Teacher 2

The correlation between engagement with the formative assessment tasks and the students' summative grade for Term 1 showed a different pattern in Class B with Teacher 2. Teacher 2 had provided students with the checklists and handouts to support the formative assessment process but had not actively implemented the process in the classroom. Despite some very disappointing grades for many students in Class B, those students who engaged with the formative assessment model to a moderate or high degree either improved their grade by up to three rungs, retained the same grade as the benchmark or dropped in grade by either one or two rungs. Those students who had not engaged with the formative assessment process, or had engaged to a minimal degree, dropped in grade by between three and thirteen rungs. One student, student B16, who was new to the subject, had engaged to a higher level with the formative assessment process and achieved a C3 (passing) grade. This student (B16) had changed into this subject half way through Term 1. Student B16 said that he achieved a passing grade in Mathematics A by teaching himself using the formative assessment tasks and support materials, which enabled him to catch up at home on the work he had missed in class.

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Results from Class B indicated that, in this class, moderate to high engagement with the formative assessment process had enabled students to retain their benchmark grade within a range of +3/-2 rungs. One student used the formative assessment materials to catch up on work missed in the first 5 weeks of term before he joined the class, and subsequently achieved a passing grade in the subject for Term 1.

Class C Teacher 3

The formative assessment program was not fully implemented during Term 1 in Class C. Teacher 3 provided Class C with the formative assessment materials on a limited basis, as supplementary learning materials rather than as a process of formative self-assessment for learning. Not all students received all of the formative assessment materials. Of those students who demonstrated a moderate to high degree of engagement with the assessment checklists, all retained their C (passing) grade over a range of +/- 4 rungs. Three students who demonstrated a low level of engagement with the formative self-assessment checklists improved their grade by up to 3 rungs in the E and D (failing) grade levels. Of students who did not engage or engaged at the lowest level, one (C2) retained the same (failing) grade of E7 and the others decreased in grade by up to 10 rungs. No students in Class C achieved higher than a C grade in Term 1 summative assessment. Students in this class voiced resentment that they had not been given the opportunity to participate in the formative assessment process during Term 1. It appeared that engagement with the self-assessment checklists to a moderate or high degree had supported students in Class C to retain a passing grade. Every student who passed Term 1 Mathematics A summative assessment in Class C, had engaged moderately with the formative self-assessment checklists.

Term 1

Teacher feedback was contentious. Although students responded positively to the feedback self-assessment checklist, they took more notice of feedback from self-assessment processes than they did of feedback from the teacher. In Class C, Teacher 3 had taken the time to write comments identifying where students had gone wrong and explaining what they should do next time to improve their response, marking questions with a cross or a tick against the student's response and on their checklist. Examples of teacher comments were: 'Need to show your working'; 'More detail needed here'; 'How did you arrive at this answer? Where is your working out?' and; 'You didn't answer the question'. Despite the intention to identify those aspects of student work that had had a negative impact on the outcome of the assessment, the overall response from the students to teacher comments was negative. In Class C, one student had written back to Teacher 3, "Question 4 was right!", and another wrote, "You're wrong!!!". Students in Class C appeared to ignore Teacher 3's guidance, although the teacher had provided extensive verbal and written feedback. It appeared that most students did not find it helpful: 'Why can't I check my own work?'.

In Class A, four students physically reacted by moving their head back when they read the teacher's comments, seven students immediately turned their papers over and moved them to the top corner of their desks, while two students wanted that it be 'take(n) away'. Comments included: 'Well I can see now why I never get anything right in maths. Teachers just mark what's on the paper. It doesn't matter whether they know you can do it or not'.

No student in Class A wanted to keep their checklist when the teacher feedback column had been completed. Asked whether they had found the teacher's feedback helpful, a resounding "No!" was the answer from fourteen of the seventeen students in Class A. One student commented, "It just showed where I went wrong" and another said, "That just showed me how dumb I am". Three students asked to speak with the teacher later about where they had 'gone wrong' and how they could improve next time. Students from Class B glanced briefly at the feedback from the teacher, putting their papers out of sight where they were not visible to other students. Four students in Class C ignored the feedback from the teacher, while the remaining students moved to the front of the class and began to argue with the teacher about specific aspects of the feedback. Examples of comments from students were; "We weren't taught this", "You didn't show us how to do this in class", "You didn't tell us we had to show all of this working when you did this question of the board".

Term 2

Despite the negative reaction to teacher feedback, student enthusiasm for the checklist was evidenced by the request, prior to the first Term 2 formative test, for the same self-assessment checklist format as had been used in Term 1. One Class B student spoke for the others: "We need that checklist that shows us how to do it properly". When questioned further, it was the basic setting out and presenting evidence - the procedural components of the task - rather than the Mathematics A assessment criteria that students had found so helpful. They also wanted to be able to "Fix up my mistakes straight away so that I can get it right" (another students from Class B). A student in a different class observed: "Assessing myself I learnt how to fix it. If you don't learn how to fix it,

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what's the point of doing the test in the first place?" (Class A). Other students agreed with this view. A second student in Class A commented, "When I go through it myself I can see how to do it!". A third student in Class B confirmed: "Assessing myself I know how to get it right!" and a fourth said, "I can think about the question. I don't have to worry about the teacher seeing how dumb I am!" (Class B).

Students reported that they wanted to self-assess and modify their responses during the formative assessment revision process. Students suggested ways they could enhance their own learning in Mathematics A and were keen to see these suggestions implemented. These ideas included completing the formative assessment task initially in class under exam conditions with time allocated for students to check their response against the formative self-assessment checklist. Several students (7) asked for extra, more diverse revision questions to work on at home, saying they believed exposure to a wide range of formative assessment tasks would enhance their learning. Four students asked for the fully worked solutions with the task sheet, although this request was not universally supported. One student commented: "Don't give me the solutions yet, let me try them first", with another commenting, "Don't even bring them to class, don't tempt me with them!". When these students were ready to assess their work, they requested the solutions to take home to compare their own response to the model A standard response and asked for a range of similar questions to attempt.

Increasingly assertive behaviour by the students in relation to their learning became evident, indicative of students' increasing willingness to attempt unfamiliar problems

and a growing reliance on the use of self -and peer-assessment to monitor their own progress.

The removal of marks and grades from the formative assessment items appeared to have 'unlocked' the students' thinking processes, 'allowing' the students to trust their own judgement, to take risks and reflect on ways to improve their performance on the next piece of assessment.

Term 2 comments reflected concerns with mathematical process, in contrast to the Term 1 comments which focussed on whether they possessed the mathematical skills required to answer the questions. More detailed scaffolding was requested by some students in each class - to guide them in developing the mathematical model needed to answer each question. Limited scaffolding was subsequently included on the feedback checklist provided with the formative assessment item for the second topic in Term 1 (Appendix L).

Others requested that the formative assessment tasks included at least one question at D, C, B and A standard. The main criticism from students was that the feedback checklist addressed the task at C standard only. Students wanted clear guidelines for an A standard response - 71% of students said they could not determine requirements for an A grade from either the QSA Criteria or the task sheet. This posed a risk for the teachers of over-scaffolding the task and, thereby, compromising the originality of the final product submitted by each student. After further discussion, the students agreed that a general statement to the effect that 'Now you need to continue with this task making sure you address the A standard assessment criteria' could be included on the self-assessment

checklist alerting students to the fact that an extended original response was required at this point to achieve an A or B grade.

The self-assessment checklists revealed that some students had difficulty relating the QSA Criteria to the tasks, written student comments indicating that some were unsure whether they had addressed the requirements of the task. In some instances, students who said they had completed a task correctly had only completed part or none of it correctly. Data from the Class C self-assessment checklists showed that the student self-assessment varied considerably from the teacher's assessment of the same piece of work - many students gave an often-generous assessment of their own work.

Comments from a range of different students indicated a problem that was deeper than not providing sufficient evidence of learning on responses to assessment tasks: 'I don't understand which questions I am reflecting on'; 'I am assuming there is no definite answer for questions 6 and 7'. Two other students' comments suggested they were not linking class work with questions on the assessment item: 'I have no idea what this is about, I must have been away.' And 'I don't remember doing all of these things in class'.

Written responses from students in all three classes in the student comment section varied in response to teacher feedback on the formative assessment modelling task: 21% of students wanted the feedback to provide direction for an A standard response; 10% believed they had 'got it right' as far as the feedback checklist was concerned and were disappointed that they had not achieved an A grade on their summative assignment; 17% said that the actual assessment task sheet required further clarification; and, 17% failed

to complete and/or print out and submit the excel spread sheet they had constructed,

even though this was the major component of both formative and summative tasks.

Variation in the way feedback had been received was captured in these comments from a

student in Class C: "I couldn't do that topic; there was red writing all over my paper".

The same student re-submitted a draft summative assignment to his teacher eliciting

feedback five times at the formative stage. Additional feedback from his teacher was

seen by this student as helpful and positive.

Term 3

In Term 3 a discussion was held in each of the three classes to clarify the

students' response to teacher comments. The students talked in general terms about the

way teachers marked student work, moving from general to specific teacher comments.

Eight students (17%) commented that there was little point in scrutinising the feedback

comments once the assessment item had been submitted. Receiving feedback during the

assessment task, so that students could implement it immediately, provoked a positive

response from three students who commented that it had helped them to learn and

remember for next time. Twenty-nine students (60%), during discussion at a combined

class meeting, agreed that receiving feedback after the formative task was submitted and

prior to the summative task was viewed negatively. Students concurred that they did not

necessarily apply the feedback received to the summative task.

There were notable differences in the way feedback from the teacher, as opposed to

feedback from a peer, was received. When the teacher in Class A walked past one

student's desk (Student A) and glanced at her work, she covered her work with her hand

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and said to the teacher, "Don't look, it's probably wrong". However, ten minutes later, during a peer assessment process, this interaction occurred between the same student who had covered her work (Student A) and the student seated beside her (Student B):

Student A: What do you think of this, is it right?

Student B: I think it's wrong, it looks wrong. That's wrong, that's definitely wrong.

Student A: Is it a little bit right?

Student B: That's wrong, wrong, totally wrong. Even your diagram is wrong.

Student A: Don't tell me, let me try it again.

Even though the peer feedback included a strong negative judgement made in front of her peers, the student appeared unashamed and unembarrassed by the seemingly insensitive peer assessment of her work.

The depth and complexity of student feedback evolved during the year. Two illustrations of comments made in Term 3 are evidence of a maturing understanding are:

Student C: I don't fully understand 'reflecting on the effectiveness of the model'. What is the model? If I do the question and get it right, is that the model? Is it effective if I get it right or if I can use this model again? (Student B5, Class B)

Student D: These 'strengths and limitations'; are they asking whether my model worked in this instance, whether it always works, or whether I can predict whether this model will work or not in each situation? (Student A10, Class A)

Codes suggested were constructive feedback, positive feedback and timely feedback.

6.3.2 Student questionnaire

Questionnaires completed in Term 1 indicated that most Mathematics A students did not prioritise time for study and, when they did, there was no discernible improvement in their summative results. Ninety four percent (94%) of students reported that they had actively connected to a range of social media such as Facebook and/or were engaged in texting while studying Mathematics A. While this may be a limiting factor in promoting improvement in learning outcomes in Mathematics A, its effect is beyond the scope of this study.

Student questionnaires also revealed that Mathematics A students did little or no homework. Three-quarters of students (75%) indicated that they did less than two hours of homework each night; 13% of students studied for between two and four hours and 10% of students said they did more than four hours of homework each night. There was no pattern evident in any of the three classes.

