Diagnostic testing and changes to teaching practice in Year 9 mathematics classes

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Abstract

Teachers can use various means, including diagnostic tests, to determine their students’ knowledge. It is of interest to know the ways in which teachers interpret and act upon such diagnostic information. The aim of this study was to examine the use of a particular diagnostic testing system by six teachers in Year 9 mathematics classrooms. The focus diagnostic system was the SMART system (Specific Mathematics Assessment that Reveal Thinking), which provides teachers with an online diagnostic test, diagnostic analysis and teaching advice. This study focused on the use of the SMART system in two topics, linear equations and linear graphs. The participant teachers were interviewed before each topic to ascertain the ways in which they gathered knowledge about student understanding, current and intended teaching practices, and how they met individual student’s learning needs. On conclusion of each topic, participants completed a questionnaire and an interview to determine if any changes had been made. The teachers found the SMART system gave them some useful data on their students. The diagnostic analysis revealed gaps or misunderstandings in some students’ knowledge, the teachers realised that they could no longer assume that all students had the requisite prior knowledge. Through this discovery, teaching practice changed in a number of ways. First, the teachers were able to decide on a better starting point for the particular topic. For example, if many students did not have the expected prior knowledge the teachers began the topic with earlier concepts. Second, teachers could identify groups of students with similar learning needs and these students could be provided with activities that supported their learning. Furthermore, for some teachers it changed their view of students mathematical ability from, ‘some students do not have the ability to learn maths’ to, ‘these students have gaps in their knowledge and if these gaps or misconceptions are addressed they could progress to more complex concepts’. Most significantly, teachers reported becoming more prepared with appropriate materials for either individual students or groups of students. Hence the SMART system supported teachers to cater for individual student needs by highlighting the learning needs of students.
Declaration of originality

I, Jacqueline Quenette, declare that this thesis comprises only of my own work and has not been submitted in any form for another degree at any university or other institute of tertiary education. Information derived from the published work of others has been acknowledged in the text and a list of references is given in the bibliography. The thesis is less than 22,000 words in length, exclusive of tables, maps, bibliographies and appendices.

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Table of Contents

List of Tables .............................................................................................................

List of Figures ............................................................................................................

Chapter 1 Introduction ............................................................................................... 1

Chapter 2 Literature Review ...................................................................................... 4
  2.1 Formative assessment ....................................................................................... 4
    2.1.1 Definition .................................................................................................. 4
    2.1.2 Why is formative assessment important in the teaching of mathematics? ................................................................................................. 5
  2.2 Diagnostic testing ............................................................................................... 6
    2.2.1 Definition .................................................................................................. 6
    2.2.2 Types of diagnostic tests ......................................................................... 6
    2.2.3 Why is diagnostic testing important in the teaching of mathematics? ................................................................................................. 10
  2.3 Differentiation .................................................................................................... 11
    2.3.1 Definition .................................................................................................. 11
    2.3.2 The purpose and importance of differentiation in the teaching of mathematics ................................................................................................. 11
  2.4 Summary ............................................................................................................ 13

Chapter 3 Methodology ............................................................................................. 15
  3.1 Design ............................................................................................................... 15
  3.2 Method .............................................................................................................. 16
    3.2.1 Pre-topic interviews and use of the SMART system ......................... 18
    3.2.2 Post-topic questionnaires ...................................................................... 19
    3.2.3 Post-topic interviews ............................................................................ 21
    3.2.4 Follow up interview .............................................................................. 22
  3.3 Participants ......................................................................................................... 22
  3.4 Data Analysis ..................................................................................................... 23
    3.4.1 Pre-topic interviews .............................................................................. 23
    3.4.2 Post-topic questionnaires ...................................................................... 24
    3.4.3 Post-topic interviews ............................................................................ 24
  3.5 Rigor .................................................................................................................. 24

Chapter 4 Research Question 1: Changes in teacher knowledge ............................ 27
  4.1 Pre-topic Interviews .......................................................................................... 27
4.2 Questionnaire..............................................................................................................28
4.3 Post-topic Interviews for Topics 1 and 2 .................................................................30
4.4 Follow up interview .................................................................................................35
4.5 Conclusion ................................................................................................................35

Chapter 5 Research Question 2: Changes in teaching practice ..............................38
   5.1 Pre-topic interviews ..............................................................................................38
   5.2 Questionnaire ........................................................................................................40
   5.3 Post-topic Interviews for Topics 1 and 2 .............................................................41
   5.4 Follow up interview ..............................................................................................45
   5.5 Conclusion ............................................................................................................46

Chapter 6 Research Question 3: Addressing student needs .................................48
   6.1 Pre-topic Interviews ..............................................................................................48
   6.2 Questionnaire ........................................................................................................49
   6.3 Post-topic Interviews for Topics 1 and 2 .............................................................50
   6.4 Follow up interview ..............................................................................................53
   6.5 Conclusion ............................................................................................................53

Chapter 7 Case Study: Bernard ..................................................................................55
   7.1 Change in Teacher Knowledge ..........................................................................55
       7.1.1 Initial position ............................................................................................55
       7.1.2 Final position .............................................................................................57
   7.2 Change in Teaching Practice ..............................................................................59
       7.2.1 Initial Position ...........................................................................................59
       7.2.2 Final Position .............................................................................................61
   7.3 Addressing Student Needs ..................................................................................62
       7.3.1 Initial position ...........................................................................................62
       7.3.2 Final Position .............................................................................................63
   7.4 Conclusion ............................................................................................................64

Chapter 8 Conclusion .................................................................................................66
   8.1 Aim of study ..........................................................................................................66
   8.2 Change in teacher knowledge..............................................................................66
   8.3 Change in teaching practice ...............................................................................67
   8.4 Addressing student needs ....................................................................................67
   8.5 Limitations of study ..............................................................................................67
Appendix

8.6 Further Research

References

Appendices

Appendix 1 – Post-topic and follow up interview questions

Pre-topic interview questions

Post-topic interview questions

Follow up interview questions

Appendix 2 – Rachael

Pre-topic 1 interview

Pre-topic 2 interview

Questionnaire results

Post-topic 1 interview

Post-topic 2 interview

Follow up interview

Appendix 3 - Svetlana

Pre-topic 1 interview

Pre-topic 2 interview

Questionnaires

Post-topic 1 interview

Post-topic 2 interview

Follow up interview

Appendix 4 – Jenny

Pre-topic 1 interview

Pre-topic 2 interview

Questionnaires

Post-topic 1 interview

Post-topic 2 interview

Follow up interview

Appendix 5 – Troy

Pre-topic 1 interview

Pre-topic 2 interview

Questionnaires

Post-topic 1 interview
## List of Tables

3.1 Details of Likert statements and relevant research questions  20  
4.1 Questionnaire responses to statements addressing Research Question 1  29  
5.1 Questionnaire responses to statements addressing Research Question 2  40  
6.1 Questionnaire responses to statements addressing Research Question 3  49  
7.1 Questionnaire responses to RQ1, topic 1 (linear equations)  56  
7.2 Questionnaire responses to RQ1, topic 2 (linear graphs)  57  
7.3 Questionnaire responses to RQ2, topic 1 (linear equations)  59  
7.4 Questionnaire responses to RQ2, topic 2 (linear graphs)  61  
7.5 Questionnaire responses to RQ3, topic 1 (linear equations)  63  
7.6 Questionnaire responses to RQ3, topic 2 (linear graphs)  64
List of Figures

2.1 The developmental stages of representing Linear Functions  8
3.1 Diagram of method and data collection  17
Chapter 1 Introduction

Currently in education there is a focus on student achievement in Mathematics. Students are required not only to be literate in basic numeracy but are expected to progress their mathematical knowledge throughout their schooling. It is essential that everyone have good numeracy skills to understand not only basic household economics as well as understanding that numeracy has a place in many tasks we undertake.

Many students experience difficulty in understanding certain mathematical concepts and consequently find subsequent concepts more difficult to grasp. The issue that teachers are faced with is the cumulative nature of mathematics. The discipline is made up of concepts that build on from previous knowledge; each concept should be understood before progression to the next level. If students miss one or more of these steps or the concepts are not consolidated, they may experience difficulties moving to the next step or have gaps in their knowledge. This results in a learning delay. Often these difficulties may not be immediately evident but revealed at a later stage, especially if the concept was essential for building further knowledge. For example, in a Year 9 maths classroom a teacher can be faced with knowledge levels that can range from Year 5 through to Year 10 or beyond. Teachers are then faced with the following questions: How do we help the lower achieving students to progress? What steps have students missed or not understood that has hindered progression? How do we allow all students to experience success in mathematics without some students feeling they are not learning anything new or attempting activities that are too difficult? If teachers take extra time to address students’ misunderstandings then how do they complete the curriculum with those students? There have been many discussion papers on the benefits students experience when they complete tasks according to their current learning needs. Teachers must be able to gain knowledge of their students’ learning needs to enable them to set appropriate tasks (Black & Wiliam, 2009). One method teachers may use is formative assessment where teachers may gather useful information that subsequently can be used to aid their students (Doig & Lindsey, 2002; Wiliam, 2009).
Formative assessment can occur in many forms (Wiliam, 2009): diagnostic testing is one type of formative assessment. Diagnostic tests are intended to provide information to teachers about their students’ understanding of particular topics. It is of interest to know the ways teachers interpret and act upon such diagnostic information, and whether they feel that the data is useful for teaching. This project examines teachers’ use of the online SMART system, *Specific Mathematics Assessment that Reveal Thinking* (Stacey et al., 2009), for Linear Equations and Linear Graphs topics. The aim of the project is to determine whether information provided by this system aids teachers to improve their own knowledge not only about misconceptions the class may be experiencing, but also the individual students developmental level. This information may have further implications for changes in teaching practice where teachers are more equipped to provide students with learning opportunities to overcome misconceptions.

The key research questions are:

1. Does the teacher’s knowledge about student learning change when their students use the SMART system?
2. What are the changes in teaching practice that occur when teachers use the SMART system?
3. Does the use of the SMART system help teachers to address individual student needs?

The project will examine the effect the SMART system has on teaching practice, teacher knowledge of students’ mathematical understanding, and the teacher’s ability to then uncover and address individual student misunderstandings. Hattie (2010, p. 22) stated, “what some teachers do matters, - especially those who teach in a most deliberate and visible manner … when these professionals see learning occurring or not occurring they intervene in calculated and meaningful ways”. The inquiry centres on how teachers discover that learning is not occurring, how they currently address student misunderstanding, and if using diagnostic analysis provided by the SMART system aids them to address student difficulties.

There are a multitude of diagnostic tests available for teachers, which range from paper based to online tests. The SMART system was chosen because it was relatively new and the analysis is less demanding on teachers than other forms of diagnostic
testing. Many formal diagnostic tests are time intensive, as teachers must analyse student answers to uncover students’ misconceptions, and pinpoint the learning needs (developmental level) of each student. Once this is completed then the teacher can implement intervention strategies. Tomlinson (2009a) suggests that this may be the reason why many teachers do not use formal diagnostic tests even though teachers are aware of the benefits. The SMART system’s automated analysis may allow teachers to use their preparation time to prepare intervention strategies rather than analysing student answers.

There has been much literature discussing the benefits of differentiation in the classroom, which is discussed in the next chapter. Research has shown that students receiving differentiated learning are empowered to gain greater depths of mathematical understanding (Chamberlin & Powers, 2010). In education, differentiation means “a process of proactively modifying instruction based on students’ needs” (Chamberlin and Powers, 2010, p. 114). Through the use of formative assessment, teachers are able to discover the student learning that is occurring and, more importantly, concepts that students have not understood; this is Hattie’s (2009) model of “visible teaching”. Teachers are then able to use this information to implement strategies that assist students to learn. The SMART system may enable teachers to differentiate learning tasks to a greater extent, enabling students to follow individual pathways ensuring that learning needs are addressed and overcome, thus changing teaching practice from one-size-fits-all to a differentiated classroom. Carol Tomlinson (2009a, p. 183) stated, “Educators have had little opportunity to study in depth the need for differentiation”. This is the main reason why teachers cling to teacher-centred methods where the students all work on the same task at the same time.

Chapter 2 examines the current literature about formative assessment, diagnostic testing, and differentiated learning. Chapter 3 contains the methodology used for this project. Chapters 4-6 discuss the data collected from the three research questions. Chapter 7 is a case study of one of the participants. Chapter 8 discusses the conclusions drawn from the data. There are seven appendices; each appendix contains a summary of the data collected from each participant.
Chapter 2 Literature Review

This chapter will review the literature associated with formative assessment, diagnostic testing, and differentiation. Research suggests that teachers’ perceptions of teaching and learning strongly influence how they teach and what students learn or achieve (Brown, 2004; Marshall & Drummond, 2006). Hattie’s (2009) model of “visible teaching” strongly supports this research. Hattie (2009) suggests that teaching involves teachers understanding when students have gained knowledge of a particular learning focus, as well as determining if this knowledge has not yet been attained.

2.1 Formative assessment

2.1.1 Definition

Wiliam (2009, p. 47) defines formative assessment as any type of assessment that “provides evidence that has the potential to improve instructional decision making”. Hence, this type of assessment can provide teachers with useful information about their students’ knowledge (Doig & Linsey, 2002). For example, Widjaja, Stacey, and Steinle (2010) conducted formative assessment about student knowledge of number lines, in the form of written tests and individual interviews, during their research involving pre-service teachers. Through this type of assessment they found that many pre-service teachers had either forgotten or not consolidated the concept of directed numbers. In this way, the researchers gained knowledge about their pre-service teachers’ level of knowledge, and could subsequently provide tasks to assist understanding (Widjaja et al., 2010).