Only 6% of students said they were part of a study group for Mathematics A an aspect of student behaviour that contrasts with that of students undertaking higher level mathematics subjects who routinely formed study groups and studied together (teacher-researcher observation). One reason offered by some students for this fact, was that Mathematics A students thought studying together might be perceived as 'cheating'. However, as the year progressed, both students and parents reported the development of regular study groups involving some Mathematics A students. Parents said they had initially viewed these groups with scepticism, anticipating time spent on the phone and Facebook, rather than studying. However, parents reported that the students were

studying together and helping each other with Mathematics A problems. The number of students involved in informal study groups for Mathematics A peaked at 19 (36%) during Term 3 and remained the same for Term 4. Most students came from Class A (13), with 5 from Class B and 1 from Class C.

Codes suggested were: peer support, self-assessment, self-directed learning.

6.3.3   Observation

By Term 2 changes in the culture of the three Mathematics A classes was evident. For example, in Class A student-teacher interactions had become more positive and the teacher was spending less time on directed teaching and more time encouraging, coaching and engaging with students. In Class C, students both stated and demonstrated by their actions that they did not want to be dependent on the teacher, declaring that they wanted to have more control over their own learning. Student responsiveness in all classes to the formative assessment modelling exercise for Assignment 1 showed that when students were enabled to work on their own, they did so.

In Class A, students carefully self-assessed, making notes on their checklists where they had misinterpreted a setting out requirement or where they had misread a question. Some students modified their response to more closely resemble the model answer. The lack of grades or marks on the formative assessment tasks appeared to encourage the students to engage more fully with the feedback self-assessment checklist.

An increasing degree of student engagement was evidenced by an increase in student participation in each lesson. At the start of the year students had been relatively passive, waiting for the teacher to finish writing up each example so that they could copy it from

the whiteboard. During Term 2, rather than demonstrate each step on the whiteboard for the students to follow, the teacher oversaw student progress and offered guidance when help was requested. Students were increasingly focussed on the learning task, and some spontaneously changed seats when, as one student described, they, as one student from Class C commented, "We can end up spending too much time chatting with friends and not enough time working on maths if we sit with our friends". A group of seven students drawn from all three classes, who were talking with the three teachers at the time this interaction took place, agreed with the student from Class C that they worked more efficiently if seated away from their close friends.

Students became increasingly willing to subject their work to the scrutiny of their peers and to answer questions and suggest strategies in group work situations; others argued with peers about the best way to approach a difficult question. It was evident that students in both Class A and B helped each other as they gained confidence in their mathematical skills. Students who had achieved poor results previously became more vocal, seeking help first from their small work group, then from other students and, finally, from the teacher when the student was no longer able to proceed towards a solution without further input. More confident students took the lead and provided peer-tutoring to other students. Some students physically moved themselves into positions in the classroom where they believed they would be most advantaged.

Over a quarter of students in the cohort (28%) requested that some lessons be conducted under exam conditions so that they would be 'forced' to attempt a range of questions without support from books or peers. Conversely, when completing summative items,

students often remained reticent and overly cautious. Two students in Class C summarised this as a fear of 'Looking dumb' or 'Showing (the teacher) how dumb I really am'.

This move towards student-directed learning was confronting for Teacher 2 (Class B) and Teacher 3 (Class C) who expressed concern about the loss of authority if they ceded control or power to the students. Teacher 3 had commented previously that she found it difficult to allow the students to self-assess commenting "I can't see where they went wrong if they have the chance to fix it up!". During an observation session in Class C, students were working through a formative assessment task. Teacher 3 was marking off the self-assessment checklist against each student's responses and telling each student where they had gone wrong. Nine of the eleven students in Class C that day were chatting about out-of-school activities while waiting for Teacher 3 to get to them. One student commented "I want to mark it myself". Two other students added "I want to do it!" and "We want to mark our own". Commenting on this incident later, Teacher 3 said "They won't take no for an answer, they want to get the formative assessment right on their own. I said to them, 'Do it yourself then' and they did!". Perhaps in response to the controlled situation in Class C, many students (71%) had approached the teacher-researcher and requested that they be given time to self-assess their work, asking to have the formative assessment tests, feedback checklists and model solutions emailed to them so that they could work through them at home. Conversely, in situations where Teachers 2 and 3 allowed the students to take control of their own learning, they noted that class control became less of a problem than it had previously been.

In Class B, a student perceived that Teacher A had helped him to get support from Teacher 2: "Thanks so much, he wouldn't help me before and now he knows I won't give up, so he comes and helps me when I ask". Later the same student commented, "I knew I could do it if I got help. Thanks for believing in me". This student's attitude towards mathematics had evolved; whereas the student had previously expressed frustration, she now described a developing confidence in her own ability to obtain the help she needed, when she needed it. By the end of Term 3, Teacher 2 (Class B) was helping students with their work during the breaks and was speaking more positively about the students in the class. There was an observable change in his attitude towards the Mathematics A students. Teacher 2 now appeared to expect students to seek out his help, in contrast to previous comments in which he described students in Class B as "Just wanting to talk about the parties". Classroom observations recorded the response of the students to their Term 4 results. A student in Class A cried "I got a B again. I must be a B student, who'd have thought? Not me!" (laughing). A fellow student asked "Does that mean you can do maths? Are you a secret maths geek?" to which the first student replied (laughing) "Maybe!".

Prior to the Term 3 summative examination, a quarter of students (24%) had emailed their teacher for help and advice over the weekend. On the morning of the examination the whole cohort of Mathematics A students arrived at school three hours before the examination was due to start, maintaining they wanted to 'fit in some final revision'. This scenario contrasts with previous examinations when most students had arrived at

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school a mere fifteen minutes before the examination was due to begin, some with cups of coffee and many without essential equipment.

Three revision classes had been provided for year 12 students. Mathematics A students were given a choice of which revision class to attend, dividing themselves between the three study rooms. In the revision sessions, the students primarily sought help from each other and some students requested revision sheets to work on independently. Students also took advantage of the help available from the Mathematics A teacher present. In one revision group (supervised by Teacher 1 and primarily made up of students from Class A), students worked together, asking each other questions, writing out solutions on the board and arguing about the best way to set out each answer. The students from Class A explained mathematical concepts and answered questions from the two students from Class B who were present. The study room was bustling, and the students remained focussed on studying together throughout the session, although the two students from Class C sat quietly, listening to the explanations other students offered. A student from Class A who had failed mathematics previously, and was isolated in the class, sought help from the teacher during this pre-examination study session. Although the student was currently achieving below a B standard in Mathematics she had a fair grasp of the mathematical concepts under examination. With the extra support, she received in this session, Teacher 1 observed that she was 'ready to achieve' and willingly accepted the help of an experienced teacher. In contrast to the previously described session, the study room supervised by Teacher 2 was silent. The students were working independently or talking quietly and, ultimately, most of the students from this room relocated to the

study room supervised by Teacher 1. The students in the class supervised by Teacher 3 remained in their study room, although the revision session was extremely passive and amounted to students simply watching the teacher go through examples on the whiteboard.

Codes identified were modelling, self-assessment, engagement, achievement and student-directed learning.

6.3.4 Focus groups

In Term 1, student comments revealed a degree of confusion about the task itself. Questioning revealed that all but one of the 8 students present could not understand the words used on the task sheet or on the QSA Criteria; 6 said they could not carry out basic mathematical directions because they could not translate the words they were reading into action and (a different) 6 students said they were unable to determine whether they had engaged with, and addressed, the task correctly after working through the question. The following comments reflected students' frustration:

Student 4: I couldn't do the D standard questions. I could do some of the harder ones but not the easy ones. That's never happened to me before (Class C).

Student 5: I got confused with the easy questions, so I started on the hard ones (Class B).

Feedback received special attention in the Term 1 focus group: students commented that feedback provided after the item was submitted, or after the work had been marked, undermined their confidence. This was summed up by one of the students who attended the focus group: "It was only helpful if I could fix up my work before it was marked".

A focus group in Term 2 confirmed that student response to the self-assessment checklists was overwhelmingly positive, although students wanted the checklists expanded to include A and B standard requirements. It became clear that many students did not know how to address the requirements for the higher-level tasks (only two students in the group expressed confidence in starting each task and working through the criteria). More self-assessment processes in class and more small group work was seen by these students as essential. Two students, one from Class B and one from Class C, were concerned that, if the teacher didn't model the response initially, they would not know whether the small group-generated solution was correct, so were happy to hear of the plan to hand out model solutions at the end of the exercise so that students could use them to critique and modify the group-generated solutions.

All eight students who attended a focus group in Term 3 reported they hadn't applied the process used in the formative assessment modelling task to the summative assessment task: one student stated, "The real assignment looked different". When asked to elaborate, another student said "There was only one question on the formative assessment task. The assignment had a whole lot (of questions). It didn't look the same".

Another Term 3 focus group revealed the change in student perceptions about feedback processes. The students' comments were centred on how to arrive at the correct solution. Individual student contributions to be focus group discussion were recorded. Some examples of these comments from Class A feedback checklists are provided here.

Student 1: We need to know how to get it right. If it's wrong, we need to know how to fix it.

Student 2: I know there'll be a lot wrong on mine. I need to find the mistakes so that I get it right on the exam. If we mark it ourselves no one else sees. We can fix it up and get it right and then we know how to do it.

Student 3: I thought I got it (formative assessment test) all right but when I went through it I didn't. Normally I would just go 'Give up' but going through it myself I could see what I should have done. It was better.

Focus group discussions in Term 4 probed why some students failed to attempt all the questions on the summative examination. Although the students reported enjoying working together and sought help from one another, several students repeatedly expressed concern about looking dumb. One student from Class B had written on her formative assessment item 'I didn't know how to write it, so I just drew a picture'. This strategy was again used by several students on the summative assessment, but they failed to provide any evidence that they could translate this picture into a diagram or use it to identify the correct formula needed to solve the problem. When asked at a focus group why they didn't label their picture and use this as the mathematical model to carry out the calculations, a second student from Class A:

I knew what it was about, and I could see it in my head. I could draw the picture and I knew what went where on my picture. But when it came to the maths I always get confused. Sometimes the hypotenuse is C and sometimes it's H and

sometimes it's the longest side. How do I know what it's going to be and where it is on my picture?

and a third student from Class C said,

I knew the hypotenuse was opposite the right angle, but I didn't use a protractor or anything for my diagram, so I might have drawn it wrong.

Nearly three quarters (74%) of students (from all three classes) who attended Term 4 focus groups said they worried about the teacher finding out that they couldn't do the work - which stopped them from seeking help. Maintaining face was more important to these students than finding out how to answer the question. A fourth student from Class B stated:

It's because we're always dumb in maths. If we can't do a question, it's because we're dumb. We don't want to show everyone how dumb we are.

and a fifth student from Class C confirmed,

Sometimes a teacher will show me how to do a question three times and I still can't do it. How dumb is that? I'm not asking again.

Consequently, when students were asked about their attitude to mathematics most in the focus groups agreed that it was just 'too hard' and that they felt inadequate.

Codes suggested were scaffolding, modelling, self-confidence, self-assessment, directed teaching and teacher control.

6.3.5   Student interviews

Students confirmed during interviews that external factors impacted on their grades. One student indicated that she had a learning difficulty relating to numbers; another had made a conscious decision to neglect Mathematics A to focus on other subjects; for several students, health issues, family breakdown, financial hardships resulting in loss of the family home, and English as a second language impacted on the individual student. While noting these influences on achievement, their effect was not considered in this study.

The interviews confirmed student comments in focus groups and information that emerged from the questionnaire. Comments from different students such as; "I didn't think I could do it until I got the checklist thingy. Then I knew how to start" and "I could do it with the checklist" confirmed the value of the self-assessment checklists. Yet, in at least two cases, the provision of the checklist had resulted in an adverse reaction - one B standard student from Class A - Student 7 - expressed anger saying: "I did everything on that checklist and I still got a C on question 3. It's not fair". Another student from Class A commented that it appeared to some of the students that some assessment items were designed to trick, meaning they were designed to be intentionally obtuse.

Student 8 from Class C complained that she could not see where she had failed to address the assessment criteria (it transpired that she had not understood that answering all questions was the basic requirement an A grade). The discussion highlighted the lack of alignment between formative and summative processes. Another seventeen students

who had successfully completed the formative assessment task failed to apply this model to the summative assessment task. Student 9 explained:

> I saw it was the same as the one we did in class, but it was in amongst all that other information and that made it look different. I didn't want to get it wrong.

Student 10 agreed:

> I saw it was the same and I got the other one right (similar formative assessment question) and I knew I had got it right, but I just didn't think I could do it when I saw it in the assignment.

Students who were negative about the formative assessment modelling process and the self-assessment checklist were a focus of interviews in the week before the Mathematics A summative assignment was due to be submitted in Term 3. One student from Class A who had not improved their grade over the course of the year said: "I just can't do it, it's really hard for me. I'm not as worried as I was, but I find it really difficult". When pressed, she clarified that it was the actual mathematics itself, the numbers and manipulation of formulae that she found challenging. A second student from Class A said, "I don't like maths, I like to talk about things not numbers. This is my extra subject. I've focussed on the other five. Now I've got my place at university I don't have to work at maths anymore".

Twenty-four students (47%) interviewed talked about 'feeling dumb' and were concerned about their mathematics performance. This feeling was exacerbated, in some instances, by the negative feedback received from the teacher. Several students commented that they would prefer to miss out on marks by not answering a question,

rather than 'feel dumb' if they provided an incorrect solution. This is well-illustrated by a tenth student from Class B who hadn't answered a question; she said she was ashamed and embarrassed by this failure: "I am so stupid. I can't do maths. I don't know how to do it. I never get it right".

Codes suggested were modelling, self-confidence, self-assessment, self-directed learning, feedback and scaffolding.

6.3.6 Teacher meetings

The teacher's role in student self-assessment was the subject of the mid-Term 1 teacher meeting in which discussion focussed on the self-assessment checklists. Teacher 2 and 3 raised concerns about student self-assessment, both saying that didn't trust the students to self-assess. They believed that the students would take advantage of the self-assessment process to assess their work as correct, regardless of whether it was or was not. Allowing the students to self-assess was seen by them as ceding control to students. They were also concerned about not assigning marks to the formative assessment tasks and the heavy reliance on other forms of feedback.

Despite their reservations, Term 2 meetings revealed that Teachers 2 and 3 were happy to continue with the formative assignment process, even though they continued to express misgivings about the students in their classes who were 'not up to much' and would not succeed due to their lax attitude to schoolwork in general and mathematics, in particular. Teacher 2 reported that some students were starting to ask for maths help at break times and for extra revision examples to work through at home. He thought these requests were a waste of his time, as Mathematics A students weren't 'serious maths

students' and he would rather concentrate his efforts on students in higher level maths classes.

Teacher 1 reported that students in Class A had expressed a desire for greater autonomy, with more self-directed learning. While Teachers 2 and 3 agreed to support this, they did not commit to trialling this model themselves, Teacher 2 asserting: "They'll just muck up". Teacher 3 reported that although students in Class C wanted to work independently and self-assess against model solutions, she still wanted to go through the work with each student individually and 'show them where they were going wrong'. She was worried that less teacher direction would result in 'chaos'.

A meeting in early Term 3 was held to discuss the results from Terms 1 and 2. The positive attitude of Class A students towards the changes in delivery of Mathematics A during Term 1 was commented upon by Teacher 1. Teacher 2 said, "Nothing like that happening in my class, they're just talking about parties on the weekend. I don't want to let them think they can do anything they want". Teacher 3 also commented on class control: "I'm flat out keeping my lot on track. If I give them an inch, I'll never get them back". Concerns about a loss of power and control in the classroom were frequently voiced. Teacher 1 advised that students from Classes B and C had asked her about how they could take more control of their learning and have more active participation in the formative assessment program. The reaction of the other two teachers indicated that their earlier stance of support for increased autonomy was not underpinned by active commitment to the implementation of strategies designed to foster it. Their statements of intent relating to implementing the formative assessment program and unwillingness to

allow student autonomy in the classroom did not align with their practices. This was demonstrated by their failure to fully implement the ongoing modifications to the formative assessment program as the study year progressed.

Codes suggested were student autonomy, self-assessment, independent learning and teacher control.

6.3.7   Classroom discussion

Informal discussions with students identified that psychological factors were seen to have an impact on student performance in summative assessment tasks. For example, some students who achieved well on the formative task reported that they felt over-confident and did not continue to work at the same level as they did prior to receiving the positive results, with the result that they got a lower-than-expected score on their summative assessment task. Two students from Class A described how this over-confidence resulted in a reduction in their study time for Mathematics A resulting in lower marks on their summative examination in Term 2. Both students believed that the amount of time they spent studying Mathematics A was directly related to the mark they received.

During classroom discussions following the Term 1 summative examination, students commented that they had felt comfortable in the examination and had a much better idea of what they needed to do to achieve well: 92% of students said that they could identify what they could and couldn't do on the examination: 75% of students said that they knew where they had gone wrong. One student from Class B commented that "I know

how we could do our class revision better next time so that it would be even more useful".

Students discussed the examination and the evidence they had provided in their responses. There was no observable focus on the mark achieved; instead, discussions concentrated on the questions themselves, on how they had responded to each question and what they needed to do to improve. Nearly 60% of students had ideas on how the teachers could support them to achieve better grades on future assessment items: 52% asked for more ownership of their learning journey; with clear views on how they could do this -– a different style of teaching, scaffolding, assessment processes that suited them and improved teacher responsiveness to student concerns and requests. Forty-five students (87%) confirmed that they wanted the opportunity to implement feedback immediately before the item was submitted for marking.

Codes suggested were student-directed learning, student autonomy and positive timely feedback.

6.4   Cluster Codes and Emergent Themes

The data revealed a range of open codes representing chunks of the data. Codes were inferred by analysing the quantitative and qualitative data for commonalities that explained an outcome or finding that re-occurred throughout. Evidence in various forms and contexts appeared as a recurring theme in the data. For example, initial data indicated the recurring topic of 'evidence': providing evidence, evidence to support grades assigned, difference standards of evidence required to achieve an A, B C or D grade, sufficient evidence. Therefore, evidence was identified as an 'open code'. Very

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early in the analysis, emerging open codes were *evidence, achievement, assessment, and mathematical reasoning.* Moving forward into cycles of overlapping data collection and analysis, the list of open codes expanded to include *mathematical modelling, developing models, modifying models, reflecting on models, challenging models, self-directed learning, self-assessment, directed teaching and teacher control.*

Progressing through to the process of axial coding using constant comparison, themes/categories began to emerge: *student-directed learning, positive timely feedback, mathematical modelling, reflection and evaluation, assessment and learning, student ownership, student autonomy and teacher control.*

The first category of mathematical modelling incorporated: developing, scaffolding, testing, modifying, and challenging mathematical models; providing sufficient evidence; reflecting, interpreting and making judgements.

The category of feedback included: timely feedback; positive feedback; constructive feedback; peer review; group evaluation; reflecting, interpreting, and making judgements; integrity; and, self-assessment.

Student-directed learning was the third category and included: student autonomy; reflecting, interpreting, and making judgements; teacher support; peer review; group evaluation; integrity; ownership; and, student self-assessment.

A fourth category related to teachers and included: teacher-directed instruction and teacher control.

Theoretical sampling narrowed these to three major categories - *student directed learning, positive timely feedback and autonomous mathematical modelling* - and these were related to the core category - Student autonomy in developing, modifying and challenging Mathematical models, as shown in Figure 10.

Figure 10   Development of a Core Category

Mathematical Modelling	Reflecting	Student Autonomy
Scaffolding Models	Interpreting	Reflecting
Testing Models	Integrity	Interpreting
Modifying Models	Making Judgements	Making judgements
Challenging Models	Positive Feedback	Teacher support
Providing Sufficient Evidence	Timely Feedback	Peer review
Reflecting	Constructive Feedback	Group evaluation
Interpreting	Peer Review	Integrity
	Group Evaluation	Ownership
		Self-assessment

Autonomous Mathematical Modelling	**Positive Timely Feedback**	**Student - directed Learning**

CORE CATEGORY
Student Autonomy in Developing, Modifying and Challenging Mathematical Models

Clustering of the codes into categories enabled a clear picture to emerge offering an explanation of the study's findings. The development of the core category enabled the researcher to construct meaning from the findings of this study which could be used for prediction and future direction.

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6.5 Summary

By the end of Year 12, most students (62%) had demonstrated improvement on the final grade that they had achieved in Year 11. There was considerable variation between the three classes in the percentage of students who demonstrated improvement: Class A had the highest number (82.4%), followed by Class C. Individual student performance was also not consistent.

Analysis of quantitative and qualitative results using triangulation and constant comparison resulted in the development of categories and the clustering of the codes in a meaningful way. The categories were re-examined considering the findings and the codes to extract meaning from the codes. This was done with the aim of identifying a core category which had the potential to explain the findings of the study. Three major categories emerged - *student directed learning, positive timely feedback and autonomous mathematical modelling* - and these were related to the core category - student autonomy in developing, modifying and challenging mathematical models.

Chapter 7   Discussion

7.1   Introduction

Prior to the commencement of this case study, students appeared to be internalising their learning in Mathematics A, based on their success in formative assessment tasks, but some of these students failed to achieve the same result in examinations and other summative assessment tasks. To understand why this discrepancy in performance existed, this study focussed on the efficacy of formative assessment practices over the period of one academic year, identifying the qualities of effective formative assessment practice that had the potential to contribute to an improvement in summative outcomes for Year 12 students. The key research question under investigation was: Does the implementation of a more comprehensive model of formative assessment improve the results achieved by Year 12 students in summative assessment tasks in Mathematics A?

Qualitative data from student self-assessments and questionnaires, interviews, focus groups, classroom observations and informal discussions with students and teachers identified the factors and teaching practices which appeared to be linked to improved levels of achievement in Mathematics A.

The new model focusses on nurturing each students' capacity for independent thinking and problem-solving, fostering their ability to communicate effectively with their peers and with the teacher, and developing in each student the ability and skill level to enable them to transfer their skills, learning and application of mathematics from known to novel situations (Davies, 2003).

The findings are in accord with a social-constructivist theory of learning (Roth & Lee, 2007; Yager, 1991) which contends that learning is an activity that is shaped and informed by different purposes in different social contexts. The new model of formative assessment was grounded in a shift from teacher-centred instruction to student-centred learning. Students were encouraged to participate in learning activities which required them to embrace higher levels of interaction and exercise greater self-reliance and control over their own learning (Vygotsky, 1978).

The research results indicate that a more comprehensive model of formative assessment was successful in supporting student learning and contributed to improvement in summative achievement for some, but not all, students. Some students were better able to employ the critical thinking skills essential to the successful completion of the mathematics modelling and problem-solving tasks and, this study contends, they could use these skills to improve their summative results. Although the findings strongly endorse the importance of collaborative learning to improving summative outcomes in mathematics, it did not deliver optimal benefits to all students.