Formative assessment can be conducted either asynchronously or synchronously. Asynchronous assessment is defined as teachers gathering data from tasks, such as class activities, to plan subsequent lessons that address misunderstandings that have become evident through these tasks (Wiliam, 2009). Synchronous assessment occurs when remediation occurs immediately after the teacher notices a problem (Wiliam, 2009). For example a teacher, who observes a student experiencing difficulties with fractions, can work with that student to uncover their lack of knowledge and then set a task to address this difficulty (Wiliam, 2011). Assessment becomes formative when a teacher uses the information from a student task to increase their understanding of
student knowledge and then use this knowledge to guide their students’ future learning (Peshak, 2012; Shute, 2008).

2.1.2 Why is formative assessment important in the teaching of mathematics?

The reasons that teachers conduct formative assessment are to uncover the learning needs of students (McMillian, 2009; Stacey, 2013), in order to enhance the learning of their students (Shute, 2008; Stacey, 2013). This contrasts with summative assessment, which used to report on the level of achievement for students and not for improving student learning (Stacey et al., 2009). Many tasks that teachers provide have the potential to be formative if the information is used to address the learning needs of students (Wiliam, 2009). It is very important what teachers then do with this knowledge (McMillan, 2009; Ryan & McCrae, 2005). For example, Stacey (2013) collated SMART test data (one type of formative assessment, which will be discussed in the next section) from a range of Year 7 and 8 students in order to investigate misconceptions around the concept of Reflections. She reported that the information gathered from this formative assessment provided their teachers with useful information about specific students’ understanding of reflections. Teachers were then able to provide specific tasks that catered for the developmental level of individual students.

Formative assessment can take many different forms. It could be a task or activity, a diagnostic test, or questions designed to uncover misunderstandings (Wiliam, 2011). When teachers have knowledge about their students’ developmental level they are able to intervene and can subsequently modify tasks to suit student needs (Black and Wiliam, 2009; Hattie, 2009). One huge impact is that teachers may uncover misunderstandings that they did not expect particular students to be experiencing, so the teachers’ specific knowledge about their students may change (McMillan, 2009). Some students are very good at concealing their misunderstandings (Widjaja et al., 2010) and through the use of formative assessment these misconceptions are more likely to be uncovered and the exact nature of the difficulty identified (Wiliam, 2009). The effect of this is twofold: first, it enables teachers to address a misconception once uncovered (Widjaja et al., 2010). Second, through addressing difficulties students increase their own mathematical knowledge and are able to progress to more complex concepts (Patel & Little, 2006; Wiliam, 2011). Thus, assessment can only be
considered as formative if it results in changed learning opportunities for students (Steinle & Stacey, 2012).

2.2 Diagnostic testing

2.2.1 Definition
Diagnostic tests or activities are designed to uncover individual students’ specific misconceptions and developmental level for a particular topic. Wiliam (2009, p. 47) stated, “If the [formative] assessment provides additional information that locates the precise nature of the students’ difficulties, then it is considered to be diagnostic”. This definition is similar to the definition of assessment for learning, which Stacey et al. (2009, p. 1) stated “occurs when teachers use inferences about student’s progress to inform their teaching; especially teaching close in time to that assessment”. Formative assessment provides the teacher with specific information about their students’ knowledge, which can then be used to plan future teaching.

2.2.2 Types of diagnostic tests
Diagnostic testing generally takes the form of a carefully constructed test (Wiliam, 2009). Such tests are crafted to allow not only the developmental level to be made evident to the teachers administering the test, but also the student misconceptions (Steinle & Stacey, 2008). When the answers are viewed, teachers gain an insight into an individual student’s understanding of a particular concept (Steinle & Stacey, 2008), thus exposing any misconceptions (Widjaja, Stacey, & Steinle, 2010). A poorly constructed test may lead to wrong conclusions about student knowledge so teachers must be clear what misconceptions or understandings they are trying to uncover (Widjaja, Stacey, & Steinle, 2010). Likewise, teachers must also be aware of the strengths and weakness of their chosen diagnostic test and use it in conjunction with another means of uncovering misunderstandings if the analysis does not reflect teacher expectations (Widjaja, Stacey, & Steinle, 2010). The analysis received from diagnostic testing should demonstrate to teachers how students think mathematically, and, depending on the style of diagnostic test, how students articulate their understanding (Baturo, 2004).

There are various styles of diagnostic tests, which may be administered online or be paper based. For example teachers using the SMART system (Stacey et al., 2009;
1) administer an online test, read through the automated analysis, and then plan an intervention. Whereas the Mathematics Online Interview developed by Clark et al. (2000), requires teachers to interview individual students, record answers and student thinking, analyse results, then plan an intervention. The next two sections will describe and contrast the amount of time required for teachers to conduct these two specific diagnostic tests, the SMART system and the Mathematics Online Interview.

**The SMART System**

The SMART system (*Specific Mathematics Assessments that Reveal Thinking*) is an online diagnostic tool designed for teachers to gain specific information about their students’ mathematical misconceptions and developmental levels. Then using this information, teachers can gain ideas of appropriate activities for students (Akhtar & Steinle, 2013). The SMART system’s purpose is to provide teachers with usable information about student knowledge (href 1). The intention of the designers was to improve teachers’ pedagogical content knowledge by constructing formative assessment. Then this aids teachers to design, plan and teach the mathematics curriculum using researched questions that uncover topic-specific student developmental levels (Steinle & Stacey, 2012). The SMART system contains a bank of topic-based diagnostic tests that teachers may use to gain specific information about student knowledge. The diagnostic assessment provides teachers with information about the different stages of understanding within a concept. These are referred to as developmental stages (Akhtar & Steinle, 2013). The developmental stage of students refers to a small number of important underpinning concepts (Stacey, 2013) (see Figure 2.1). It describes learning along a hierarchy of topic-specific concepts (Stacey et al., 2012). The SMART system diagnosis places students into a developmental stage according to where their learning falls along this hierarchy (Stacey et al., 2012).

The SMART system focuses on the developmental stages of Years 7-9. Each diagnostic assessment involves students completing a short online test of approximately 5-10 minutes, generally conducted at the beginning of a topic. The SMART tests examine the prior knowledge of students (Stacey et al., 2012). If a teacher is aware of prior knowledge then teaching can be altered to address any student misconceptions (Stacey & Steinle, 2012). Once a student has submitted the
test the teacher quickly receives an automated diagnostic analysis via the SMART website. This detailed diagnosis includes identification of misconceptions, the mathematical developmental stage of the student, and web links for teachers. These web links inform teachers of possible activities to aid students in overcoming misconceptions, how they occur, and links to the Victorian Mathematics Developmental Continuum P-10 (href 2).

**Figure 2.1** The developmental stages of Representing Linear Functions from the SMART system website, reproduced with permission of V. Steinle (www.smartvic.com).

Steinle and Stacey (2012) reported that teachers found the SMART system a useful tool to help increase teachers’ knowledge of the student developmental stages from Year 7 through to Year 10. Data received by teachers is concise yet detailed enough for teachers to adjust teaching plans to cater for individual student needs (href 1). This information enables the teacher to form groups of students that may require targeted teaching, future teaching to be designed then implemented (Price, Stacey, Steinle, Chick, & Gvozdenko, 2011). The SMART system designers believe that through the
use of the system, teachers will be able to uncover and subsequently address the misconceptions of their students (Stacey et al., 2012).

**The Mathematics Online Interview**

“The Mathematics Online Interview” can be found on The Mathematics Domain on the Department of Education and Early Childhood Development (DEECD) web site (href 2). The interview is conducted one-on-one with students and takes approximately 30-40 minutes for each student the interview questions can be found on https://www.eduweb.vic.gov.au/MathematicsOnline. The interview consists of a series of questions designed to elicit thinking behind student responses. Although typically used for primary students the Mathematics Online Interview is suitable for any Year 5 to Year 9 student (href 2). Classroom teachers conduct these interviews, record student responses and then analyse the results. Through their analysis of the results teachers may uncover student misunderstandings. The advantage of this form of diagnostic testing is that teachers can gain a deep understanding of a student’s mathematical thinking whilst the student is completing a problem (href 2). However, these misunderstandings may only become evident if the Mathematics Online Interview is conducted in its entirety. The teachers may then use the links to the Mathematics Developmental Continuum (href 2) to find teaching strategies to address misunderstandings (href 2). While conducting these tests is rewarding, because teachers gain knowledge about individual students’ mathematical understanding, the tests may require a large amount of time for analysis before student learning needs can be addressed (Stacey et al., 2009). Each interview must be read through and answers compared to known misconceptions for identification. For an individual student it takes approximately 1.5 hours to interview and then analyse one student’s data (href 2).

In comparison the SMART system takes much less time to administer and analyse due to its automated analysis system (Stacey et al., 2009). Teachers are able to test their students and receive a detailed diagnostic analysis almost instantly. This means that the SMART system could easily be used for every topic covered during a year. The time it takes for teachers to conduct and complete the Mathematics Online Interview makes it impossible to conduct more than once or twice a year. Teachers are then able to spend their preparation time using the analysis from the SMART
system to gain insights into student knowledge and prepare appropriate tasks to address individual developmental levels (Stacey et al., 2009).

### 2.2.3 Why is diagnostic testing important in the teaching of mathematics?

Diagnostic testing is a type of formative assessment which is very important as teachers can uncover student strengths and weaknesses then plan future lessons accordingly (Linsell et al., 2012). As previously mentioned, formative assessment may cause a change in teaching practice as a teacher has more precise knowledge of a student’s understanding (Shute, 2008; Steinle & Stacey, 2012). For example, Linsell et al. (2012) found that when teachers used the diagnostic analysis developed by Linsell with Year 9 and 10 students in New Zealand, they gained insights into student understanding. This subsequently enabled teachers to construct a deep understanding of students’ mathematical thinking, build a profile of individual students learning achievements, and inform their own teaching (Linsell et al., 2012). This furthermore empowers teachers to provide students with tasks to address and improve algebraic knowledge (Linsell et al., 2012). The use of diagnostic tests could be seen as an essential skill to enable teachers to change their teaching practice to bridge the knowledge gap of students at earlier developmental levels (Kettedin-Geller & Yovanoff, 2009).

This supports the suggestion by Wiliam (2009 p. 47) that “they [diagnostic tests] also yield insights into the kinds of next steps in instruction (including possibly steps to be taken by learners) that are likely to be most effective”. Once a particular misunderstanding has been uncovered then both teachers and students are empowered. For example, Bukula (2010) found that formative assessments enabled her to discover misconceptions and misunderstandings of her seventh-grade students in Missouri, U.S.A., which subsequently led her to change and reshape her lessons to ensure tasks addressed these difficulties. This meant that misconceptions could then be overcome rather than covered over or ignored (Steinle, 2004). Linsell et al. (2012) used the information they gained from diagnostic tests to target specific learning tasks. Steinle and Stacey (2012) similarly reported that teachers found that they changed their teaching plan when they used the SMART system to diagnose student knowledge.
Through diagnostic analysis, teachers can give students the opportunity to improve their knowledge from the unknown to the known (Wiliam, 2009). Weaknesses or misunderstandings can be viewed as a new pathway rather than become a stumbling block forever affecting a student’s mathematical comprehension (Widjaja, Stacey, & Steinle, 2008). For example, pre-service teachers who struggled with calculations containing negative numbers found once their difficulties were addressed their understanding of other mathematical concepts improved (Widjaja, Stacey, & Steinle, 2008). When summative tests are given at the end of a unit of work when the teacher identifies students who are struggling, it is often too late to reteach the concept (Bukula, 2010). Bukula (2010, p. 43) states this is because “too much time has passed” or “if retaught then students do not make the connection to why they misunderstood the concept”.

2.3 Differentiation

2.3.1 Definition

It is important that when misconceptions or misunderstandings are uncovered teachers know the different learning strategies to address these issues (Hattie, 2009). Chamberlin and Powers (2010, p. 114) define differentiation as “a process of proactively modifying instruction based on students’ needs”.

2.3.2 The purpose and importance of differentiation in the teaching of mathematics.

The purpose of differentiation is to provide access to information and skills for a range of knowledge levels within a classroom. This means that all students can improve their understanding of mathematical concepts regardless of where they are in their mathematical developmental stage (Chamberlin & Powers, 2010; Tomlinson, 2003). It is important that teachers are well informed about student knowledge so they are able to effectively construct a differentiated learning environment for students (Moon, 2009). Moon (2009, p. 227) states “decisions should be based in large measure on good assessment data, rather than on casual observation and instinct”. Chamberlin and Powers (2010) and Moon (2009) highlighted the principles of differentiated learning. The main ideas they outline are: teachers take account of student differences, teachers are aware of essential knowledge for the unit of work, teachers challenge students at the most appropriate level for student learning, students
and teachers collaborate in learning, and students are taught in flexible groups in accordance to learning needs. These ideas help teachers to link assessment and learning together as well as cater for student differences whilst still allowing students to work collaboratively with peers (Chamberlin & Powers, 2010). This type of learning enables all students to take part in learning, resulting in enhanced student engagement (Peshak, 2012). Chamberlin and Powers (2010, p. 114) state “Effective characteristics of differentiated instruction include clear learning goals, ongoing and diagnostic assessments that modify instruction and challenging tasks for all students”. Thus, differentiated instruction involves the following in a classroom:

1. Teaching practice can be proactive and not reactive (Chamberlin & Powers 2010). Teachers can have tasks prepared for students that addresses student learning needs rather than answering student difficulties with individual textbook questions and not uncovering the cause of the difficulty (Stacey, 2013). Through using diagnostic testing teachers are able to uncover misconceptions and gain knowledge of individual students’ developmental level before formal teaching begins (Widjaja, Stacey, & Steinle, 2008).

2. Instruction is not individualized rather individual needs are met as the teacher varies tasks for groups of students with similar learning needs (Chamberlin & Powers 2010). Individual instruction would be time consuming and difficult for a teacher to plan. Students working in small groups according to learning needs would be less time consuming for teachers to prepare tasks for (Chamberlin & Powers, 2010) allowing the teacher to spend time finding activities that best address students’ learning needs.

3. Learning is not differentiated for every class; whole class teaching is still employed (Chamberlin & Powers 2010).

Tomlinson (2009a) states that differentiation has been slow to make its way into general teaching because of the impact on teacher planning time. Teachers lack the time to analyse diagnostic tests for individual students as they have many students and often teach multiple classes (Tomlinson, 2009a). However, there are many cases where differentiated instruction has occurred. Sullivan et al. (2010) examined the relationship between task, teacher action, and student learning with a group of Year 5
and 6 teachers with students in Melbourne, Australia. All students were pre-tested with a diagnostic test before teachers planned the task. Students were grouped according to similar learning needs, which was determined from the diagnostic test. Each group had different set tasks (dependent on the diagnostic data), where “students could choose the order which they worked, and this choice was emphasised by the teachers as having a pedagogical purpose” (Sullivan et al., 2010 p. 135). Sullivan et al. concluded that the teachers directly influenced the learning needs of the students by the construction of this task using the data from the pre-test.

Differentiation allows both teachers and students to become empowered. Once students have comprehension of an individual concept that they have had difficulties with other subsequent concepts may become clearer (Bakula, 2010). This may allow students to build links between concepts, to develop deeper understanding and clarify other concepts (Bakula, 2010; Hattie, 2009). When students experience more success through increased understanding of concepts, the benefit is two-fold: students become more confident with their own mathematical understanding and they are more likely to take risks with their learning (Hattie, 2009). The key goal for differentiation is to increase student understanding regardless of whether students are operating above, below or at the expected level (Tomlinson, 2009b). Students are required to gain knowledge for the particular concepts. Some students will gain this understanding more quickly than others who may require greater scaffolding to comprehend these concepts (Moon, 2009).

2.4 Summary

Diagnostic tests, as a type of formative assessment, can lead teachers to change their pedagogical practice (Moon, 2009) due to the specific information received about their students’ knowledge (Steinle & Stacey, 2012). Through such tests, teachers are informed about misconceptions and developmental levels of individual students (Steinle & Stacey, 2012). This may subsequently impact teaching practice as teachers could become more explicit in their teaching. Hence ensuring activities undertaken address any misconceptions and also do not perpetuate any further misconceptions (Widjaja at al., 2010). Once teachers are aware of student developmental levels through the use of formative testing, differentiation of teaching may occur (Moon, 2009). Through differentiated learning students may experience gains in knowledge
by overcoming misconceptions (Steinle & Price, 2008) and increased confidence in their own mathematical knowledge (Hattie, 2009).

This literature review leads to some important questions. If diagnostic testing increases teacher preparation time, does the SMART system allow teachers to conduct diagnostic testing without impacting on their time? As teachers frequently use tasks to gain further information about their students, does a diagnostic test change teacher knowledge? Does teaching practice actually change? Does the teacher’s thinking change? Does the SMART system actually aid teachers to address student needs because it is an online diagnostic test?
Chapter 3 Methodology

3.1 Design

The key research questions are:

1. Does the teacher’s knowledge about student learning change when their students use the SMART system?
2. What are the changes in teaching practice that occur when teachers use the SMART system?
3. Does the use of the SMART system help teachers to address individual student needs?

To investigate the change involved in these research questions two sets of data must be collected; one set before the use of the SMART system and the second set after the use of the SMART system in order to determine if any change has occurred. Specifically, the researcher needs to understand the way in which teachers collect knowledge about student understanding, address student difficulties, and how individual student needs are met, without the use of the SMART system. This knowledge can then be compared to the data collected when teachers have used the SMART system. Since change often takes place over time, the comparison will be made after the teachers have used the SMART system for two topics. This will allow teachers the opportunity to work through any difficulties they may experience using the SMART system for the first time and be well equipped to use it to its full capabilities by the second topic.

Key research questions for this project require teachers to reflect on their own teaching practice, the usefulness of the SMART system, and if it aids them to differentiate the curriculum. This would be difficult information to gather with a purely quantitative project as quantitative data does not take into account context nor would it allow participants to voice any opinions about their quantitative responses (Creswell & Plano Clark, 2011). The three research questions are all suitable for a quantitative project however, by interviewing participants (qualitative data) enables them to elaborate and think deeply on each of the interview questions, thus gaining a more detailed view of participant thinking.
The project used a fixed, explanatory mixed method design as described by Creswell and Plano Clark (2011) to investigate the research questions. Creswell and Plano Clark (2011, p. 132) state if “the use of quantitative and qualitative methods [was] predetermined and planned at the start of the project” then the design is fixed. The methodology for this project was determined before the data collection commenced. Quantitative data collected in the form of a Likert scale questionnaire can be used to gain information about the key research questions. Results gained from the questionnaires may need further explanation to gain deeper understanding, which can be achieved via an interview. This design purpose, to explain the quantitative results to gain further understanding, is termed as an explanatory design (Creswell & Plano Clark, 2011). This quantitative strand (Likert scale questionnaire) will serve to inform the qualitative data collection, allowing the researcher to develop interview questions based on the results from the questionnaires.

Mixed method designs have advantages over using either quantitative or qualitative design methods for this study as it combines the strengths of both of these methodologies while offsetting their weaknesses (Creswell & Plano Clark, 2011). Qualitative data can give teachers a voice and allows for expression of opinion. However, data could be seen as interpretations, which are not transferrable to larger contexts unless there is multiple data sources (Creswell & Plano Clark, 2011; Hesse-Biber & Leavy, 2011).

3.2 Method

Two Year 9 mathematical topics have been identified as being of interest for this project: Linear Equations and Linear Graphs. These topics were chosen as student have first, have traditionally found these topics difficult (Akhtar and Steinle, 2013) and, second, SMART test availability. These topics were taught sequentially at the participating school (see Figure 3.1 for the method sequence). Before teaching began for Linear Equations (topic 1) the researcher interviewed all participating teachers (pre-topic 1 interview). During this interview teachers were asked questions to gain information on their current teaching methods and the ways in which they proposed to discover current student knowledge. Teachers were also shown how to use the SMART system, given assistance with registering, and asked to complete the Writing and Solving Equations SMART test with their class. The Writing and Solving
Equations SMART test was the diagnostic test for Linear Equations; it investigates the prior knowledge students are expected to have obtained throughout Year 7, 8, and 9. At the conclusion of teaching topic 1, the participants were asked to complete a questionnaire and another interview (post-topic interview). The data collected from this questionnaire was then used to determine the questions asked during the post-topic interview. This interview was conducted approximately 30 minutes after the completion of the questionnaire so that reasons behind answers on the questionnaire were still in the participants’ minds. These steps were then repeated for the Linear Graphs topic (topic 2) with students completing the Representing Linear Functions SMART test. Three months after the conclusion of topic 2, a follow up interview was conducted to collect information on teachers’ experiences of using the SMART system including whether they had continued to use it. Each of these instruments is described in the following subsections (3.2.1, 3.2.2, 3.2.3).

**Diagram of Method and Data Collection**

![Diagram of Method and Data Collection](image)

*Figure 3.1 Diagram of method and data collection.*
3.2.1 Pre-topic interviews and use of the SMART system

Qualitative one-on-one interviews (see Appendix 1 for interview questions) between the researcher and the participant teachers were used to uncover teaching practices and the methods that participants currently use to identify and address student difficulties with linear equations and linear graphs. These qualitative interviews can be powerful tools that capture how the participants make meaning from their experiences (Rabionet, 2011). Interviews allowed the researcher to gauge the self-reported, current teaching practice of each participant and the current diagnostic analysis used in the classrooms. Self-reporting meant that participants outlined their perception of their teaching practices, rather than what actually occurred in their classroom. Video evidence would provide objective data but that was outside the limits of this study. A semi-structured interview was employed. Semi-structured interviewing allowed the researcher to ask the same questions to all participants, while also allowing the interview to flow, hence permitting the participants to add details about aspects that interest them (Hesse-Biber & Leavy, 2011). Through this style of interviews, the interviewer may gain more information about particular aspects of the research questions that had not been considered during the development of the project design. Questions were designed to investigate individual participants’ teaching practice, knowledge of possible student misunderstanding, and if the curriculum or teaching plan for either linear equations or linear graphs had changed. This gave the researcher a baseline to make a comparison. Then used to determine if any change had occurred in participant teachers’ knowledge, their teaching practice, and their ability to meet the learning needs of students.

At the conclusion of the pre-topic interview, participants were requested to include a specific SMART test from the SMART website at some stage during their teaching of each topic: “Writing and Solving Equations” for the Linear Equations and “Representing Linear Functions” for the Linear Graphs. In light of this, teachers were given freedom to choose when to administer the SMART test during their teaching allowing them to choose the ideal time to use the diagnostic test. The SMART system was demonstrated to teachers including a general explanation of how to use the SMART system. Participants were told that once the students have completed a
particular SMART test then a diagnostic report of their class is available on the SMART system website for individual participants to use.

3.2.2 Post-topic questionnaires

A Likert scale is the most widely used scale to gather quantitative data (Dowling & Brown, 2010). It consists of a number of statements related to the key research questions that measure participant’s attitudes on a linear scale (Dowling & Brown, 2010). To compile a list of possible Likert statements, research questions were examined and broken down into smaller ideas. For example, Research Question 1 contains complex ideas such as: does the diagnosis give teachers information about the misunderstandings of their students and did the participants learn about different misunderstandings through the diagnosis. Statements were carefully considered and formulated with advice from the other researchers to ensure each statement was clear, used language that participants would understand, focused on single concepts, and phrased so that responses would fit on a scale of strongly agree (1) to strongly disagree (5), giving a scale from 1 – 5 (Dowling & Brown, 2010). The statements were also vetted with another teacher who was not involved in the research. This involved the teacher completing the questionnaire and then commenting on the following criteria for each statement: clarity, contained only one aspect, and relevance to topics.

Each Likert statement was aligned with one of the Research Questions (1-3) depending on the type of information that the statement was investigating, refer to Table 3.1. Statements concerned with teacher knowledge were associated with Research Question 1. Statements that examined teaching practices were aligned with Research Question 2 and Research Question 3 was aligned with statements investigating the meeting of individual student need through the use of different activities. Participants were asked to complete the questionnaire at the conclusion of the linear equations topic and an identical questionnaire at the conclusion of the linear graphs topic (see Figure 3.1). The data collected from the questionnaires was used to develop the post-topic qualitative interview questions. Although the statements were vetted, some statements could have been further improved. However, the researchers wanted to note if participants observed any improvement in student outcomes.
Table 3.1 Details of Likert statements and relevant research questions

<table>
<thead>
<tr>
<th>Likert Statement from Questionnaire</th>
<th>Research Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The diagnosis uncovered student misunderstandings</td>
<td>1</td>
</tr>
<tr>
<td>2. I gave some groups of student different activities because of the diagnosis</td>
<td>3</td>
</tr>
<tr>
<td>3. The SMART test diagnosis matched my own expectation of student knowledge</td>
<td>1</td>
</tr>
<tr>
<td>4. The diagnosis led me to change the way I taught some of the _________ topic</td>
<td>2</td>
</tr>
<tr>
<td>5. The diagnosis caused me to investigate student misunderstanding further</td>
<td>1</td>
</tr>
<tr>
<td>6. The diagnosis led me to revise some topic's concepts with my students</td>
<td>2</td>
</tr>
<tr>
<td>7. Compared to last year it was easier to address difficulties because of the diagnosis</td>
<td>2</td>
</tr>
<tr>
<td>8. Because of the diagnosis I could differentiate the curriculum</td>
<td>3</td>
</tr>
<tr>
<td>9. The diagnosis made it easier to discover student difficulties</td>
<td>3</td>
</tr>
<tr>
<td>10. Due to the information I gain from the SMART test the students achieved a higher outcome on the end of topic test</td>
<td>4*</td>
</tr>
<tr>
<td>11. I learnt about student misunderstanding through the diagnosis</td>
<td>1</td>
</tr>
<tr>
<td>12. Student outcomes improved in comparison to last year</td>
<td>4*</td>
</tr>
<tr>
<td>13. I discovered misunderstandings that I previously had not thought about</td>
<td>1</td>
</tr>
<tr>
<td>14. SMART test diagnosis improved student outcomes</td>
<td>4*</td>
</tr>
<tr>
<td>15. The diagnosis showed me misunderstandings that I did not know students could have</td>
<td>1</td>
</tr>
<tr>
<td>16. The diagnosis led me to revise some concepts, other than the particular topic, with my students</td>
<td>2</td>
</tr>
<tr>
<td>17. I gave different student different tasks due to the diagnosis</td>
<td>3</td>
</tr>
<tr>
<td>18. I researched student misunderstandings because of the SMART test diagnosis</td>
<td>1</td>
</tr>
<tr>
<td>19. The diagnosis helped me to improve the way I taught the topic</td>
<td>2</td>
</tr>
</tbody>
</table>
Unfortunately Research Question 4 did not generate any useful data and was subsequently omitted from the research questions. The statements indicated previously, as Research Question 4 in Table 3.1 do not appear in the following chapter discussions.