7.2   Quantitative outcomes

The research question asks whether a more comprehensive approach to formative assessment in Mathematics A will result in improved summative assessment outcomes. For this cohort of students, the data supports an overall improvement in the grades achieved by students at the end of the year.

What these broad results do not highlight is the marked diversity in the performance of students in the three classes. There is considerable variation in the grades achieved by

students in each of the three classes and between students themselves. While it is acknowledged that trends in the cohort rather than individual performance is central to this study, and reliance on changes to individual performance is not a reliable indicator of efficacy, in the context of this study - its focus being the use of a more diverse range of formative process to support learning outcomes in summative assessment - the performance of some students, particularly those whose performance failed to improve, is notable.

Four factors may have contributed to the failure of some students to produce satisfactory gains in summative assessment. First, most of these students appeared to give priority to memorising and applying the formalistic components of mathematics, a preference that resulted in an overemphasis on prescriptive conventions. This focus did not offer the students the opportunity to improve their mathematics modelling ability and to demonstrate their capacity to test, modify and challenge models.

Secondly, student engagement, as measured by the proxy of the number of student responses on the self-assessment checklists, appears to have had the effect of limiting their motivation. If this were the case, the lack of engagement may have limited the development of requisite mathematical skills, the outcome of which was that these students had little interest in exploring and expressing their thoughts and ideas or establishing connections between them.

Thirdly, student mathematical skills and strategies were under-developed. Many did not respond positively to the social interaction that was embedded in the new model, from the timely support and feedback of the teacher and of peers which may have assisted

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them to 'test, modify and challenge' more effectively. This factor appears to have had a negative impact on their capacity to improve their summative assessment task outcomes.

Fourthly, the findings suggest that some of the students who failed to improve upon their grade over the course of the year had failed to internalise the processes and strategies incorporated into the new approach to formative assessment and showed little evidence of 'knowledge-transforming' behaviour (Bereiter & Scardamalia, 1987).

Notably, the new model of formative assessment support was delivered over a relatively short period; some students appear to have needed extra time, with more explicit instruction, systematic practice and more focused exposure to model solutions to respond adequately to the new approach.

7.3   Themes

The second element of the research question centres on whether a new model of formative assessment can result in improved summative outcomes for Mathematics A students in their final year of study. Seeking to answer this question, a wide variety of themes presented themselves early in data analysis. Four categories emerged, the first of which concerned mathematical models - testing, modifying, and challenging; providing sufficient evidence; reflecting, interpreting and making judgements. The second category focussed on the elements of feedback on formative tasks: timeliness; quality, and involvement of group, peer and self-assessment; and its importance in supporting students to better interpret and make judgements about mathematical problems. It was also clear that student-directed learning was a key component of the data: student autonomy, ownership; and student self-assessment were major codes. Finally, a category

which related to teachers focussed on teacher-directed instruction and teacher control. This study has shown that all components of these categories must be recognised and addressed in teaching practice if learning outcomes are to be improved (Alderman, 2013; Brophy, 2013; Entwistle & Ramsden, 2015; Kulik & Kulik, 1988; Shute & Kim, 2014; Wijaya, van den Heuvel-Panhuizen, Doorman & Robitzsch, 2014; Seaton, Parker, Marsh, Craven & Yeung, 2014).

7.3.1   Autonomous mathematical modelling.

Many of the Mathematics A students in this study demonstrated that they could grasp complex mathematical problems conceptually and describe a model in words or pictures. Some students could not, however, demonstrate the procedural understanding needed to translate their conceptual model or picture into a mathematical model. Another group of students were not able to move beyond procedural knowledge to apply conceptual knowledge to unfamiliar contexts, while a small number were unable to understand sufficiently some of the questions on the task sheet to enable them to develop a model response (Breen & O'Shea, 2015; Meyer & Land, 2006).

Entwistle (2013) and Black and Wiliam (2004b) suggested that traditional approaches to teaching do not probe students' reasoning behind answers (Bardini, Pierce, Vincent & King, 2014; Franke, Turrou, Webb, Ing, Wong, Shin, & Fernandez, 2015; Makonye & Khanyile, 2015; McCarroll, 2014) and traditional modes of assessment do not demand detailed explanations of concepts (Boaler, 2015; Ryan, 2017; Tobey & Arline, 2014). Mathematics learning was first differentiated into conceptual/relational understanding and procedural/instrumental understanding by Skemp (1978). Skemp suggested that a

student was thought to have comprehended the underlying principles of conceptual/relational understanding if they could create a formula or theorem and understand the relationship of this formula or theorem with other formulae or theorems. Achievement of procedural/instrumental understanding in mathematics could be demonstrated by completing a mathematical task by applying mathematical rules and formula. Rittle-Johnson, Siegler & Alibali (2001) found that a student's acquisition of conceptual understanding in mathematics could influence their level of acquisition of mathematical understanding at procedural level. This could explain why some students demonstrated conceptual understanding but failed to provide any or sufficient evidence of procedural understanding and were sometimes able to arrive at the correct answer to a problem without providing any evidence of the process they had employed. There was a need to understand alternative conceptions to design appropriate learning activities (Dawson, 2012).

The difficulty these students experienced in developing mathematical models resulted in them being unable to progress their initial response to a task through to a mathematical solution (Hiebert, 2013; Von Hippel & Von Krogh, 2015). Some students could not begin complex modelling questions independently as they had not translated the skills they had successfully demonstrated when carrying out the formative modelling exercise to similar questions on the summative assignment. Vincent and Stacey (2008) maintain that having procedural competency in mathematics learning does not help to enhance conceptual understanding. Conversely, the students evidencing difficulty with navigation appeared to be experiencing the reverse problem - they could understand the

problem conceptually but not address it procedurally. There appeared to be a disconnect between the student's ability to carry out the task successfully and their confidence to apply this skill set to a different task and context (Hassi & Laursen, 2015; Nicholas, Poladian, Mack & Wilson, 2015; Saragih & Napitupulu, 2015).

Modelling of the summative task had familiarised the students with the testing process (Areelu & Akinsola, 2014; Doyle, 1988). However, when scaffolding was provided, some students did not progress their response from the point where the scaffolding stopped giving direction or were unable to move past the scaffolded questions on formative and summative assessment items. This suggests that the students lacked the skills to enable them to independently translate information from one form to another (Nethercote, 2011), to make links between procedural and conceptual understandings so that they could respond to novel problems in unfamiliar contexts (Bowie, 2015; Breen & O'Shea, 2015).

The formative assessment program in Term 4 was on a topic that students had not previously encountered. In line with results in the preceding three terms, it was anticipated that student learning outcomes would demonstrate continual improvement. This proved not to be the case. Several students provided no evidence that they had developed a model which applied their new skills to the final topic, although some students demonstrated that they understood the question conceptually (Greeno, 1988) by producing or describing a correct picture of the problem. The students' written discussion indicated that they were cognisant of the correct mathematical model as a concept yet were unable to carry out the necessary mathematical modelling.

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Examination of the model for underpinning assumptions and their associated effects and identification of its strengths and limitations provided insight into this phenomenon.

The first formative assessment item addressed the topic of navigation in a real-world context. Student responses indicated that students were unable to filter out irrelevant information or to understand the concept of estimation in the real world. Other studies have also found that some of the contexts used by teachers to relate mathematical concepts to real world problems creates confusion in the minds of the students (Ainley, Pratt & Hansen; 2006; Silverman, Winograd & Strohauer, 1992; Ziebarth, 2004) This lack of connection between conceptual and procedural understanding in terms of real world context can be an issue in mathematics learning (Bell, 1993; Nickerson, 1985).

Most of these students recognised this skill deficit (Brophy, 1999, Brophy, 2008) and used the formative self-assessment checklists as scaffolding to enable them to develop mathematical models to address each question. The modelling exercise scaffolded the students through the process of the developing a mathematical model required to complete the summative assignment task (Fatade, Mogari & Arigbabu, 2013; McCarthy, 2016; Nethercote, 2011), providing them with the opportunity to learn how to arrive at the correct answer (Ernst, 2014; Fox, 2014). This enabled the students to take risks in a protected environment (Moerkerke, 1996).

Practising these skills enabled the students to reflect continuously on their own behaviour and learning processes and on the work that they produced (Sarwadi & Shahrill, 2014; Widyatiningtyas, Kusumah, Sumarmo & Sabandar, 2015). The mathematical model demanded may have been as simple as selecting the correct formula

and understanding why that formula was appropriate for that task (Bruner, 1985; Gipps, 1994). Students memorised the skills needed to develop a mathematical model by grouping specific skill sets and chunking information to facilitate memory recall (Davis & McGowen, 2007; Ng & Stillman, 2007). Unrelated skills may have been grouped simply because they were taught in the same teaching block. The mathematical skills required were incorporated into strategies and models that could be used by the students to solve problem presented to them (Awofala, 2014; English & Gainsburg, 2015; Widyatiningtyas et al., 2015). Although many students showed that they could address some of the higher order thinking criteria in the more complex questions, they continued to experience problems with the lower order processes involved in developing mathematical models (Resnick & Omanson, 1987). Students described difficulty removing the real-world variables, such as the ship moving up and down in the water with a swell, from the problem such as finding the distance from the boat at sea to the cliff. Students had difficulty developing a diagram for some of the questions, even though they drew a 'picture' that could adequately had stood for a diagram if labelled correctly. The also had problems with deciding on the correct formula to apply when the presenting problem was novel and not known to the student. Scaffolding and feedback processes on the self-assessment checklists had not adequately addressed this issue.

By engaging with the problem-solving process, students discovered when and how facts and skills were important and how they could be applied to reach a solution (Mislevy, Yamamoto & Anacker, 1990) and developed competence through this process of problem solving (Dahms, Geonnotti, Passalacqua, Schilk, Wetzel & Zulkowsky, 2007).

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The students began to rely on their problem-solving skills rather than a memory of the solution to a similar problem they had seen in the past.

7.3.2   Positive timely feedback

This study found that positive timely feedback was an important component of the model. The mathematics teacher is challenged to present modelling and problem-solving activities that take students through various activities so that "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" is reduced (Vygotsky, 1978, p. 86). Teacher input provides feedback to help students improve upon their current levels of achievement and allows them to confront increasingly complex learning goals with greater confidence: "Instruction would be completely unnecessary if it merely utilized what had already matured in the developmental process, if it were not itself a source of development" (Vygotsky, p. 212).

In this study, students' progress in Mathematics A was closely linked to the provision of feedback to students, mostly through comments on student self-assessment checklists. These dynamic forms of formative assessment required the teacher to work closely with students to assess their response to scaffolding interventions and to use formative feedback as the springboard for identifying student strengths and areas in need of further development by providing information about how to build a bridge between actual and desired performance level.

It is evident in this study that Teachers 2 and 3 preferred to continue with highly conformative assessment procedures (Torrance, 2012) rather than engage in the self-, peer- and group-assessment processes that underpinned the new model. Their attitude to student feedback was exacerbated by the obvious discomfort of students when receiving individual feedback from the teachers, especially in classroom situations. Students appeared to be concerned about looking stupid and were worried that the teachers would identify that they couldn't do the work. Students often failed to respond to feedback provided when they felt singled-out in some way. When students believed that they were being strictly monitored, they interpreted feedback as an attempt to compare them unfavourably with their peers, a way of usurping their autonomy, and represented their loss of control in the learning process (Deci & Ryan, 1985).