3.2.3 Post-topic interviews

Qualitative one-on-one semi-structured interviews were conducted after each participant completed the Likert scale questionnaire. This interview allowed the researcher to probe more deeply into the responses given on the questionnaire (Creswell & Plano Clark, 2011; Hesse-Biber & Leavy, 2011). The interviews also contribute and validate the trustworthiness of the data collected in the post-topic questionnaires as the scale ratings are solely about teacher self-perception. Like the pre-topic interview, the post-topic interview was semi-structured, allowing the researcher to ask the same or similar questions to each participant. The interviewer also had the flexibility to focus on individual participant responses from the questionnaire. A number of steps were followed for the development of the post-topic interview questions.

Step 1. Using each statement from the questionnaire a list of possible interview questions was developed. For example if a participant had answered agree or strongly agree to questionnaire statement 4, topic 1 then the researcher posed the following question; “In what ways did the diagnosis change how you taught linear equations?” These questions were designed to elucidate more information on the key research questions.

Step 2. To ensure the interview covered all research questions, the interview questions were mapped to the relevant research question.

Step 3. Post-topic questions were vetted by the other researchers to ensure the questions were clear, and only addressed one idea. This subsequently helped to maximise the detail in participant responses. Questions were also graded to ascertain their importance to the particular key research question. This ranking was done due to the time limit of 20 minutes for each interview. Questionnaire responses that were Strongly Agree and Agree, or Strongly Disagree and Disagree were deemed of high
importance because it indicated that the participant had a particular attitude to the statement, whereas, neutral responses were less important as the participant did not have a strong opinion of agreement or disagreement.

Step 4. From this list of possible questions (developed as part of step 1 above) a template (see Appendix 1) was constructed consisting of all possible post-topic interview questions and their importance to key research questions. After each questionnaire was completed, the participant questionnaire responses were compared to the template of post-topic interview questions. The researcher could then quickly determine the relevant post-topic interview questions that would be asked.

3.2.4 Follow up interview

A qualitative one-on-one interview was completed approximately one term after the two focus topics had been completed (see Appendix 1). Questions for this interview were developed after data analysis of the pre-topic, post-topic interviews, and the questionnaires that had been completed. The purpose for the follow up interview was to determine:

1. If any permanent changes in the teaching practice of the participants were due to use of the SMART system.
2. If participants had continued use the SMART system in their Year 9 class for other topics.
3. If the SMART system aided participants to differentiate the curriculum and hence address individual student needs.

3.3 Participants

The research school is a school in the eastern suburbs of Melbourne, Victoria, Australia. It was chosen as the research site for two reasons: first, because is it a large secondary school and second, the ease of access as it was the researcher’s place of employment. Teachers at this school are committed to enhancing the education of students in every cohort in the school, evident in high V.C.E. (Victorian Certificate of Education) results. The Mathematics faculty had been trialling diagnostic testing at Year 7 and wanted to expand to other year levels. Teachers had expressed the need for non time-consuming diagnostic testing that gave reliable results.
All teachers of Year 9 mathematics within the school were invited to be part of this research. Six out of the eight teachers volunteered to take part in this study. The following names are all pseudonyms. Bernard was a teacher who had taught Mathematics for more than 10 years. Jenny was a teacher of Science and Mathematics who had been teaching for 6 years. Chen taught mainly Mathematics, but also some Physical Education and he had taught for more than 10 years, including internationally. Rachael, a teacher of predominately Mathematics, had taught for 5 years. Troy was a Physics teacher who had taught a mixture of Science and Year 9 Mathematics for 6 years. Svetlana, a graduate Science teacher in her second year of teaching, had not previously taught Mathematics. All participants, except Svetlana, had taught Year 9 previously, representing a purposeful rather than a random sample. The goals of this study were to investigate if diagnostic testing provokes changes for Year 9 Mathematics teachers. Although the sample is small, the data collected will be able to give some in-depth qualitative indications of (Hesse-Biber & Leavy, 2011; Patton, 2002) the usefulness of the SMART system, and the ways in which teachers could make use of it.

3.4 Data Analysis

3.4.1 Pre-topic interviews

Creswell and Plano Clark (2011, p. 345) state that, “qualitative data analysis involves coding the data, dividing the data into small units (phrases sentences, or paragraphs), assigning a label to each unit, and then grouping the codes into themes”. The researcher transcribed all interviews verbatim enabling the researcher to later read through each full interview and code units with RQ1, RQ 2, or RQ 3. These codes were then placed together in tables and further grouped into themes of relating to the research questions. Summaries of each interview were placed into individual participant data tables for ease of comparison (see Appendices 2-7). This enabled the researcher to build a picture of how teachers gain knowledge of student understanding, their perception of their own teaching practice and how teachers met student needs. Consequently developing a baseline for the post-topic questionnaires and interviews.
3.4.2 Post-topic questionnaires

The responses for each questionnaire were analysed in two ways. Firstly, the responses were examined to formulate the questions for the post-topic interviews. This was achieved by comparing the responses to the post-topic interview question template (Appendix 1) from which interview questions were then selected. Secondly, the transcripts from all of the participants were coded and collated into themes the same way the pre-topic interviews were sorted. The aim of the project was to determine the change over the entire project rather than the change between topics. This is because change between topics may be attributed to vastly different reasons such as, one test may be deemed more appropriate than the other test. The data was then examined further, to look at overall attitudes towards the various aspects of the research questions. There are some limitations in analysing the data in this manner, for each group of 12 responses (two from each participant) it is impossible to determine how many teachers have chosen a particular response. For example, 4 Agree responses for one questionnaire statement could be from 2 teachers (twice) or from 4 teachers (once). However, the project was investigating if an overall change occurred rather than a change for individual participants. Analysing data for each research question in a single table permitted the researcher to look for overall attitudes towards the SMART system.

3.4.3 Post-topic and final interviews

The post-topic and final interviews were transcribed verbatim, and then a summary for each question was placed into a table for ease of comparison between participants. Each post-topic interview was then compared to responses on the questionnaire. This was to gain a deeper understanding of the teacher’s views. Creswell and Plano Clark (2011) explained that data from the qualitative interviews could be compared to data gained from the quantitative questionnaire. Quotes used as evidence have been selected on the basis of relevance to the research question and to show the range of views for participants.

3.5 Rigor

A component of all good research is the use of procedures that ensure the validity of data, results, interpretation and data analysis to ensure accuracy (Creswell & Plano
Clark, 2011). There are many strategies to determine accuracy for qualitative interviews.

1. Checking of transcripts by the participants for accuracy of what was said or what was meant (Dowling & Brown, 2010). All participants read their transcripts to verify the transcript was a correct record of the interview.

2. Many statements in the questionnaire were paired to allow confirmation of responses. Statements were paired by stating the same idea, but in a slightly different way. For example, statements #2 and #17 were paired because statement #2 (I gave different groups of students different activities because of the diagnosis), and statement #17 (I gave different groups of students different tasks because of the diagnosis) address the same idea.

3. Interviews transcribed verbatim enabled the researcher to examine exactly what was said and what may have been left out (Rabionet 2011). All pre-topic and post-topic interviews were transcribed verbatim.

4. All pre-topic and post-topic interview questions, and Likert statements were closely examined to confirm they gathered information for one idea, to ensure the credibility of the research. Data that is well documented allows others to follow the decisions, analysis and the interpretations make conclusions more credible (Dowling & Brown, 2010).

5. Consultation with the other researchers provided feedback and validity to the research. Researchers checked and discussed all aspects of the project with the researcher. This ensured validity of the project as discrepancies could be uncovered and then addressed. Creswell and Plano Clark (2010) state that feedback is important to uncover discrepancies and, hence, improve analysis.

Creswell and Plano Clark (2011, p. 45) state, “Quantitative validity means that the scores received from participants are meaningful indicators of the construct being measured”. The strategies that were used to ensure quantitative validity were
1. Likert statements assessed by researchers and the Mathematics co-ordinator at the participant school in order to verify they were clear, only contained one idea and were understandable.

2. The researchers closely examined the Likert statements to ensure they were designed to measure the intended research questions. This was accomplished by an audit of all statements to ensure they matched the research questions.
Chapter 4 Research Question 1: Changes in teacher knowledge

The focus of this chapter is to investigate Research Question 1: Does the teachers’ knowledge about student learning change when their students use the SMART system? Specifically, do teachers gain more knowledge of individual students’ misconceptions and developmental stages? Are teachers increasing their own knowledge about developmental stages? Are teachers learning new methods to address misconceptions?

4.1 Pre-topic Interviews

The pre-topic interview questions were designed to investigate the methods that individual teachers employed to gather information about student knowledge. Teachers reported the use of many different methods, which they felt revealed the student’s prior knowledge. On closer examination, the various methods can be viewed as two main methods: asking students questions, and drawing upon previous teaching experience where teachers assumed that past students’ difficulties would be the same as those of current students.

Teachers employed information-gathering methods in a variety of ways. Five teachers said they asked students questions to uncover prior knowledge. The style of questioning varied among teachers and included brainstorming, observing the questions students asked throughout the particular unit, and asking individual students questions. Rachael stated she had used the SMART system to provide a pre-test to gain knowledge about student misunderstanding with Year 7 the previous year, but she had not used the SMART system at Year 9. The term ‘general student knowledge’ has been used to designate teachers gaining information about student knowledge without the use of diagnostic testing. Three participants stated they used previous teaching experience of Linear Equations (topic 1) as their main way to determine general student knowledge. This meant they assumed that the difficulties that their past students had experienced with this topic, would be exactly the same as the difficulties current students would experience. In other words, teachers used previous teaching experience as a source of knowledge to inform them about general student knowledge. Teachers did not use diagnostic testing in any form to systematically gather specific evidence of individual student learning needs. Instead they uncovered
student difficulties when students asked questions about a specific task. This may result in teachers not having accurate knowledge about the developmental stage of individual students, which in turn decreases the ability of the teacher to address these misconceptions. However, the participants did not acknowledge this during the pre-topic interviews.

It was anticipated that, during the pre-topic 2 interviews, the teachers might have indicated they would use diagnostic testing for the Linear Graphs topic (topic 2). However, the results demonstrated that the teachers tended to rely heavily on previous teaching experiences as an indicator of student knowledge, rather than questioning and brainstorming. None of the teachers stated that they generally undertook diagnostic testing for linear graphs. Only one teacher reported that they would ask students questions to determine the level of prior knowledge. None of these methods represent diagnostic testing and was primarily information gathering. These methods do not allow the teacher to gain knowledge about specific misconceptions of individual students. This means in terms of uncovering student knowledge, teachers lack a deep insight into misunderstandings or the developmental stage of students.

Pre-topic interviews uncovered that teachers relied heavily on their own predictions from previous teaching experience about student knowledge especially for topic 2, which was conceptually more difficult than topic 1. It was clear that five teachers, for topic 2, felt they had a great amount of knowledge of students from past teaching experience and this knowledge was used to predict misunderstandings of current students. The majority of teachers did not employ any method to uncover prior student knowledge or misconceptions, except for Rachael who had used the SMART system with Year 7s. All teachers stated that they did not initially intend to use any formal diagnostic test apart from the SMART system that the researcher requested they complete.

4.2 Questionnaire

The teachers completed a Likert scale questionnaire after the completion of each topic. The results from both questionnaires were compiled into one table for ease of analysis (Appendices 2 to 7 for individual results) as the research questions focus on change that occurs in general rather than for each teacher. This means that the total for
each statement does not indicate the number of teachers that chose this response. Table 4.1 shows the responses for statements linked to Research Question 1.

Table 4.1 Questionnaire responses to statements addressing Research Question 1

<table>
<thead>
<tr>
<th>Likert questionnaire statement</th>
<th>Topic 1 and 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The diagnosis uncovered student misunderstandings</td>
<td>SA</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3. The SMART test diagnosis matched my own expectation of student knowledge</td>
<td>1</td>
</tr>
<tr>
<td>5. The diagnosis caused me to investigate student misunderstanding further</td>
<td>2</td>
</tr>
<tr>
<td>11. I learnt about student misunderstanding through the diagnosis</td>
<td>7</td>
</tr>
<tr>
<td>13. I discovered misunderstandings that I previously had not thought about</td>
<td>7</td>
</tr>
<tr>
<td>15. The diagnosis showed me misunderstandings that I did not know students could have</td>
<td>5</td>
</tr>
<tr>
<td>18. I researched student misunderstandings because of the SMART test diagnosis</td>
<td>1</td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree, BL = blank, no response

The questionnaire provided some interesting data. First, most responses (eleven out of twelve) agreed that the SMART system uncovered student misunderstandings (Likert statement #1). Just over half of the responses indicating that the SMART system matched the teacher’s expectation of student knowledge (#3), suggesting no change in teacher’s knowledge of student learning. Surprisingly, a reasonably high number (42%) said that the diagnosis did not match their expectations or were neutral. Reasons for this will be discussed in the following section (4.3). Second, seven out of twelve responses indicated that teachers learnt about student misunderstanding (#11). The results for paired statements #13 and #15 indicated seven out of twelve responses discovered misunderstandings they had not thought about (#13) and five out of twelve responses discovered misunderstandings that they did not know students could have (#15). These statements sought to investigate if participants had learnt about misconceptions they were unaware students may experience. There were a few responses to statements #11, #13, and #15 that disagreed or were neutral. This result will be further discussed in 4.3. Six out of twelve of the participant responses agreed that the SMART system diagnosis led them to investigate student misunderstandings (#5). Yet the paired statement (#18) that the teachers researched student misunderstandings due to the diagnosis only one response indicated agreement. This
may be due to teachers’ interpretation of the statements. These responses will be discussed in the following section.

4.3 Post-topic Interviews

Uncovering student misunderstandings

Teachers reported that when the SMART system was used, they learnt not only about individual students’ prior knowledge but also the students’ developmental stages. During the post-topic interviews the teachers compiled a list of misunderstood concepts that the diagnosis uncovered for their students. Through this, the teachers reported they were able to quickly build knowledge, based on evidence of concepts that students did not understand or had not consolidated. “It [the diagnosis] clarified and articulated the data well,” reported Troy. Not only did the diagnosis uncover a range of student misunderstandings for teachers, such as “they can’t do negatives” (Svetlana) and “pronomerals are an issue” (Troy), but also gave teachers specific information about the mathematical development stage of each student. Troy went on to say, “I thought the effort [of teaching] would have to go into gradients and intercepts [when] in actual fact I needed to spend more time on things like what is a data point, x goes before y; the very basics”.

Data from the post-topic interviews supported and explained the questionnaire data. The distribution of responses to statement #1 (Table 4.1) shows the majority of participants agreed that the diagnosis helped teachers to find misunderstandings. Chen disagreed with this statement; further probing revealed that Chen’s class had found the SMART test for linear graphs too challenging. However, this SMART test was testing students on previous knowledge. Chen’s comment was “they were all at sea, even the smart kids couldn’t access it”. “It [the diagnosis] didn’t help me at all because it [the SMART test] was too hard, so I had to start the topic at the beginning”. Chen found the students did not understand even the basic linear graphs concepts to be able to complete the online test. In this case, Chen gained more useful information on the class as a whole, rather than on individual students, although he did not perceive it this way. He then used this information to make decisions on topic approach, which is evident when he stated that he had to begin the topic from an earlier developmental stage than expected. Although Chen felt the SMART system did not identify individual student’s misunderstandings, it did show that the class as a
whole had problems. The purpose of the SMART system is to show the level of misunderstandings and the diagnosis did increase Chen’s knowledge about student understanding. Rather than assuming the students had consolidated Year 7 and 8 linear graph concepts he found in fact they had very little knowledge of linear graphs. Chen stated that after he had administered the SMART test for linear graphs he discovered that the students “had little experience of linear graphs”. This was a good outcome for Chen because he learnt that his class had a gap in their knowledge that could be addressed. Before using the SMART system Chen assumed that his class had the prior knowledge of linear graphs that would have been covered in Year 7. After using the SMART test he learnt that his students did not have this prior understanding, but did not recognise this overtly, Chen stated, “it [SMART test] was not a worthwhile exercise”. However he did act upon this new knowledge by changing the starting point for teaching this topic. This caused Chen to change the way in which he taught the topic, to be further discussed in the next chapter.

**Teachers’ expectations of student knowledge**

The teachers explained that the diagnosis gave them better knowledge of where to begin the topic with their class, such as whether or not they had to revisit concepts from previous year levels. In their interviews the teachers explained that the diagnosis gave them better knowledge of their students’ knowledge, in particular the misunderstood concepts such as order of operations. Some teachers felt the diagnosis did not match their expectations of student knowledge because it brought to light gaps or misconceptions where the teacher had assumed prior knowledge. Two participants reported that they assumed their students understood basic concepts of algebra that had been taught during the previous two years (Year 7 and 8). The diagnosis showed that the students in fact, did not understand or had not consolidated basic algebraic concepts. “I was completely surprised, they [the class] did not understand pronumerals,” said Rachael, “I was actually shocked when I saw that [diagnosis]”. Rachael found that many students in her class did not understand the meaning and use of pronumerals. Her students did not recognise that pronumerals could be used to represent the variable in an equation. On reading the diagnosis she spoke to the class and very quickly ascertained that this was indeed true. She then addressed this issue before continuing to teach more advanced algebraic concepts; this is explained further in the next chapter.
Similarly Svetlana found that she had much higher expectations of student prior knowledge and was very surprised with the diagnosis as it showed many areas of weakness, particularly basic algebraic knowledge. “It [the diagnosis] helped me understand that I had to start from the basics”, stated Svetlana. The diagnosis revealed her overestimation of student knowledge, showing that her own knowledge of student knowledge was incorrect. Svetlana said, “The diagnosis showed that a lot of them [students] struggled with many concepts whereas I thought some of them would grasp it [concepts] a lot easier based on the previous topic”. Svetlana had to revise basic algebraic concepts before moving on to the more complex Year 9 concepts. She surmised that her high expectations possibly came from not teaching linear equations previously (see appendix 3 for more detail), so had an inflated view of student prior knowledge. The effect of the diagnosis for teachers, in particular for Svetlana, was two-fold: first, some teachers discovered their own knowledge of student levels of understanding was incorrect and, second, the gain in knowledge had an effect on teaching practice, which had to change to support information obtained from the diagnosis. This will be discussed in the next chapter.

Responses for questionnaire statement 3 showed three neutral responses and two that disagreed with the statement that the diagnosis matched their expectations. The post-topic interviews revealed that these responses were either due to high expectations that teachers had of student knowledge (Svetlana) or teachers discovered misunderstandings they did not expect (Rachael). Chen, as discussed previously, found the linear graph SMART test was too difficult for his students and it also did not match his expectation of student knowledge.

**Teachers’ knowledge of individual students**

Some teachers felt that the SMART system confirmed what they knew or felt about individual student knowledge. This supports the responses in the questionnaire (statement 3). Over half the responses indicated that the diagnosis matched what the teacher thought about the knowledge of their class. Rachael had contradictory feelings about the diagnosis. On one hand she said, “it [the diagnosis] wasn’t an eye opener” and that she felt that she already knew which students were having difficulties and those students who had a higher ability (see Appendix 2 for more detail). So in this light Rachael stated, “it just confirmed what I already knew”, indicating no change in
knowledge in terms of which students required extending and those that had many misconceptions. However, Rachael also stated that it was nice to have confirmation about what she felt about her students’ knowledge as the diagnosis gave her evidence of student knowledge. The responses from four of the other teachers indicated similar sentiments.

The teachers said that they improved their own knowledge about student knowledge from the SMART system. Chen found the teaching advice and links from the SMART system more useful than the diagnosis because the website included explanations about the misunderstandings and developmental stages of mathematical concepts, and offered some links to *Mathematics Developmental Continuum P-10* (href 2). Chen stated that the SMART system, “gave me concepts [misconceptions and developmental stages] to think about”. He went on to explain he used the SMART system to learn about misconceptions that students may have and the reasons why these misunderstandings occur.

Teachers used the website not only to gain further insight into common misunderstandings, but to enhance some of their own worked examples to their class. Worked examples, modelled on the SMART test questions, were now included as class questions. These questions were used by some teachers, specifically Bernard and Chen, as worked examples on the board for the class. Bernard and Jenny found the application style questions useful as another way of demonstrating concepts. “I found the questions [from SMART test] interesting and the way some of the questions were presented to students” commented Jenny.

**Teacher learning**

Statements #11 (teachers learnt about misunderstandings) and #15 (diagnosis show misunderstandings teachers did not know students could have) indicated that while most teachers learnt about student misunderstandings there were a few responses that either disagreed or were neutral. Troy felt the diagnosis did not help him learn about student misunderstandings. He said, “I have been teaching Year 9 long enough to be aware of specific misunderstandings surrounding this topic”. He further commented, “it doesn’t tell me anything I didn’t already know but it certainly clarifies what I suspected and enables me to focus on this as the biggest area [of difficulty].” This
comment demonstrates a positive aspect, even though Troy’s view was the diagnosis was not that helpful. The diagnosis clarified and led him to focus on the areas of student misunderstanding. Thus empowering Troy to be better at addressing these issues than if he did not have specific information of student misunderstandings. These teachers felt they already knew their lower and higher achieving students, so the diagnosis confirmed what they already knew about their individual students, rather than learning new aspects of students. The diagnosis was a confirmation rather than a change in knowledge. Rachael commented, “It reaffirms what you see or know what students have problems with”. Troy found that the diagnosis did not directly help him to uncover student misunderstandings that were not topic specific, as he reported many of the student difficulties were concepts to do with number strand that had been taught in previous year levels, (particularly in primary school), although it did help him to begin to uncover individual student problems.

Some teachers found the SMART system challenged their belief about student learning. The researcher noticed a change in the language Troy and Bernard used in the post topic interviews. This was particularly evident in the language that Troy used as his language changed from stating, “they can’t get this” to “I don’t know how to address this issue as students have many gaps in their knowledge. It’s difficult to address them all, that’s why they can’t understand the topic”. These comments demonstrating that he no longer viewed students who were at an earlier developmental stage as weak students, but began to recognise that the developmental stages of students were impacting on their learning. Bernard also changed his language during the post-topic 2 interview and the follow up interview. He echoed Troy by stating, “the diagnosis showed they can’t get this” and changed to “many [students] had basic misunderstandings … this was why I think we got bogged down [during topic 2]”. Troy and Bernard understood that this meant students experienced difficulties, making it harder for them to move forward until this issue was resolved. This change of view was not part of the research, but something that became evident. It would be of interest to further study the impact the SMART system has on the views of teachers towards students’ mathematical ability.
4.4 Follow up interview

Three months later the teachers were interviewed to gauge their thoughts about the SMART system. All participants stated they gained insight into student misunderstandings and developmental stages. It gave them a good starting point for the topic and they did not have to waste time in class to find out which students had not grasped the topic or had misunderstandings from previous years. They could enter the classroom armed with knowledge about their students.

The teachers stated it was important to administer the SMART test at the beginning of a topic, to gain useful information about individual student knowledge. Teachers also stated that they needed to examine the particular SMART test before administering it to the class to ensure that it was the right diagnostic test for the class. The SMART tests diagnoses knowledge students are expected to have attained prior to Year 9. Two participants said that if students have little or no experience with the topic (topic had not been taught at previous year level) then the SMART test should be conducted slightly later in the topic but still during the first half of the topic to enable misunderstandings to be addressed before summative assessment. These were interesting comments because if diagnostic testing was not done early teachers then teachers would not know the current learning needs of their students. For example, to understand linear graphs students must understand Cartesian planes and basic linear equations. Without diagnostic testing teachers may not address any student misunderstandings for these concepts. This may lead to decreased ability of students to grasp the fundamentals of linear graphs. This, in turn, may have a negative impact on student learning in the early stages of a new topic.

4.5 Conclusion

Research Question 1 sought to determine if teachers gained more knowledge about the amount of understanding that individual students have about particular mathematical concepts, whether teachers are increasing their own knowledge about learning stages, and what misconceptions students may have about particular concepts. At the very beginning of this project none of the teachers used any formal diagnostic testing to uncover student misunderstandings for Year 9 students.
The questionnaires and interviews brought out some noteworthy information. The SMART diagnosis uncovered student misunderstandings that the teachers did not expect. This was a good outcome, since teachers were unaware that students were struggling to understand certain concepts. Rather than continue with teaching the topic, they could pause to address the issue either with the whole class or with small groups of students. Teachers found that by using the SMART system they could intervene and address student misunderstandings. Troy stated, “the report basically put their misunderstandings under headings and that made it easier”. Hattie (2009) states that if teachers have specific information on student misunderstandings teaching could be changed to address the issue. On the whole, some teachers found their knowledge had increased about student misconceptions and student mathematical development stages although it was not always recognised immediately. Jenny stated that the SMART system “identified which areas they [students] struggled”. This supports the proposal by Stacey et al. (2009) that the SMART system can be used as formative assessment. Through formative assessment teachers can gain evidence about student knowledge (Wiliam, 2009) and use this to inform subsequent lessons. Rachael stated that “it was nice to have confirmation of what I thought,” showing no change in teacher knowledge. She confirmed that some students were operating at higher levels however, Rachael had not thought about individual student learning needs. For some teachers the information from the diagnosis was surprising and they found that they had to begin the topic with concepts from the previous year level. Teachers, who found that the diagnosis did not match their expectations tended to either have higher expectations of students’ knowledge or discovered that students had forgotten previous concepts. Participants realised that they could not assume students had consolidated or remembered concepts from previous years. This supports McMillan’s (2009) suggestion that through formative assessment teachers were more able to understand the learning that students had achieved. Teachers found that by using the SMART system they could more easily observe students’ prior learning.

A few teachers found the diagnosis matched expectations and they now had data to use as evidence of student knowledge, in order to set appropriate tasks to enhance student learning. Teachers frequently used their general knowledge of students, built over time, to determine overall student understanding. For some to confirm that students were operating at a more advanced level was confidence boosting. One
participant found the particular the SMART tests were too difficult for his class. However, though not enamoured by the process, he did learn that his students had not experienced the content of topic 2, causing him to begin the linear graphs at an earlier level. This was a positive outcome as it prevented him from starting at a point where the students would not be able to grasp more complex concepts due to their little experience with the basics of the topic. He went on to use the SMART system to learn about misconceptions and mathematical development stages.

Troy and Bernard found the SMART system challenged their view on students and student learning. They found that students they had previously thought of as “non-maths” students could in fact do maths; it was just that they were missing some key elements or knowledge, which disrupted further learning. “Many students have not consolidated basic numeracy like order of operations,” stated Troy whereas early in the project he spoke about “weaker students” and how “they just don’t get maths” or “they’re not maths students”. It was clear that teachers uncovered gaps in student knowledge. Some, for example Rachel, found specific activities for students to do to address their misconceptions or gaps in knowledge. This view of student achievement is very important as these students can be provided with activities that address the gaps in their knowledge. The aim of formative assessment is to improve student learning through accurate knowledge of student misunderstandings (Shute, 2008). Students can then experience success in mathematics, building their confidence and encouraging them to tackle more challenging tasks.
Chapter 5 Research Question 2: Changes in teaching practice

Research Question 2 investigates the changes in teaching practice that occur when a teacher uses the SMART system. For this research question student management issues are excluded, as the focus of this study is on the changes in mathematical teaching practice.