This study also made it clear, in line with other studies, that the timing of the feedback is crucial to whether that feedback had a positive or negative effect on student learning. To be effective, feedback needs to occur before the assessment item is submitted for marking (Ernst, 2014; Hendry, White & Herbert, 2016; Ralston & Bays, 2015). The feedback should be integrated into the formative assessment task, so that it can be implemented immediately (Hendrickson, 2012; Opitz, Ferdinand & Mecklinger, 2011; Wiggins, 2012).

Feedback provided after the item was submitted, or after the work had been marked, was received negatively by the students and was described by the students as 'undermining their confidence' (Nolan, 2011; Black and Wiliam, 1998b). Late feedback also appeared to reinforce the poor self-concept some students had about their mathematics ability.

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When the feedback was delivered during a formative assessment task, enabling the student to implement the advice immediately and see the positive result of their revisions, it was generally well-received. In these circumstances, the students perceived the feedback to be useful; that is, they had learned something from it that they considered to be valuable to their learning.

For those students for who got little or no guidance and feedback from the teacher and received little by way of explanation or modelling of tasks, the lack of support appears to have hindered progression from their current level of mathematics achievement to a higher level (Larkin, 2002; Van Der Stuyf, 2002) by curtailing the development of reasoning skills and limiting their capacity to assess the relevance and quality of the evidence they put forward.

7.3.3 Student-directed learning

The desire of students to direct their own learning and to exercise more autonomy over their learning emerged as powerful themes in this study. As most students took control of their own learning, they began to display greater self-confidence in their work in mathematics, which manifested itself in changes to classroom culture, evidenced by the emergence of a 'community of learning' and by behaviours such as seeking help from teachers and other students and developing informal study groups for Mathematics A. Teachers 2 and 3 initially found this emergent culture as a challenge to their preconceived ideas of the primacy of teacher power and control in the teacher-student relationship, which impacted negatively on the potential outcomes of the study.

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By the end of Term 1, the achievement of students in the three classes had begun to differentiate. In Class B, particularly, nearly three quarters of students (73%) achieved a lower grade than that received at the end of the previous year. The situation was better in Class C, although more than half the students failed to achieve an improved grade. Interview data from the teachers and students, together with observation data, pointed clearly to differences in the way the three teachers approached the use of more varied formative assessment tools and in their attitude towards Mathematics A students seeking greater self-direction in their work. While Teacher 1 had exhibited a growth mind-set and demonstrated strong adherence and support for the action research process, Teacher 2 exhibited a more fixed mind-set towards the students, providing only token support to the action research process by agreeing to meet with colleagues to monitor progress and by handing out formative assessment materials and learning aids; however, this teacher demonstrated little commitment to working through the formative assessment processes with the students and reacted strongly to student demands for increased autonomy. Teacher 3 demonstrated selective adherence to the action research process and modified the formative assessment processes in line with her pre-existing convictions regarding student autonomy and teacher control. By the end of Term 1 these differences in teaching style and attitude had become apparent to the students, many of whom voiced their dissatisfaction with their situation perceiving the intransigence of Teachers 2 and 3 as an impediment to their learning.

When the teacher provided students with the opportunity to self-assess their responses, they were seen to modify their response within the time allowed for the task (Black &

Wiliam, 1998a, 1998b). This timely feedback encouraged students to identify areas for improvement and to question and challenge their own processes (Kilpatrick, 1993). During Terms 3 and 4, students rigorously self-assessed their work. They identified each error they had made and commented accordingly and were less concerned with about whether they had ticks or crosses on their self-assessment checklists and more concerned about knowing how to provide an A standard response with evidence that could be favourably assessed against the assessment criteria. Although only one assignment and one exam had been subject to the formative self-assessment model by the end of Term 1, the increased level of student engagement as evidenced by the number of student responses on the self-assessment checklists (as a proxy) and improvement in the students' formative assessment performance is clear in the data. The improved formative outcomes suggest that students were internalising their learning in Mathematics A, although some students continued to struggle to translate this learning to the problems in the mathematics examination and the summative assessment task. Modifications to the formative assessment model (applied during the remaining three terms of the year) designed to maximise students' potential to align formative and summative assessment outcomes appeared to be successful.

The greater proportion of students took on the characteristics of self-directed learners (Costa & Garmston, 2015; Goos, 2004; Skager, 2014), in line with expectations of outcomes for a socio-constructivist interpretation (Cresswell, 2013; Semerci & Batdi, 2015). Knowledge and understanding were constructed through interaction, rather than transmitted through instruction (Torrance, 2012). Most students actively engaged with

the learning process, arguing and debating among themselves and offering a range of responses in the process of working towards the correct solution. The characteristics of a community of learners became more evident.

Increasing levels of interaction between student and teacher, student and task, and student and student were apparent, as most students established autonomous learner behaviours (Nethercote, 2011). Self-and peer-assessment emerged as crucial to the development of self-confidence in the students. Students were encouraged to work together and use peer review and group evaluation in pairs or small groups (Marshall & Drummond, 2006). Students reported and evidenced a positive reaction to peer-feedback within the formative assessment process, even though the language used to provide the feedback was often less than subtle and delivered in front of other students. For example, feedback from a peer - "That's wrong totally wrong!" -elicited laughter all round and resulted in the student making another attempt to complete the task, whereas feedback on the same task from the teacher in front of other students was "Showing how dumb I am!".

It appeared that the use of self- and peer-assessment broke down the barriers erected by students' previous failures in mathematics and the negative comments about their mathematics ability which had eroded their confidence (Bobis et al., 2016; Lee, 2014; Wilkie, 2016) and led to maths anxiety in some students (Hadfield & McNeil, 1994; Whyte & Anthony, 2012). Many of the students had come to think of themselves as failures because they had not achieved high grades in mathematics in the past. This may have, in part, resulted from de-formative assessment (Torrance, 2012) where repeated

negative feedback reinforced their feeling of inferiority. In the new formative assessment program, student mistakes could be rectified without embarrassment or the negative repercussions that had previously accompanied low marks or poor grades (Chen, Chiu & Wang, 2015; Heinz & O'Mahoney, 2016; Iannone & Simpson, 2015). This situation nurtured learner confidence and facilitated the practices of peer-tutoring and group work in the classroom (Bamford & Topping, 2013; Curry, 2016).

Student desire for more autonomy and control over the learning process was clearly observable in the focus group, interview and observation data. Both formative assessment and the feedback processes were enhanced when it was student-directed (Friedlaender, Burns, Lewis-Charp, Cook-Harvey & Darling-Hammond, 2014; Keeley & Tobey, 2016). Students wanted to take an active role in the development of all aspects of the formative assessment process, including revision processes, the scaffolding of tasks and to be able to ask for what they needed to complete the task successfully. Students came to trust their own judgement and risk an incorrect response rather than leaving questions blank for fear of attracting criticism or ridicule (Collins, Usher & Butz, 2015; Schiefele & Schaffner, 2015).

This growth in confidence as students became more familiar with the formative assessment process was demonstrated by an increasingly 'trial-and-error' approach and in the efforts of many to elicit feedback from peers (Dowell, Cade, Tausczik, Pennebaker & Graesser, 2014). Students discovered the freedom to make mistakes without fear of censure and the feedback process became a positive rather than a

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negative experience for them (Harks et al.,2014; Marsh & Seaton, 2013; Pekrun, Lichtenfeld, Marsh & Goetz, 2017).

The students' changing perceptions of themselves as able to achieve in mathematics and their evolving behaviours as individual learners were evidence of an evolving 'positive mind-set' (Dweck, 2010) which is normally ascribed to independent autonomous learners (Zimmerman, 2002). As student confidence grew, this increasingly positive mathematics self-concept impacted on their mathematics performance and most students began to exhibit the characteristics of independent learners (Bagley, 2016; McCartney, Boustedt, Eckerdal, Sanders & Zander, 2017; Priess-Groben & Hyde, 2016). Lessons veered away from being directed by the teacher towards student-centred learning, students exhibiting attributes usually associated with lifelong learners (Lawson, Askell-Williams & Murray-Harvey, 2006; Merriam & Clark, 2006). This change of power structure was difficult for Teacher 2 and Teacher 3 to accept (Clark & Sharf, 2007; Jones & Stanley, 2008; Nolan, 2011) given their concern about loss of control. As they came to accept that the students could confidently and competently take control of their own learning, classroom control became less of a problem for these teachers than it had been previously (Gillies, 2006; Wang & Eccles, 2016; Zimmerman, 1990).

Increasing mastery of knowledge and skills emboldened the students to move toward being 'full participants in the class' (Groen, Coupland, Memar & Langtry, 2016; Hopkins, Lyle, Hieb & Ralston, 2016). For many students, the meaning of learning was reconfigured through this participation (Lave & Wenger, 1991). A class hierarchy developed as abler students took the lead and provided peer tutoring to less able students

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(Broadfoot, 1996). Students recognised that peers may be helpful to them in some situations and impede their learning in others (Perret-Clermont & Schubauer-Leoni, 1988; Sternberg & Wagner, 1994; Zimmer & Toma, 2000). They also became more resilient, coping with the stressful influence of the summative examinations (Lipnevich, Preckel & Krumm 2016; McMillan & Reed, 1993; Obilor, 2011).

Students developed 'new learning personalities' (Bate, Hommes, Duvivier & Taylor, 2014; Lave & Wenger, 1991; Lebow, 1993) as the study progressed, personalities that could withstand the influence of negative feedback. Rather than being ashamed of their work and worried others would see it, students began to offer their work to one another for peer-assessment and feedback. Humour and increasing confidence about their mathematics ability were often in evidence.

As the year progressed, the importance of classroom culture and context to student achievement became increasingly evident (Kim, 2001). As the students grew in confidence in mathematics, they began to exhibit some of the characteristics exhibited by high achieving mathematics students (Homel & Ryan, 2014; Kogan & Laursen, 2014): they formed independent study groups outside of set class time in which they worked; they developed and implemented a range of simple to complex revision processes designed to address their individual learning needs; they requested that their teachers modify standard mathematical teaching models to address specific learning requirements. In response to the changes in the students' approach to mathematics, the classroom culture evolved from teacher-directed teaching towards student-directed learning (Nethercote, 2011) - students gained in confidence and took control of their

own learning, forming a 'community of practitioners' (Lave and Wenger,1991). This was evidenced by the development of student-directed study groups, by the quality and level of ongoing debate and discussion around each topic in the classroom and by the students' willingness to offer their ideas and written work for scrutiny and review by their peers and the teachers.

There was a clear preference among Mathematics A students for self- or peer-assessment rather than teacher-marked work, a view supported in the literature which consistently reports feedback delivered in this way to be more effective (Andrade & Brookhart, 2016; Brown, G., 2015; Black, 2015; Heinz & O'Mahoney, 2016; Anson & Goodman, 2014; Harris & Brown, 2013; Schunk & DiBenedetto, 2016). Student comments provide insight into the evolving positive response to the self-assessment process, indicating that students could receive feedback without reacting negatively. The students recognised that they were developing skills and a growth mind-set and that they could receive feedback positively and constructively (Hyland, 2015; Wilkie, 2016). Shorn of negative consequences, feedback based on self-assessment or from peers empowered the students, encouraging them to make connections between the feedback they received and the characteristics of the work they produced (Askew, 2000; Ifamuyiwa & Akinsola, 2008; Lizzio & Wilson, 2008).