5.1 Pre-topic interviews

The interview before topic 1 (linear equations) uncovered the variety of methods teachers employed to aid students’ understanding. These common teaching practices included: one-on-one help; worked examples; breaking problems into simple steps including annotations on worked examples associated with the process of each step. For example Bernard stated “I’ll sit with them on a separate basis… I’ll go through the more basic parts”. In contrast, Jenny stated “… repeating these steps every time we go over a different example [on the board]”. There was some variation in teaching practice among different teachers. Chen indicated that he did not like to rush through concepts and preferred students to have good work habits such as correct setting out format. Jenny stated that she gave students a wide range of questions to practice. Troy indicated that he was not sure how to address student difficulties and that he intended to ask other teachers how they approach difficulties to enable him to develop his own teaching practice. Recording each participant’s class through the use of video would have improved the amount and quality of the information for teaching practice.

It was also interesting to note if teachers intended to make any changes to the general teaching outline in response to experiences from the previous year teaching the topics; in particular, changes to their own teaching practice. For example, if another teacher had developed an activity, which students could complete to increase understanding of a concept, then this activity may be included in the year level teaching plan. Three participants reported no intention to change any part of their planned teaching practice. This means that any changes in teaching practice that did occur were presumably due to the use of the SMART system (discussed in section 5.3). Rachael intended to extend and engage upper end students, while consolidating the lower end students, indicating an intention to differentiate to some extent. Jenny intended to revise simplifying equations with her class before she began linear equations because
she had noted in the previous year that some students had forgotten this concept. She hoped by revising simplification that students would not experience difficulties with this aspect of linear equations. Chen expressed that he would strive to be more explicit, teaching basic skills, focusing on terminology, and using some concrete materials for the lower end students. He felt that in the previous year it had aided student understanding when he had done this for other topics and was hoping that this might also help his current students. Troy, although he said he would have no specific change to his teaching plan, indicated he would like to keep better track of the students, so he knew the knowledge students had gained.

When participants were asked, for topic 2 (linear graphs), how they intended to address common misunderstandings, most teachers expressed the same view as for topic 1. At the time of the interview, the researcher did not ask participants to distinguish between changes due to using the SMART system for topic 1 and changes made for other reasons. It would have been useful to include these questions in the interview to make this distinction. It was anticipated that the participants would highlight the reasons why they made these changes. There were some interesting results. Troy intended to highlight steps to make it easier for students to follow because he has used this method previously for linear graphs. Bernard intended to use ICT to help with understanding of linear graphs. In contrast, Chen did not intend to use ICT whereas he did in topic 1. Bernard intended to continue to use a step-by-step logical order he had been using for other topics. None of the participants stated the use of the SMART test for topic 1 had influenced their decision to alter teaching practice.

There were some intended changes to the teaching plan for linear equations (topic 1). Most of this stemmed from the move to the Australian Curriculum. Jenny and Bernard stated the concept of sketching a line with the y-intercept and gradient had been removed and not taught until Year 10. The rest of the curriculum remained unchanged. This was the most significant change, although some teachers planned other minor changes to their teaching practice. For example, Troy intended to create some podcasts and vodcasts for students to access outside of class because he thought students would find the topic difficult. He hoped that they would use these extensively to help with homework tasks. Rachael was going to approach the concept of finding
intercepts differently, though she was not sure how to achieve this at the time of the pre-topic 2 interview. Chen intended to use an activity he saw at the Mathematics Association of Victoria conference the previous year. This was a planned change from the previous year and was not linked to the SMART system. Svetlana stated no changes because she had not taught the topic before.

Comparison of intended teaching practice between topic 1 and topic 2 brought to light minor changes in teaching practice between the two topics, such as removal of one concept and using a slightly different approach. However, none of the participants suggested during the interviews that the minor changes were due to the SMART system.

5.2 Questionnaire

The participants completed a Likert scale questionnaire after the completion of each topic. The results from both questionnaires were compiled into one table to examine responses over the entire project (see appendix 2 to 7 for individual results). Table 5.1 shows the responses associated with Research Question 2.

<table>
<thead>
<tr>
<th>Likert questionnaire statement</th>
<th>Topic 1 and 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. The diagnosis led me to change the way I taught some of the specific topic</td>
<td>SA 7, A 2, N 3</td>
</tr>
<tr>
<td>6. The diagnosis led me to revise some topic specific concepts with my students</td>
<td>SA 7, A 4, N 1</td>
</tr>
<tr>
<td>7. Compared to last year it was easier to address difficulties because of the diagnosis</td>
<td>SA 1, A 1, N 3, D 7</td>
</tr>
<tr>
<td>16. The diagnosis led me to revise some concepts, other than current topic, with my students</td>
<td>SA 2, A 6, N 3, D 1</td>
</tr>
<tr>
<td>19. The diagnosis helped you to improve the way you teach the topic</td>
<td>SA 6, A 5, N 1</td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree

Two thirds of the responses indicated that the diagnosis from the SMART system changed the way they taught topics (Likert statement #4). Just over half the participant responses agreed that the diagnosis prompted them to revise certain concepts for both topics with their students (#6). One third of the responses found that the diagnosis aided them to revise mathematical concepts that were not directly part of the topic (#16). Statement #19 posed the idea that the participant’s teaching had
improved due to the diagnosis, with half the participant responses agreeing with this statement.

5.3 Post-topic Interviews

Understanding prior knowledge

The participants indicated that the diagnosis made it easier to focus on student difficulties, rather than continue to teach the curriculum whilst assuming that most students comprehended the concepts covered. Rachael changed her teaching practice because of the diagnosis. The previous chapter discussed how Rachael found that the diagnosis did not match her expectations of student knowledge as the diagnosis indicated that the students did not have an understanding of pronumerals. Rachael then modified her teaching plan to address this issue before moving back to her original plan. This demonstrates that by understanding the students’ prior knowledge, Rachael could address the forgotten concept of pronumerals before it became an issue for many students in her class. “It [the diagnosis] just highlighted areas that I particularly needed to go over again just to re-establish their understanding and to make sure they [students] did really understand,” reported Rachael. The class could then move forward and learn new concepts. The diagnosis caused her to look for an activity she could do with her class to revise the concept of pronumerals. Rachael said that the activity took little of her class time. Yet it was good that she did it, because then she knew the students had consolidated earlier concepts before she began to build on them. If Rachael had not uncovered this lack of knowledge and addressed it many students may not have completely understood the more advanced algebraic concepts, possibly leading to further misconceptions.

Svetlana found in topic 1 that many of her students had difficulties with directed numbers, which was brought to her attention by her students completing the first SMART test. Svetlana stated during the topic 1 post-topic interview that “I focused on these [directed numbers]” because of the diagnosis she received. Svetlana discovered that many of her students did not have or could not remember the basic concepts of linear equations. This meant that she had to start with concepts from an earlier developmental stage. This aided Svetlana in the development of her teaching practice. “I loved the SMART tests, they were very useful for me,” Svetlana stated anecdotally, stated after the interview had concluded. Although, she could not assume that her
class had consolidated concepts or reached assumed developmental stages. Through using the SMART system Svetlana could develop a more effective teaching practice. The questionnaire data for statement #6 where the majority of participant responses agreed that the diagnosis led them to revise topic specific concepts is supported by these post-topic interview responses. Jenny said that the diagnosis made it quicker for her to see which of her students struggled with concepts such as order of operations. In particular she found that she had to focus on fractions and directed numbers for both topics. This supports the data from the questionnaire for statement #4 where the majority of participant responses agree that the diagnosis allowed teachers to change the way they taught aspects of the particular topics. Through the use of the SMART system the participants found they could identify then revise or address any misunderstandings their class may have been experiencing. For example, Jenny found the diagnosis changed her teaching practices with topic 2. The diagnosis revealed that her students struggled to interpret graphs, and so she found additional simple graphs to use with her class. Jenny said she spent one lesson looking at different graphs, asking students questions about each graph to help improve their understanding of graphical information. Jenny said that she had not really done this before to the same extent. She found that it was very useful as students increased their understanding of graphs, not only in terms of understanding the information but also why linear graphs were useful.

**Information of the class as a whole rather than of the individual**

There was one strongly disagree response for statements #6 and #16. Examining the data of individual participant responses revealed that these responses were from Chen. During Chen’s post-topic interview he stated that the online SMART test for linear graphs was too difficult for his students: “It was a level above most of the kids so they were all at sea in terms of an introduction to linear graphs”. Subsequently, Chen decided the information from the diagnosis was not useful in terms of gaining specific information about student knowledge. “It [the SMART test] was so poorly done [by students] it wasn’t a worthwhile exercise. There were so many gaps it was hard to pinpoint a focus area,” Chen stated. Nevertheless because of this information from the diagnosis Chen began the topic at an earlier developmental stage than he originally planned. Chen went on to say, “I taught it a little bit differently than I have in the past,” and “took it right back to, perhaps, the Year 7 or 8 level to an introductory level
and went from there”. Chen says that the diagnosis was not helpful but he did change his teaching practice, demonstrating a change because of information received from the diagnosis. Without this information Chen may not have changed his teaching plan and many students may have experienced difficulty because their understanding was at an earlier developmental stage. However, Chen did state that he used the SMART system to gain ideas of misconceptions and made sure he explicitly taught those concepts to ensure students’ understanding, thus indicating a change in his teaching practice.

Observations of class completing SMART test

The SMART test diagnoses misconceptions within a particular topic. For example the Writing and Solving Linear Equations SMART test examines a number of misconceptions related to linear equations, one such misconception is giving a pronumeral an arbitrary value. Some teachers reported that observing their students completing a SMART test also gave teachers information about student knowledge. For example, Svetlana said her students were, “doing a lot of guessing work with their multiple choice questions on that side and just filling in random numbers, especially with negative numbers”. She went on to state that the SMART linear equations test did not specifically test for knowledge of negative numbers. Through observing the way in which her students completed the SMART test she discovered that a few students had misunderstandings about negative numbers. Svetlana then acted upon this information by revising the number line, indicating a change in teaching practice. This was the main reason given for her neutral responses for statement 6 (Table 5.1) during the post-topic interviews.

Teaching practice

The participants felt that by gaining knowledge of student misunderstanding through the diagnosis they could address individual or groups of students’ difficulties. Jenny found that she emphasized the steps in solving linear equations to a greater extent than she had before, though she thought that some of the change might also be due to previous teaching experience, knowing where students tend to struggle. “I taught them [students at an earlier developmental stage] in a different way, the same sort of concepts but in a different format that had more visual references,” said Jenny. Svetlana commented during the post-topic interview about a group of students within
her class: “It [the diagnosis] just showed me that I had to go back to ground work with them and build up from the very beginning rather than assume they [students] had prior knowledge, so I had to go back to ground work again,” demonstrating a change in teaching practice.

Half the responses on the questionnaire for statement #19 (that the diagnosis helped the teacher to improve their teaching practice) agreed that the diagnosis helped the teachers to improve their teaching practice. Troy commented, “I was able to focus more on those areas [misconceptions]”. The questionnaire shows that 5/12 responses were neutral to this statement. Two teachers stated they were unwilling to say whether their teaching practice had improved or not. For example, Bernard preferred a third party to observe his class or survey groups of students so he could have data to support improvement of his teaching practice. One participant said that any improvement might not have necessarily been because of the information they received from the SMART system. It may have been due to other information teachers received such as student observation or previous teaching experience. However, it is clear that some changes were made due to the information teachers received from using the SMART system. The increased teacher knowledge meant that teachers were able to alter some teaching practices to allow them to address student knowledge.

For Bernard, this gain in knowledge about his students’ knowledge came too late to address any student misunderstanding for topic 2, as he chose to use the SMART test for topic 2 at the end of the topic whereas other teachers completed the test at the beginning of the topic. Instead he used it as preparation for end of topic test. This made it difficult for him to address any misunderstandings before the final assessment. His students completed both the linear graphs test and redid the linear equations test. He found that his students were still operating at backtracking level and had not moved on to inverse operations. Bernard realised that this is why his teaching became “bogged down” during topic 2. Students were moving very slowly through the concepts and found concepts extremely difficult to understand. Bernard said that if he used the SMART system earlier he would have addressed this issue and then altered his teaching practice so students may have found topic 2 easier to comprehend.
During topic 1, Rachael said she gave struggling students more visual references for linear graphs, to aid in their understanding of concepts as the diagnosis indicated that these students required extra help. Chen, Svetlana, Rachael, Troy and Bernard said they gave the struggling students visual references or concrete materials to help make connections between particular concepts. They indicated that although they had used visual references before, they were now focusing on addressing misconceptions and found concrete examples to help explain concepts.

The data from the post-topic interviews for topics 1 and 2 found that five participants stated that the diagnosis from the SMART system enabled them to focus on particular misunderstandings with groups of students, or with individual students. As discussed previously, before using the SMART system some teachers found they were entering classes with inflated expectations of student prior knowledge. The teachers were able to address misunderstandings either as a class or with small groups because the diagnosis uncovered student difficulties. Previously teachers spoke to individual students about a particular difficulty with a specific question, rather than addressing any misconceptions. The diagnosis enabled the participants to become aware of issues, before the students started working on specific problems and teachers spent more time addressing specific misunderstandings. Chen commented, “once I saw how much at sea they [students] were with it, we did a little bit of collecting like terms and basic algebra operations”.

5.4 Follow up interview

Follow up interviews were conducted approximately three months after the conclusion of topic 2. This interview gave the participants an opportunity to reflect on their use of the SMART system and the subsequent effect it may have had on their teaching practice. The participants indicated that by using the SMART system they needed to ensure they reviewed earlier developmental stages before moving on to more advanced concepts. For example Rachael had to revise the concept of pronumerals before she began the linear equations topic. Troy, Svetlana, and Rachael also reported that they became more focused on ensuring that individual students had gained the required knowledge for the topic or that students had learnt concepts from earlier developmental stages. Bernard stated that he was much better prepared for class and could teach groups of students the concepts they needed to know to progress.
their knowledge and continue learning. The participants reported they had become better prepared for class because they used the SMART system; they walked into class fully prepared with knowledge of concepts students misunderstood. Troy reported, “I could come up with examples or find examples that targeted where I knew their [the students’] issues were”. Bernard stated that stated that struggling students no longer had time to misbehave as he could provide an appropriate activity. Although teachers found many benefits in using the SMART system they did not use it for subsequent topics. Jenny stated, “[It’s] the time factor, we’re running out of time to fit in the curriculum before the major exam”. However, Troy said, “I haven’t got into the habit”. Both these teachers indicated they were keen to use the SMART system due to improvements in teaching it provided, but there were other perceived issues they had to overcome.

5.5 Conclusion

Initially, teachers used two main methods to overcome student misunderstandings: either teachers helping one student or demonstrating worked examples for the entire class. A couple of participants expressed the desire to give groups of student’s different activities that would assist students in consolidating their knowledge.

Results from the questionnaires showed that participants felt the diagnosis made it easier to address difficulties than in previous years and many agreed that it improved their teaching practice. This supports the findings by Linsell et al. (2012) that teachers can use diagnostic analysis to increase their understanding of student knowledge then plan lessons accordingly. The investigations uncovered that when one of the teachers used the SMART system late in the topic, it was not then possible for him address any student misunderstandings before the summative assessment. The participants who used the SMART system early in the topic found the diagnosis enabled them to target students who had misunderstandings. Through the diagnosis teachers discovered misunderstandings common to the class and used this to help them plan revision lessons.

The specific nature of the SMART system is an example of the formative assessment that Shute (2008) describes as potentially causing a change in teaching practice. Participants stated that because they went into class prepared with detailed
information about individual students pertaining to a topic, they were much better prepared for class. They could make decisions about the appropriateness for activities for low and high achievers, based on evidence. This supports the findings of Stacey and Steinle (2012) that teachers are more prepared for class when they use the SMART system. A few participants used the SMART system website to find ideas of how to use concrete materials and visual aids to help students comprehension of concepts.

Overall, the use of the SMART system did stimulate changed teaching practice as teachers were better prepared for class, and had practices targeted at improving student knowledge. However, over a longer period of time the participants indicated that they did not tend to use the SMART system. They stated that this was due to high workloads and that they often forgot to use the SMART system even though it gave them valuable information. In order to ensure the SMART system was used by all year 9 teachers; participants embedded the SMART system into planning documents to remind them of this diagnostic tool. Teachers revised teaching plans to include links to the SMART system website and to the relevant SMART tests so students could complete relevant SMART tests prior to the beginning of each topic.
Chapter 6 Research Question 3: Addressing student needs

It is important that teachers gain understanding of their students’ knowledge, and implement teaching practices that are aligned with this information. Research Question 3 examines whether or not the use of the SMART system helps teachers to address individual students' needs.

6.1 Pre-topic Interviews

During the pre-topic interviews, all participants indicated that they intended to give their students different tasks during their teaching of topic 1. The researcher was probing the idea of how teachers could differentiate learning if a diagnostic test was not completed. Rachael, Troy, Jenny, and Bernard intended to have students, who they perceived were higher and lower achieving students, working on different tasks at certain times. Through the pre-topic interviews, the researcher was able to gain some idea of how these teachers grouped their students, although teachers did not explicitly state it. Groups were constructed using the teachers’ general knowledge of individual students; this meant that if a student experienced many difficulties in class they were assumed to be a lower achieving student or “a student that could not do maths” as Troy stated. In contrast students who experienced few difficulties were assumed to be higher achieving. Most teachers stated that they used their previous experience rather than diagnostic testing to construct these groups, and so the groups were not constructed on firm evidence of specific student misconceptions. Although grouping is one method for differentiating, the tasks undertaken may not address the specific needs of individual students. However, teachers may have also used other legitimate and evidence-based sources of information that they did not state, to form student groups. For topic 1, Chen envisioned giving lower achieving students some concrete materials to work with if they had difficulties understanding a concept but preferred the class to stay predominately as a homogeneous group. Chen reported he would only give minor extension work to certain students for topic 2. Svetlana had little experience of differentiating learning and stated that she would give “just one small group [a task to help them to understand a particular concept] if they need more assistance”. 
Four teachers at the outset intended to give different students different tasks through the use of textbook questions. The participants intended to give easier textbook questions to the lower achieving students and more complex questions to high achieving students. This method of teaching, while still a form of differentiated learning, does not address specific issues students may have nor does it allow students to progress to the next developmental stage if they have any misconceptions. These teachers had not planned to give students a diagnostic pre-test, instead they planned to use their general knowledge of the students gathered over the term. Bernard stated that, for topic 2, “Ideally [he would give students different tasks] but probably not, due to [the] time factor needed to create different tasks”. He felt different curriculum paths would need to be created to cater for three main groups of students (below, at, and above Year 9) to be able to address misconceptions. This view demonstrates that Bernard was changing the way in which he formed student groups, now he was considering specific student needs and misconceptions.

6.2 Questionnaire

Table 6.1 contains the responses for Research Question 3 for the six participants over both topics.

<table>
<thead>
<tr>
<th>Likert questionnaire statement</th>
<th>Topic 1 and 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. I gave some groups of student different activities because of the diagnosis</td>
<td>SA</td>
</tr>
<tr>
<td>8. Because of the diagnosis I could differentiate the curriculum</td>
<td>6</td>
</tr>
<tr>
<td>9. The diagnosis made it easier to discover student difficulties</td>
<td>6</td>
</tr>
<tr>
<td>17. I gave different student different tasks due to the diagnosis</td>
<td>8</td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree

The Likert statements for Research Question 3 were developed to investigate if teachers were using the information they received from the diagnosis to implement activities to help them address individual student needs. The specific activities that teachers used were not examined as to whether or not they addressed the misconceptions indicated by the diagnosis. This was outside the scope of this project, although it may be an interesting and informative extension at a later stage. Examining the data from Research Question 3, the majority of the participants agreed they could differentiate the curriculum using the diagnosis and that the diagnosis
made it easier to see where students were experiencing difficulties, (Likert statements #8, #9, and #17). It is interesting that statement #2 (giving students different activities), which was paired with statement #17 (giving students different tasks), has a different result. Statement #2 has only one third of participant responses agreeing that the diagnosis enabled them to give different students different activities, whereas three quarters agreed with statement #17 that they gave students different tasks. Almost half of the other responses from participants were neutral to statement #2 and one-quarter responses indicated a disagreement. Three responses disagreed with the suggestion that teachers gave students different activities because of the diagnosis; this will be dealt in section 6.3.

6.3 Post-topic Interviews

Addressing student needs through the use of data

The information gained through the diagnosis meant that some teachers were able to address the needs of groups of students. Svetlana, Troy, and Bernard said the students at a later developmental stage could begin the topic from the appropriate stage rather than repeat the concepts they had previously consolidated. Bernard stated that during topic 1, he spent some time with students at an early developmental stage so they could attempt more difficult questions. He said that he gave “explanations … to advanced students so they could start at more difficult tasks”. This in turn also meant that he could supply “struggling students more basic tasks to help them [overcome a difficulty, such as understanding the concept of solving for basic linear equations]”. In comparison, Rachael and Svetlana spent some time with the lower achievers giving them tasks they had designed for students at an earlier developmental stage to work through misunderstandings and consolidate concepts. Rachael stated that she gave these students “different material to work with” that she indicated she had previously used with Year 7 students. Svetlana also indicated that she gave some students slightly different questions to other students. “I’d sit down with them [students at an earlier developmental stage] one-on-one and go through a few extra questions together,” commented Svetlana. These questions focused on concepts for the earlier developmental stage and enabled basic concepts to be practised, showing differentiation of the curriculum.
Some of the responses for statements #17 were either neutral (one quarter) or disagreed (one out of twelve). On further questioning, it was discovered that some teachers claimed that they gave students different tasks based more upon their observations, than their general knowledge of students in class, and past teaching experience. However, Troy stated that “it [the diagnosis] was able to highlight these are the areas [of difficulty]”, demonstrating the possibility that the information from the diagnosis combined with the participant’s observations of students gave participants specific information that led them to assign particular activities to individual students.

Chen preferred to treat all students as a homogeneous group where all students worked on exactly the same task at the same time. His aim was for all students to reach the developmental stage appropriate for Year 9 as stated in Australian Curriculum documents, regardless of their current developmental stage. This target meant that all students had to satisfactorily complete the end of topic test (summative assessment), which was developed in accordance to the Australian Curriculum Standards. “Weaker [early developmental stage] students do easier questions but must hit a benchmark [Australian Curriculum Standards]” Chen stated. The questions Chen set were not investigated for alignment with misconceptions or developmental stage. There is a possibility that these questions may not actually address individual student misconceptions nor take into account an individual student’s developmental stage. This means that students may not be gaining the specific knowledge they require to make deep connections with the concepts they are learning. In addition, higher achieving students may be working on concepts they have previously consolidated, consequently not learning new skills to advance their knowledge to subsequent developmental stages.

**Differentiation**

From the data in the questionnaire, half the participant responses agreed with the statement that they could differentiate the curriculum because of the diagnosis (Likert statement #8), which is greater than the number that agreed with statement #2. Jenny and Troy stated that they gave students at an early developmental stage tasks that would consolidate their knowledge and address misconceptions before they moved on to subsequent concepts. Troy said he could work “one-on-one with brighter students [students experiencing little difficulties with mathematics]” because “it [the
diagnosis] highlighted areas to cover with students”. Through use of the SMART system Troy stated that he could give individual students or small groups of students specific tasks to increase student knowledge. “It [the diagnosis] told me misunderstandings of each student and what I needed to focus on with them”, said Troy. He continued by stating, “Basically because their misunderstandings were grouped through the diagnosis it made it easy for me to say this is the heading [concept] for your misunderstanding so these are the things that you and I will focus on.”

One reason for the differences in responses between statements #2, #8, and #17 was that Bernard disagreed with these statements (#2 and #8) due to completing the SMART test for topic 2 late in the topic. However, during topic 1 Bernard gave slightly different tasks to some groups of students based on evidence from the diagnosis. Bernard stated during the first post-topic interview, “Because if you [students] don’t understand the basics [early developmental stage] there’s no point doing questions that are deeper [later developmental stage]”. Participants’ responses that were neutral to Likert statement #8 were not investigated due to time constraints in the interview.

The participants found the diagnoses highlighted students who had misunderstandings and those that required more advanced tasks. Five out of the six participants generally reflected Rachael’s statement (reported in section 5.3) that it took less time to discover student misunderstanding so they could then address that particular issue with students. This supports the responses for Likert statement #9 where half of the participant responses agreed that the diagnosis made it easier to discover student difficulties. Svetlana found that she was able to plan slightly different activities for groups of students with like misconceptions or like developmental stages, due to the diagnosis. She stated that because she could “see [diagnosis of] multiple concepts at the same time” and could easily prepare appropriate tasks such as “looking at a problem and trying to formulate a linear equation”. This sentiment was reflected by Troy who stated that he could put students into groups of like developmental stages to address “underpinning misunderstanding”. He felt that he could give specific tasks, such as “directed numbers” or “understanding BODMAS” to different groups to consolidate the misunderstandings.
6.4 Follow up interview

Teachers were asked if they thought that using the SMART system had improved student learning and outcomes through teachers’ ability to discover student misconceptions. Overwhelmingly, all teachers agreed that if a teacher reads and takes on board the information from the SMART diagnosis and addresses misunderstandings, then student outcomes should improve. They all stated that they felt that using the SMART system did help student outcomes. However, because they did not all have accurate records of previous Year 9 outcomes, they did not have any evidence that outcomes were better using SMART. This evidence would be needed for future research conducted on this topic.

The diagnosis enabled teachers to alter parts of the planning to suit their class or individual students’ needs, because, as Jenny commented, “we can adjust our teaching to suit individual students”, thereby enabling students to progress in their learning. Svetlana stated that by using the diagnosis she “Could give them [students] some differentiated tasks”.

6.5 Conclusion

There are many pressures on teachers to ensure that individual needs of students are met. These needs can vary and, for Year 9, may encompass students that require knowledge from Year 7 through to students that require Year 10 or above (Hattie, 2009). It is challenging for teachers to provide the right materials and experiences at the right time so students are able to gain the knowledge they require regardless of their current development stage. At the start of this project teachers stated they intended to differentiate tasks in terms of textbook questions and using their general knowledge of students. Although this is a form of differentiation, it might not address specific student learning needs. A couple of teachers were intending to give different hands-on tasks to different groups of students based on their general knowledge of their students’ understanding. The participants intended to assign textbook questions from their general knowledge of students. This was to be done without specific evidence of student developmental stages.