Students showed higher levels of motivation and exhibited a deeper understanding when student-teacher barriers were removed (Somervell, 1993). Peer assessment was perceived by students as less judgemental than teacher assessment (Adediwura, 2015; Harris & Brown, 2013). They could laugh at their mistakes, even though it was often

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delivered using harsher language. In addition, self-, and to a lesser extent, peer- and group-assessment challenged students to attempt a wider variety of problems than they had when a teacher was assessing their work (Vinner, 1992). Evidence collected from throughout the study year showed that teacher feedback, when perceived negatively, had the effect of closing down the student, and limiting risk taking behaviour. The students described this a "Showing how dumb I am". In contrast feedback from peers, often delivered publicly, encouraged the students to try again as demonstrated by one student's response to negative peer feedback, "Don't tell me the answer, let me try it again". It appears to have enhanced their willingness to work constructively towards a solution and to persist when it became difficult (Sadler, 1998). The self-assessment checklists encouraged the students to attempt questions they would previously have skipped, as shown in Table 4. Student requests in relation to the checklists were focussed on asking for more scaffolding and scaffolding for increasingly complex questions, rather than asking for sample solutions as soon as the formative assessment task was distributed. This showed that students wanted to know how to do the task themselves rather than focussing on rote learning a set of sample solutions to problems and hoping a similar problem would be on the summative examination.

Marks and grades on student assessment items acted as barriers to the learning process (Marsh, Kuyper, Seaton, Parker, Morin, Möller & Abduljabbar, 2014; Nguyen, Borrego, Finelli, Shekhar, DeMonbron, Hendersen, Prince & Waters, 2016). The mark or grade was perceived by students as devaluing the feedback, no matter how detailed the feedback was. Feedback was perceived as criticism when it was received after the item

had been submitted for marking (Brickman, Gormally & Martella, 2016; Dietz, 2014; Du & Wu, 2014). This was the case even when a topic carried over from one summative item to the next. The need for feedback to be scaffolding or directing students towards a correct solution rather than highlighting student errors (Bandura, 1993; Hattie & Yates, 2014; Junor Clarke & Thomas, 2009) is highlighted in this case study. When marks and grades were removed from formative assessment items students engaged more readily with the tasks. Assessing without marks or grades appeared to unlock the student's readiness to attempt questions and take risks (McKeachie & Svinicki, 2013; Rawlins, 2008; Wiggins, 1989; Wormeli, 2006). Anxiety about marks receded with the removal of marks and grades from the formative assessment process (Berenson, Ramnarayanan & Oppenheim, 2015; Jansen, Louwerse, Straatemeier, Van der Ven, Klinkenberg & Van der Maas, 2013). This phenomenon was evidenced by students' detailed responses to formative assessment tasks where they knew that marks would not be assigned. When the same questions were presented on a summative item, some students did not attempt the question for fear of getting it wrong or looking dumb. In contrast, when students found that their response was way-off the mark in formative items, and marks were not assigned, they were observed to laugh and show each other their mistakes. The focus of the feedback needed to be on how to get it right, not on what was wrong; on self-assessment, rather than teacher marking, reaffirming Taras; (2010b) and Nolan's (2011) view that the purpose of formative assessment was to improve the students' work and allow students to self-assess and modify their responses within the task.

7.4   Teacher influence

Action research is concerned with transforming teacher practices and teachers' understanding of their practice (Kemmis, 2009). Although teachers can be prompted to initiate powerful and sustainable changes in the ways they work, tension may be created by the disparity between their traditional teaching (Ratnam-Lim & Tan, 2015) practices and the unfamiliar or untried approaches which they agree to trial (Walters, Garii, B & Walters, 2009). The findings from this case study reaffirm the significance of teacher effects and highlight the qualities of effective teaching practice in producing changes in student learning outcomes: a more flexible style of teaching, use of scaffolding and assessment processes that suit students, and improved responsiveness to student concerns and requests (Hargreaves, Earl, Moore, & Manning, 2001; National Research Council, 2013; Salend, 2015; Simmons, 2014; Watt, 2005).

In this case study, the early negative response of Teachers 2 and 3 to the growing confidence and assertiveness of the students in their Mathematics A classes was clear, confirming the findings of other studies (Black & Wiliam, 2004b; Jones & Stanley, 2008; Clark & Sharf, 2007) that a loss of power can result in a 'clash of various parties'. Teachers 2 and 3 experienced difficulties in accepting and implementing student-directed learning and self- and peer- assessment (Fisher, den Brok & Rickards, 2006) and had trouble relating to students as the 'rules of the game' began to change (Brady, 2011).

They were challenged by alternative models of formative assessment that did not include marks and grades and that did not hold the student accountable in some way. Segers and

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Tillema (2011) suggest that the way teachers and students deal with assessment practices is influenced by the conceptions they hold about the purpose of assessment: teachers who do not distinguish between formative and summative purposes of assessment, maintaining a belief that the purpose of both formative and summative was accountability, will find the transition to student-directed learning and self- and peer-assessment threatening, a contention that appears to be substantiated in this case study.

Teachers 2 and 3 initially had a fixed perception about the students in Mathematics A, who they had stereotyped as 'less able' mathematically. McGatha, Bush and Rakes (2009) posited that some teachers embrace new concepts wholeheartedly, while others implement new ideas superficially, and a smaller number remained resistant to new concepts. Teachers 2 and 3 appeared to fit in the second of these categories. Consequently, they demonstrated ambivalence towards the study's goals. Teacher 2 had difficulty validating a process that did not, in some way, hold the student accountable and had difficulty with the concept of feedback that did not include marks or grades; Teacher 3 struggled with the obligation to allow students to assess themselves, seeing it as their prerogative or responsibility to identify and point out to each student where they had gone wrong.

Class A was characterised by students who actively participated in the formative assessment case study and, consequently, appeared to experience greater achievement gains compared to students in Classes B and C (based on the summative results achieved in Term 1). This was particularly evident in Class B, where student results showed minimal improvement. This raised a potentially difficult dilemma common to a teacher-

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researcher participating in action research within their own workplace. Whereas the teacher-researcher (Teacher 1) shared the positive attitudes exhibited by the Class A students towards the changes in delivery of Mathematics A during Term 1, her colleagues were challenged and felt threatened by this changing culture. The students in their Mathematics A classes were actively seeking help from teachers and peers to improve their grades rather than passively accepting that they were not capable mathematics students and had little control over their learning and the grades they received. Although Teachers 2 and 3 agreed to make a conscious effort to participate more actively in the formative assessment program and to observe the response of the students in their class, Teachers 2 and 3 failed to fully engage in the revised assessment process (Clark & Sharf, 2007; Jones & Stanley, 2008), provide appropriate and timely clarification of areas of misunderstanding, and to be supportive rather than judgemental (Kilpatrick, 1993).

The inequitable situation this created in the three classes demanded a change in the teacher's role. It was apparent that the teachers did alter their pedagogical approach from one that was largely teacher-directed to an approach that facilitated student-directed learning. Growing student confidence and increased student autonomy resulted in some students persistently seeking support from these teachers with the result that they became more supportive of, and increasingly positive towards, the students in their Mathematics A classes and became willing participants in the developing classroom culture of student-directed learning. Their task came to be one of collaborating with students to bring about learning, to be alert to the generation of unpredictable outcomes

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and to regard the production of unpredictable and unintended outcomes as an indication of success, not lack of compliance with the program.

These findings were consistent with those of Dweck (2010) who described the educator with a growth mind-set as perceiving learning to be a collaboration in which the teacher has great responsibility and Torrance (2012) assertion that teachers need to make the rules of the game as apparent as possible, but also needed to communicate that they would be happy to see the rules change, if someone came up with better ones. When Staton (in Richmond & McCroskey, 2012) investigated the issue of power in the classroom, the manifestation of power changed as the teacher's career progressed. All three teachers were in the 'late teaching phase', one characterised by 'impact' on student learning and the affective and individual needs of students. Their metamorphosis from self-directed to student-directed teaching is a positive outcome of this case study.

As Teachers 2 and 3 came to accept that students needed, and wanted, autonomy in their learning, their practice responded accordingly. The students themselves had applied pressure to change traditional teaching practices, with a notable change in classroom culture in all three classes - from a culture of dependent students requiring behaviour management to a culture of self-motivated, self-directed learners. What was also obvious was that it was necessary to find ways to augment the teachers' capacity to construct, transform, and manage knowledge in new and innovative ways as learning took unpredicted pathways (Beggs, Shields, Telfer & Bernard, 2015).

7.5   Limitations of this Case Study

A limitation of this case study was the small sample size - 52 commencing students (reduced to 48 students by the end of the study), in one mathematics subject, in one school. By comparing and contrasting findings from this case study to similar studies, the sample limitation was minimised - the study by Harris and Brown (2013) in New Zealand which investigated using peer- and self-assessment to improve student learning , the Norwegian study by Havnes, Smith, Dysthe and Ludvigsen, (2012) which researched a two-year intervention project involving six Norwegian upper secondary schools, the collaborative research study by Cooper and Cowie (2010) into the practice and impacts of assessment for learning, the focus group study by Peterson and Irving (2008) and the formative assessment model described by Torrance (2012).

Both a strength and a limitation of the case study was that the cohort was divided between three classes with three different teachers. Although, the three teachers used the same curriculum provided for senior Mathematics A by the Queensland Studies Authority (2013b), teacher mindsets varied and pre-conceived ideas about the role and authority of the teacher, the role of students and the most appropriate style of teaching to be employed, were problematic. The teachers' divergent teaching styles and philosophical positions were a limitation. The susceptibility of the research to individual teacher commitment and beliefs posed a significant risk to the outcomes of the research.

7.6   Recommendations for Future Research

An investigation into the thinking processes of students experiencing barriers to learning in mathematics would be a useful complement to this research. A focus on the way

procedural and conceptual understanding and mathematical modelling had been taught during earlier years of schooling and its impact on achievement in senior secondary mathematics would complement this research.

The trialling of the formative assessment model with other cohorts of mathematics students in different mathematics subjects or with students of different ages, differing mathematical abilities and educational circumstances, would establish the generalisability of the findings.

7.7   Conclusion

This research emerged in response to the knowledge that some students appeared to be internalising their learning in the Mathematics A (based on their success on formative assessment tasks) yet were unable to achieve success in examinations and other summative assessment tasks.

Post-positivism - the meta-theoretical framework for this study – enabled the teacher-researcher to discover what students and colleagues believed about formative assessment processes in Mathematics A and how these processes could be modified to produce improved summative outcomes (Wiliam, 2000). Given that Giarelli & Chambliss (1993) suggest that post-positivist research aims to provide a substantive resolution to a problem of practice based on questions concerning what practices should be in place and what can bring about change, the outcome of this research has immediate relevance as it suggests new directions for assessment practice in mathematics.

The hypothesis tested was whether implementing a range of different formative feedback processes would improve student outcomes on summative tasks. The testing of the trial hypothesis led to the confirmation of the hypothesis and the development of a provisional theory: By ensuring that formative assessment processes respond to the key issues of student directed learning, positive timely feedback and autonomous mathematical modelling, summative outcomes in Mathematics A will be improved.

The findings reported in this study suggest that the implementation of a new model of formative assessment has the potential to improve Year 12 Mathematics A grades. Findings showed a direct relationship between the introduction of new approaches to formative assessment and improved results for most students in summative assessment tasks in Mathematics A.

The formative assessment program is a four-term iterative approach which embraces research findings about the means to achieve improved outcomes in the study of mathematics. Its key components are:

1. The early introduction of a modelling task like the routine modelling and problem-solving questions on the summative assignment.
2. The provision of scaffolding in the form of a draft assignment checklists.
3. Exposure to the full range of question standards (D-A), like those on the summative examination.
4. Development of the same mathematical skills and attributes demanded by the summative assessment tasks, particularly those related to modelling tasks and problem-solving questions, which allow students to independently translate

information from one form to another and make the necessary links between procedural and conceptual understanding.

5. A strong emphasis on self-assessment, aided using checklists and sample solutions.

6. The removal of marks and grades from the formative assessment tasks and a focus on the provision of teacher comments that are constructive and positive.

7. Feedback on each formative task that is immediate, critical and which clearly articulates what the student must do to improve, timed so that students can modify their response within the task.

8. The integration of student self-assessment and peer-feedback into the formative process.

9. The creation of opportunities for open discussion in which students can present, challenge, review and modify problem-solving activities.

10. The implementation of appropriate revision processes to meet individual learning needs.

11. The building of a classroom culture that eschews teacher-directed learning and embraces pedagogy that fosters self-directed learning and increased student learning autonomy.

This case study has expanded on earlier findings and added a new dimension to current knowledge about formative assessment processes in mathematics, by providing a deeper understanding of students' response to effective feedback practices. It differs from other studies through the use of grounded theory in an action research framework to identify

the barriers to the effectiveness of formative assessment practices experienced by Mathematics A students. The outcome of this study is a model of formative assessment that can be used in Mathematics A with future cohorts of students and which has the potential to be translated to other mathematics subjects and settings.

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Appendix A

Assessment Criteria for Mathematics A (QSA, 2013b)

	Standard *A*	Standard *B*	Standard *C*	Standard *D*	Standard *E*
Knowledge and procedures	The student's work has the following characteristics: • accurate use of rules and formulas in simple through to complex situations	The student's work has the following characteristics: • accurate use of rules and formulas in simple situations or use of rules and formulas in complex situations	The student's work has the following characteristics: • use of rules and formulas in simple routine situations	The student's work has the following characteristics: • use of given rules and formulas in simple rehearsed situations	The student's work has the following characteristics: • attempted use of given rules and formulas in simple rehearsed situations
	• application of simple through to complex sequences of mathematical procedures in routine and non-routine situations	• application of simple sequences of mathematical procedures in non-routine situations or complex sequences in routine situations	• application of simple sequences of mathematical procedures in routine situations	• application of simple mathematical procedures in simple rehearsed situations	• attempted use of simple mathematical procedures in simple rehearsed situations
	• appropriate selection and accurate use of technology	• appropriate selection and accurate use of technology	• selection and use of technology	• use of technology	• attempted use of technology
Modelling and problem solving	• use of strategies to model and solve problems in complex routine through to simple non-routine situations	• use of strategies to model and solve problems in routine through to simple non-routine situations	• use of familiar strategies for problem solving in simple routine situations	• use of given strategies for problem solving in simple rehearsed situations	• attempted use of given strategies for problem solving in well-rehearsed situations
	• investigation of alternative solutions and/or procedures to complex routine through to simple non-routine problems	• investigation of alternative solutions and/or procedures to routine problems			
	• informed decisions based on mathematical reasoning in complex routine through to simple non-routine situations	• informed decisions based on mathematical reasoning in routine situations	• informed decisions based on mathematical reasoning in simple routine situations		
	• reflection on the effectiveness of mathematical models including recognition of the strengths and limitations of the model	• recognition of the strengths and limitations of the model in simple situations			

	The student's work has the following characteristics:	The student's work has the following characteristics:	The student's work has the following characteristics:	The student's work has the following characteristics:	The student's work has the following characteristics:
Communication and justification	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine through to complex routine situations	• accurate and appropriate use of mathematical terminology and conventions in simple non-routine and/or complex routine situations	• appropriate use of mathematical terminology and conventions in simple routine situations	• use of mathematical terminology and conventions in simple rehearsed situations	• use of mathematical terminology or conventions in simple rehearsed situations
	• organisation and presentation of information in a variety of representations in simple non-routine through to complex routine situations	• organisation and presentation of information in a variety of representations in simple non-routine and/or complex routine situations	• organisation and presentation of information in a variety of representations in simple routine situations	• presentation of information in simple rehearsed situations	
	• analysis and translation of information displayed from one representation to another in complex routine situations	• analysis and translation of information displayed from one representation to another in simple routine situations	• translation of information displayed from one representation to another in simple routine situations		
	• use of mathematical reasoning to develop logical sequences in simple non-routine through to complex routine situations using every day and/or mathematical language	• use of mathematical reasoning to develop logical sequences in simple non-routine and/or complex routine situations using everyday and/or mathematical language	• development of logical sequences in simple routine situations using every day and/or mathematical language		
	• justification of the reasonableness of results obtained through technology or other means				

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Appendix B

Sample Formative Assessment Modelling Task

Task 1

Construct a spread sheet for a home loan with principal $300,000, interest rate 7% p.a. and repayments of $2000 per month over 30 years. Use the Σ function to find the total repayments and total interest paid over the life of the loan.

Task 2

Modify your spread sheet for repayments of $2200 per month. Find the new term of the loan with these repayments. Use the Σ function to find the total repayments and total interest paid over the life of the loan.

Formative Assessment	Yes	No	Comments
TASK 1			
Principal stated correctly			
Interest Rate stated correctly			
Term of loan stated correctly			
Repayment stated correctly			
Appropriate Headings			
All necessary columns included			
First line correct (highlight errors)			
Formulae correct (highlight errors)			
Final row corrected for zero balance			
Repayments totalled correctly (using Σ)			
Interest totalled correctly (using Σ)			
Term to zero balance stated			
TASK 2			
Repayment amount changed			
Repayments totalled correctly (using Σ)			
Interest totalled correctly (using Σ)			
Term to zero balance stated			
Additional Comments:			

Appendix C

Term 2 Formative Assessment Feedback Checklist. Topic 1

Answers should include the following:	Evidence Provided (List Questions)	Student's Comment	Teacher's Comment's
Problem stated			
Information sorted			
Information tabulated when necessary			
Diagram using nodes and arcs, all correctly labelled			
Correct formula/e stated if needed			
Units stated and converted when necessary.			
Forward scan performed correctly			
Back scan performed correctly			
Critical path identified and labelled			
Float times calculated			
Earliest completion time identified			
Non-critical activities identified			
Maximum total flow calculated			
Knowledge and Procedures Criteria (QSA, 2013b)			
• accurate use of rules and formulas in simple through to complex situations			
• application of simple through to complex sequences of mathematical procedures in routine and non-routine situations			
• appropriate selection and accurate use of technology			
Modelling and Problem Solving Criteria (QSA, 2013b)			
• use of strategies to model and solve problems			
• investigation of alternative solutions and/or procedures			
• informed decisions based on mathematical reasoning			
•reflection on the effectiveness of mathematical models including recognition of the strengths and limitations of the model			
Communication and Justification Criteria (QSA, 2013b)			
• organisation and presentation of information in a variety of representations			
• analysis and translation of information displayed from one representation to another			
• use of mathematical reasoning to develop logical sequences			
• justification of the reasonableness of results			

Appendix D

Semester 1 Self-Assessment Assignment Checklist

Task 1	Task	Evidence	Conclusion	Yes	No	Not Sure
a	Find tax payable	Printout from tax website or calculations	Net pay after tax and Medicare levy			
b	Construct projected monthly budget	Printout of budget table and table saved in excel	Monthly amount you can afford to repay			
c	Investigate borrowing power from lender 1	Printout from financial institution (lender 1)	Borrowing power (lender 1)			
d	Find affordable property to purchase	Printout from website or cutting showing property	Property you have chosen to purchase			
e	Investigate second home loan option (lender 2)	Printout from financial institution (lender 2) showing loan details and associated costs	Information about second home loan option for purchase of property (lender 2)			
f	Construct excel spreadsheet to determine loan costs for lender 1.	Excel spreadsheets. Printout of loan details and costs for lender 1.	Total cost of the loan and total cost of the property (lender 1)			
Task 2 **a**	Construct 2nd spreadsheet showing all loan costs for lender 2.	Excel spreadsheet Printout of loan details and costs for lender 2	Compare and contrast loans 1 and 2. Select a loan and justify your decision.			
b	Construct 3rd spreadsheet showing interest rate rise	Excel spreadsheet. Printout from lender showing increased repayment amount	Discussion of effects of rate rise on buyer.			
c	Find comparable rental property. Construct spreadsheet to determine rental costs over same period as loan	Printout or cutting of comparable rental property. Excel spreadsheet showing total costs for renting over same period of time.	Compare and contrast renting v buying for this scenario. Justify conclusions.			

Semester 1 Self-Assessment Assignment Checklist

Semester 1 Report - Checklist for Home Loan Excel Spreadsheets

Formative Assessment	Yes	No	Comments
TASK 1 (f) and Task 2 (a)			
Principal stated correctly			
Interest Rate stated correctly			
Term of loan stated correctly			
Repayment stated correctly			
Appropriate Headings			
All necessary columns included			
First line correct (highlight errors)			
Formulae correct (highlight errors)			
Final row corrects for zero balance			
Repayments totalled correctly (using Σ)			
Interest totalled correctly (using Σ)			
Term to zero balance stated			
TASK 2 (b)			
Repayment amount changed			
Repayments totalled correctly (using Σ)			
Interest totalled correctly (using Σ)			
Term to zero balance stated			
Questions you need to ask your teacher:			
Evidence you still need to provide:			
Additional Comments:			

Appendix E

Term 1 Formative Assessment Feedback Checklist Topic 1

Answers should include the following:	Evidence Provided (List Questions)	Student's Comment	Teacher's Comment's
Problem stated			
Information sorted			
Information tabulated when necessary			
Graphs & diagrams drawn showing correct labels, titles and scales			
Correct formula/e stated if needed			
Units stated			
Substitution correct			
All working shown			
Calculations correct			
Correct Answer identified			
Answer given in correct format			
Answer justified			
Solution explained			
Knowledge and Procedures Criteria (QSA, 2013b)			
• accurate use of rules and formulas			
• application of simple through to complex sequences of mathematical procedures			
• appropriate selection and accurate use of technology			
• use of strategies to model and solve problems			
• investigation of alternative solutions and/or procedures			
• informed decisions based on mathematical reasoning			
• Reflection on the effectiveness of mathematical models including recognition of the strengths and limitations of the model			
Communication and Justification Criteria (QSA, 2013b)			
• organisation and presentation of information in a variety of representations			
• analysis and translation of information displayed from one representation to another			
• use of mathematical reasoning to develop logical sequences			
• justification of the reasonableness of results			

Appendix F

Term 2 Formative Assessment Feedback Checklist. Topic 1

Answers should include the following:	Evidence Provided (List Questions)	Student's Comment	Teacher's Comment's
Problem stated			
Information sorted			
Information tabulated when necessary			
Diagram drawn using nodes and arcs, all correctly labelled			
Correct formula/e stated if needed			
Units stated and converted when necessary.			
Forward scan performed correctly			
Back scan performed correctly			
Critical path identified and labelled			
Float times calculated			
Earliest completion time identified			
Non-critical activities identified			
Maximum total flow calculated			
Knowledge and Procedures Criteria (QSA, 2013b)			
• accurate use of rules and formulas in simple through to complex situations			
• application of simple through to complex sequences of mathematical procedures in routine and non-routine situations			
• appropriate selection and accurate use of technology			
Modelling and Problem Solving Criteria (QSA, 2013b)			
• use of strategies to model and solve problems			
• investigation of alternative solutions and/or procedures			
• informed decisions based on mathematical reasoning			
• reflection on the effectiveness of mathematical models including recognition of the strengths and limitations of the model			
Communication and Justification Criteria (QSA, 2013b)			
• organisation and presentation of information in a variety of representations			
• analysis and translation of information displayed from one representation to another			
• use of mathematical reasoning to develop logical sequences			
• justification of the reasonableness of results			

Appendix G

Sample topic test question

(Elms, Simpson & MacPherson, 2009, Supplementary worksheets)

Question

If 6 m lengths of trench mesh were laid in the footings around the perimeter of the house, how many lengths would be required for two layers of mesh?

The mesh must overlap at the corners and where two sheets meet, the overlap must be 500 mm. Note that the mesh lengths can be cut if necessary.
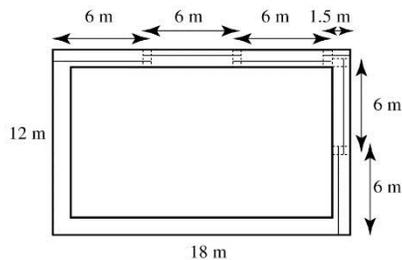
Sample solution

Remember to allow for 500 mm overlap.

The length of the plan would require 3 lengths (17 m) + 1.5 m.

So, both lengths would require 6 lengths + 3 metres i.e. $6\frac{1}{2}$ lengths

The width of the plan would require 2 lengths (11.5 m) + 1 metre

So, both widths would require 4 lengths + 2 metres

Total required = (6 lengths + 3 m) + (4 lengths + 2 m)

= 10 lengths + 5 m

So, number of lengths required for 1 layer = 11

∴ Two layers would require 11 ×2 = 22 lengths

Appendix H

Semester 2 Modelling Exercise Self-Assessment Checklist

Question	Task	Evidence	Conclusion Sufficient evidence to justify your conclusion?	Yes	No	Not Sure
1	In detail using numbers and descriptions:	Explain the differences between Graph 1 and 2				
	Referring back to the initial question:	Explain why you think the advertisers used these 2 graphs				
	Using both numbers and descriptions:	Explain the effect of each graph on the consumer. Why?				
		What did you think when you saw these graphs?				
		Why?				
		Which petrol would you buy?				
		Why?				
		Do you think other people would think this way?				
		Do you think this advertising plan would be successful?				
2	**Calculate mean Route 1**	Definition of mean				
		Explain method of calculation.				
		Answer stated.				
		Answer justified by alternate method. State method.				

Question	Task	Evidence	Conclusion Sufficient evidence to justify your conclusion?	Yes	No	Not Sure
	Calculate mean Route 2	Method of calculation explained.				
		Answer stated				
		Answer justified by alternate method.				
2	Discussion	Compare means using actual values and the difference between the two values				
	Calculate SD Route 1	Provide definition of SD and explain its use				
		Method of calculation explained.				
		Answer stated				
		Answer justified by alternate method. State method used.				
	Calculate SD Route 2	Method of calculation identified.				
		Answer stated				
		Answer justified by alternate method. State method used.				
	Discussion	Compare SD's using actual values and explain what these values mean in real terms				
	Route 1	Find total time travelled				
		Find range of travel times using SD				
		State meaning of range				
	Route 2	Find total time travelled				
		Find range of travel times using SD				
		State meaning of range				
	Travel time 40 mins	Which route/s enables travel to be completed in 40 mins?				

Question	Task	Evidence	Conclusion Sufficient evidence to justify your conclusion?	Yes	No	Not Sure
		Which route gives 'late' travel time within its range?				
		Which route gives 'very late' travel time within its range?				
	Decide which route to recommend	State your answer and justify.				
		Explain your decision using data and statistics.				
3	Graphs should show	2 **different** pairs of graphs. Not hand drawn.				
		Graphs should be 'misleading' and should support your argument				
		Graphs labelled with title				
		Axes labelled with titles				
		Scales shown on axes and units stated clearly on axes				
	Graphs should:	Should support manager's case				
	Argument	Argument must justify increasing wages throughout the year.				
		Make at least 3 strong points to support case and justify				
		Use your graphs to support your arguments				
		Present conclusion based on your statistical display				
4.1	Skulls data	Entered into spread sheet correctly				
		Columns labelled				
		Data unsorted				
	Label data tables	Include data tables as **Appendix A Data Tables**				
		Format ready to be printed				

Question	Task	Evidence	Conclusion Sufficient evidence to justify your conclusion?	Yes	No	Not Sure
4.2	5 Number summary	Identify method used to calculate values				
		Show working or formulae				
		Results tabulated table				
		Tables labelled correctly				
4.3	Box and whisker plots	Computer generated				
		Side by side				
		Plots labelled				
		Each box and whisker labelled				
		Code provided				
		Scales appropriate to display				
		Axes labelled				
4.4	Mean	Calculated and stated				
		Method and working shown				
	SD	Calculated and stated				
4.5	Scatter plots	Bivariate data displays				
		4000BC and 150AD comparison using standardised scales on X and Y axis				
		Graph titles shown				
		Axes titles shown				
		Axes scales shown				
		Any trends identified				
		Trend lines and equations shown				
4.5	Read question carefully	Answer appropriately				

Question	Task	Evidence	Conclusion Sufficient evidence to justify your conclusion?	Yes	No	Not Sure
Part 2	**Modelling and Problem Solving**					
1	Statistical data	Presented as graphs and tables				
		These should be labelled				
		Presentation in professional format				
	Correct report format	Report presented in text form with headings, paragraphs, etc.	Report Format following			
		Diagrams and graphs inserted into your text document at appropriate points				
		Data and graphs to support text				
		Discussion supported by data				
		Conclusion drawn from stated evidence				
2	Strengths and limitations	**Comment on** sample collection techniques				
		Sample size				
		Trends				
		Other evidence				
	Conclusion	Supporting evidence stated				
		Conflicting evidence stated				
	Comment on skulls study	Assumptions				
	Comment on skulls study	Effect of assumptions on accuracy of conclusions				
	Modification	Improvements?				
		Sample size?				
		Extra information?				
		Analysis of data?				
	Bibliography	References correctly cited				

	Questions for your teacher?					
Before you submit your assignment check the following…						
Word Document	Check headings					
	Check spelling					
	Setting out					
	Printing					
Excel Document	Set out correctly for printing					
	Graphs with their tables					
	Titles shown					
	Pages set out appropriately					
	Page scale appropriate for printing					

Report Format for Question 4 Skulls of Thebes 4000BC and 150AD

- Introduction
- Method of Analysis
- Data Analysis
- Tables with Graphs and Plots
- Results
- Discussion
- Conclusion
- Strengths and Limitations
- Assumptions and Associated Effects
- Modifications Suggested

Student Questionnaire

Curtin University

Curtin Research in Higher Education

Questionnaire

It is not compulsory to complete this questionnaire. By responding you consent to participate in this phase of the Mathematics A formative assessment study. Your responses will be used for research purposes only. Your responses will have no impact on your marks or grades.

Name.. Teacher.....................................

Please answer each of the following questions by circling the response that best describes your Maths A study pattern. You may circle more than one response.

1) How long do you spend studying Maths A each week?

   < 2 hours   2-4 hours   > 4 hours

2) Where do you usually study?

   Room by myself   Family area   With friends

3) How often do you do Maths A homework?

   Never   Sometimes   Twice a week   After each lesson

4) Circle the answer that best describes your revision for Maths A.

   Revise weekly   Revise before exams   Seldom revise Maths A

5) Do you have a private tutor for Maths A?

   No, never had a tutor   Yes, sometimes   Yes, regularly

6) **After you received your diagnostic test results did you study, revise or complete homework for Maths A:**

Less often   No change   More often

7) **For Maths A do you study, revise and/or do homework with other students:**

Never   Weekly   Regularly   For assignments   Before exams

8) **How will you prepare for your Maths A exam? (Tick box/es)**

☐ Read through textbook

☐ Revise and practice questions with textbook and notes

☐ Attempt practice questions under exam conditions

☐ No preparation

9) **How many hours will you spend preparing for the Maths A exam?**

< 2 hours   2 – 4 hours   > 4 hours

10) **While studying and revising Maths A are you connected to other people via:**

Mobile phone   SMS texting   Facebook   Email   Other social media

Thank you for completing this Questionnaire

Appendix J

<center>**Student Interview Sample Questions**</center>

<center>**Mathematics A Formative Assessment Study**</center>

Participants will be invited to participate in the interview process. They will be informed as follows:

This interview forms part of the Mathematics A formative assessment study. Your responses will be used for research purposes only. They will not be added to your student file and they will not impact in any way on your results for Mathematics A.

By consenting to this interview, you are stating that you understand you can decline to be interviewed and you are free to terminate the interview and withdraw at any time.

Name: …………………………………   Teacher………………….……….

I consent to be interviewed for the Mathematics A formative assessment study.

Signed: ....Date: ....

The interview will begin with four structured questions to link the interview to the questionnaire. This will be followed by four open ended questions.

Semi - Structured Questions:

1. Did you think that you understood the topic of this Maths A exam?

   No   Some of it   All of it

2. What were the signs that led you to believe that you understood the topic?

   ☐ Understood the teacher in class

   ☐ Read through the textbook and it made sense

   ☐ Could do the questions in class

   ☐ Helped other students

   ☐ Could do the questions at home

   ☐ Could do practice questions under exam conditions

3. How did you study for this Maths A exam? Please describe your study plan.

☐ Read through textbook

☐ Practised questions with textbook and notes

☐ Practised questions under exam conditions

☐ Worked with tutor

☐ Informal study group

4. When you left the exam room what did you estimate your grade would be for this Maths A exam?

E   D   C   B   A

Open-ended Questions

5. Why do you think you didn't do well on this exam?

6. Where there any personal issues that may have impacted on your ability to do well on the exam? (sickness, family crisis etc.).

7. Where there any external factors that may have impacted on your ability to do well on the exam? (party night before, too many exams in short time period, left study to the last minute etc).

8. What could you do differently next time that would improve your chances of success?

Appendix K

Memorandum

Curtin University
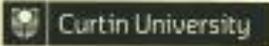
To	Melinda Stockwell, SMEC	Office of Research and Development
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre	Human Research Ethics Committee
Subject	Protocol Approval SMEC-46-12	Telephone 9266 2784
Date	31 October 2012	Facsimile 9266 3793
Copy	Vaille Dawson, SMEC	Email hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Low Risk (Ethical Requirements)" for the project titled *"Developing effective formative assessment practices for Grade 12 Mathematics A classes"*. On behalf of the Human Research Ethics Committee, I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **31st October 2012** to **30th October 2013**.

The approval number for your project is **SMEC-46-12**. *Please quote this number in any future correspondence.* If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

[signature]

PAULINE HOWAT
Administrator
Human Research Ethics
Science and Mathematics Education Centre

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved under Curtin University's process for lower-risk studies (Approval Number SMEC-46-12). This process complies with the National Statement on Ethical Conduct in Human Research (Chapter 5.1.7 and Chapters 5.1.18-5.1.23).
For further information on this study contact the researchers noted above or the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

Appendix L

Term 1 Formative Assessment Feedback Checklist Topic 2

Answers should include the following:	Evidence Provided (List Questions)	Student's Comment	Teacher's Comment's
Problem stated			
Information sorted			
Correct Formula/e			
Substitution correct			
Calculations correct			
Correct Answer			
Solution explained			
Questions 6 and 7			
Graph drawn with ruler and given title			
X and Y axes labelled correctly with both scale and title			
Points plotted accurately using data in table.			
X axis extended as directed in question to June 2009.			
Line of best fit drawn and extended to June 2009			
Modelling and Problem Solving Criteria (QSA, 2013b)			
Write at least three sentences for each one addressing each of the four criteria below.			
Reflection on the effectiveness of mathematical models			
Strengths and Limitations of models			
Assumptions and their associated effects			
Justification of the reasonableness of results			