The teachers stated that they used the information from the SMART system to differentiate their teaching. There were two disagree responses for statement #2, in the
questionnaire due to a teacher completing SMART test later in the topic when it was too late to address misunderstandings. Chen responded with disagreement to statement #9, that it was easier to discover students’ misunderstandings, because he thought the test was too challenging for students and claimed he did not use the diagnosis. In contrast, teachers with “agree” responses stated the diagnosis gave them enough information to be able to differentiate learning thereby ensuring students had the opportunity to gain knowledge. Through this they could give effective activities or questions to groups of students as the diagnosis highlighted which students required particular knowledge. This supports Stacey’s (2013) proposition that teachers who have knowledge of their students’ misunderstandings can plan effective teaching to address these issues. The participants stated the diagnosis made it easier to uncover misunderstandings and understand student developmental stages. Through this information teachers could address student issues with small groups of students, and differentiate learning. Providing intervention is important for students to develop skills they have not already learnt (Hattie, 2009). Participants stated that if teachers take note of the diagnostic test results and put strategies in place to aid student understanding then student outcomes should improve because student may gain a deeper knowledge of concepts.
Chapter 7 Case Study: Bernard

Bernard was a mature, experienced teacher in his late 40s, who had been teaching for more than ten years. He taught predominantly Year 8 through to Year 10. Bernard was an enthusiastic teacher who continually strived to help students within his classroom. Bernard was chosen for this case study because his experiences and views of the SMART system changed greatly during the project.

This case study is divided into four main sections; the first three sections each examine one of the research questions and the final section (7.4) is a conclusion. Within each of sections 7.1, 7.2 and 7.3 there are two subsections that investigate the changes of view Bernard had during the project. For ease of highlighting his changing thoughts, the first subsections (7.1.1, 7.2.1, and 7.3.1) discuss Bernard’s initial views of the SMART system. The second subsections (7.1.2, 7.2.1, and 7.3.2) discuss Bernard’s final view of using the SMART system. See Appendix 6 for interview details.

7.1 Change in Teacher Knowledge

7.1.1 Initial position

Initially, during the pre-topic interviews, Bernard stated that the two main methods he used to gain general knowledge of students’ misunderstandings were: consideration of the questions that students ask him pertaining to particular tasks, and the overall behaviour of students. He stated that misbehaviour was a great indicator of student understanding since if students do not understand the content they would become disengaged, not complete the set tasks, and often disturb other students learning. At this point, Bernard did not state that observation of student questions or the disengagement of students enabled him to uncover specific misconceptions or assess the developmental stage of individual students. The questionnaire conducted at the end of topic 1 depicts how Bernard viewed the SMART system (see Table 7.1) after he had first used it for the first time.
Bernard agreed that the diagnosis matched his expectations of student knowledge levels and found it uncovered a number of misunderstandings. However, Bernard disagreed that the diagnosis made him investigate or research any misunderstandings further (Likert statement #5). He found that diagnosis did not uncover any misunderstandings that he had not previously thought about (#15) and he was neutral to learning about misunderstandings through the diagnosis (#11).

The post-topic interview was used to gain insights into Bernard’s questionnaire responses. Bernard stated that students had a variety of misunderstandings and the SMART system helped him to identify student knowledge. He stated that for topic 1, the diagnosis did not help him to learn about specific student misunderstandings, and that he had been teaching Year 9 long enough to be aware of the misconceptions in the topic of linear equations. Through his general knowledge of that class he stated, “I already knew who the lower ability students were and the diagnosis only confirmed what I already knew about individual students”. However, Bernard was interested in the overall student knowledge of the class and stated, “It took too much time to consider individual students [misconceptions]”. This meant that he only used the diagnosis to confirm which students were working at an earlier or later developmental stage. He did not use the diagnosis to look deeply into what the developmental stages meant for individual students. This matched his response on the questionnaire where he indicated that the diagnosis did not cause him to research or investigate student misunderstandings further. Bernard stated that he had encountered these types misconceptions in the past and felt equipped to deal with misunderstandings. This

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### Table 7.1 – Questionnaire responses to RQ 1 for topic 1, linear equations

<table>
<thead>
<tr>
<th>Likert questionnaire statement</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The diagnosis uncovered student misunderstandings</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The SMART test diagnosis matched my own expectation of student knowledge</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. The diagnosis caused me to investigate student misunderstanding further</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>11. I learnt about student misunderstanding through the diagnosis</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I discovered misunderstandings that I previously had not thought about</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. The diagnosis showed me misunderstandings that I did not know students could have</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. I researched student misunderstandings because of the SMART test diagnosis</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree
may also account for his neutral responses to statements #11 (learnt about student misunderstandings through the diagnosis), and #13 (discovered student misunderstandings that he had previously not thought about) since in his prior experience he may have encountered a range of misunderstandings and the diagnosis did not reveal any other than previously faced.

At this point Bernard felt that the SMART system uncovered student misconceptions, but did not give him any new information about students. The SMART system for him was “just another tool to use in class to possibly gain some knowledge on misunderstandings”.

### 7.1.2 Final position

Bernard was very excited about the SMART system during the follow up interview for this project. Bernard found the diagnosis informed him about individual student knowledge that he could use to guide teaching practice. The questionnaire responses for topic 2 (see Table 7.2) show many changes, as all statements, except statement #1, had changed in comparison to topic 1. These changes may have been due to many reasons, such as Bernard may have thought the test for topic 2 was better than for topic 1. The post-topic interview for topic was used to gain insights into Bernard’s reasons for these changes. These changes are discussed in this section, his final position.

<table>
<thead>
<tr>
<th>Likert questionnaire statement</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The diagnosis uncovered student misunderstandings</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The SMART test diagnosis matched my own expectation of student knowledge</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>5. The diagnosis caused me to investigate student misunderstanding further</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. I learnt about student misunderstanding through the diagnosis</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I discovered misunderstandings that I previously had not thought about</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. The diagnosis showed me misunderstandings that I did not know students could have</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. I researched student misunderstandings because of the SMART test diagnosis</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree
Bernard did not use the SMART system for topic 2 until the end of the topic. He decided to administer the SMART test as part of a revision lesson, the lesson before the summative test. At this time, Bernard requested his students complete both the linear graphs test (topic 2) and repeat the linear equations SMART test (topic 1). Bernard reported that the results from the diagnosis were unexpected. The diagnosis indicated that many of his students were still at the earlier developmental stage of backtracking and had not progressed to the subsequent stage of using inverse operations. At this point Bernard said, “it became clear to me why I got bogged down during topic 2 and students were moving very slowly through the concepts and found them extremely difficult to understand”. He also commented in frustration, “That’s why they were asking me basic questions time and time again”. Bernard went on to state “It [the SMART test] definitely should be done at the beginning [of a topic]”. For Bernard using the SMART system at the beginning of a topic meant he would “know what the common problems are before you attack it and deliver it”. He anecdotally mentioned, after the post-topic 2 interview, that if he had used the SMART system earlier he could have easily addressed student misunderstandings of solving equations. This is the reason behind his response to statement 3: the diagnosis gave him unexpected results. He was surprised at the diagnosis as topic 1 dealt with inverse operations. He assumed students had consolidated that concept whereas, in fact, they had not. Bernard did not gain this information from the end of topic summative test for linear graphs, showing the importance of using the SMART system to gain accurate and detailed information about student knowledge. Bernard stated that he discovered that the SMART system would have given him invaluable information about his students’ knowledge. He uncovered reasons for his class becoming “bogged down” where they didn’t seem to progress at the expected rate. This was a light bulb moment for Bernard.

Bernard said there were many benefits to using the SMART system. In particular, he stated, “the diagnosis lets you know where students are at” and “you could discover common problems or misunderstandings”. He had begun to look more closely at the diagnosis for individual students to learn about developmental stages and what that meant for each student. During the follow up interview, Bernard said that he had incorporated the SMART system for his Year 8 classes and was planning to extend his use of the SMART system into other year levels. Bernard said that by using the
SMART system he could walk into class aware of the developmental stages of individual students. This meant he could ensure he supported students fully in their learning.

7.2 Change in Teaching Practice

7.2.1 Initial Position

In the beginning, Bernard could be viewed as a traditional teacher. When describing his teaching practice Bernard stated, “I give a question … that I … set out [on the board] including the whole class” … “I’ll go through the more basic parts to it [a question] then give them [students] questions to do”. Bernard was asked how he knew if a student did not understand a concept he replied “If the students are actually misbehaving and not completing the work that it’s either they need to be enticed to do the work or they just don’t have the skills to do it”. Patterson et al. (2009) suggested that, in traditional mathematics teaching, the teacher presented new problems to students, which were worked through on the board. The teacher then facilitated students’ learning by moving around the room reminding students to stay on tasks or helping with individual questions (Patterson et al., 2009). This was the way in which Bernard presented his teaching practice during the pre-topic 1 interview. Bernard demonstrated mathematical concepts by posing a problem then wrote step by step how to approach the question, and how to set out an answer. Students were then requested to complete selected textbook questions. Bernard preferred to help students one-on-one to overcome misunderstandings about particular tasks. If many students asked the same question he would complete that particular question on the board. He would use concrete materials, activities, or ICT for the entire class if he felt it would aid student understanding. The questionnaire at the end of topic 1 (Table 7.3) indicates how Bernard viewed the SMART system in relationship to his teaching practice.
Table 7.3 – Responses to statements addressing RQ 2 – topic 1 (linear equations)

<table>
<thead>
<tr>
<th>Likert questionnaire statement</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. The diagnosis led me to change the way I taught some of the specific topic</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>6. The diagnosis led me to revise some topic specific concepts with my students</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Compared to last year it was easier to address difficulties because of the diagnosis</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. The diagnosis led me to revise some concepts, other than current topic, with my students</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. The diagnosis helped you to improve the way you teach the topic</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree

Bernard disagreed that the diagnosis led him to change the way he taught linear equations (Likert statement #4). Likewise, he was neutral as to whether or not the diagnosis helped him to revise linear equations with his students (#6), although he did revise other concepts that were used in the linear equation topic but not specific to linear equations (#16), such as directed numbers and order of operations. It is interesting to note that he was neutral to whether or not the diagnosis improved the way he taught (#19).

The post-topic interview brought to light the reasons behind Bernard’s responses in the questionnaire. Bernard stated that the questions students were asking and not the diagnosis changed the way he taught. This was the reasoning behind his disagreement with statement #4. Bernard found the diagnosis led him to revise concepts other than concepts specific to linear equations, such as directed numbers. Bernard stated that he always structured revision around the major concepts and had not referred to the diagnosis to gain topic specific information. This ties in with the response for statement #6. Bernard was unsure if the diagnosis improved his teaching practice even though he stated that the diagnosis “helped a bit”. This view was reflected in his neutral response to statement #19, that the diagnosis helped to improve the way he taught topic 1. However, there was evidence of change in teaching practice, though at the time of the interview Bernard did not recognise the change. He stated during the post-topic 1 interview that the diagnosis told him “more precisely where they are having trouble” and that once he knew he could address the misunderstanding.
7.2.2 Final Position

Bernard completed the SMART test for topic 2 late; his responses on the questionnaire do not uncover any major changes in teaching practice (Table 7.4).

Table 7.4 Responses to statements addressing RQ2 - topic 2 (linear graphs)

<table>
<thead>
<tr>
<th>Likert questionnaire statement</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. The diagnosis led me to change the way I taught some of the specific topic</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>6. The diagnosis led me to revise some topic specific concepts with my students</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Compared to last year it was easier to address difficulties because of the diagnosis</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. The diagnosis led me to revise some concepts, other than current topic, with my students</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. The diagnosis helped you to improve the way you teach the topic</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree

As in topic 1, Bernard did not believe that the diagnosis helped him to change any part of his teaching practice (Likert statement #4) and was still neutral to thinking it had helped him improve his teaching practice (#19). Bernard revised some of the concepts that were both topic specific (#6) and not of that topic (#16).

The post-topic interview brought to light the reasons behind Bernard’s responses. The late completion of the SMART test meant it was not possible for the information Bernard received from the diagnosis to change his teaching practice (#4). Although Bernard used the SMART system late, he stated that he completed a little revision on directed numbers during the 10 mins before students began the summative end of topic test. This supports the agree responses for statements #6 and #16. Bernard could not agree with statement #19, but recorded a neutral response because he stated that the diagnosis would have helped him if he had used the SMART system earlier. “I did the test too late to be of any real use”, he said. This made it difficult for him to address any misunderstandings before the students’ final assessment.

Bernard stated that for topic 1, the diagnosis made it easier to focus on general student difficulties (explained in more detail in section 7.3). During the post-topic 1 interview, he explained how he changed a small portion of his teaching. The SMART test had brought to light that students had difficulties with negative numbers. When asked about the misconceptions the diagnosis had uncovered “Negative numbers
absolutely”, he replied. Bernard was concerned that this was causing many students to experience difficulties. He subsequently researched better or different ways of reviewing the concept of directed numbers and then reviewed this concept with the class. Bernard stated, “I changed entirely the way I taught it [directed numbers as part of linear equations and inequalities]”. He went on to explain that students were able to consolidate and gain a clearer understanding of directed numbers.

At the end of topic 2 Bernard had a light bulb moment about the benefits of using the SMART system early in a topic. He discovered that the SMART system gave him invaluable information about his students. Bernard reasoned that if he had used information from the diagnosis, he would have been able to identify the developmental stages of students and would have changed his teaching practice to support student learning.

Bernard became extremely animated when talking about teaching practice and the SMART system during the follow up interview. He said there were many benefits; in particular he became better prepared for class because he knew the developmental stages of his students. Bernard stated he “knew what problems to expect” and could anticipate issues that groups of students may encounter. He found himself researching different activities that he could incorporate into his teaching practice that would aid students in overcoming their misconceptions. He could then use these activities to aid both students at an earlier developmental stage (“the low ability students” as he called these students before the project began) and those at a more advanced developmental stage.

7.3 Addressing Student Needs

7.3.1 Initial position

Bernard stated that some students had difficulty with mathematical concepts; that “they were not maths students”. He gave students he perceived to be “struggling” the easier questions to complete from the textbook and helped them one-on-one as required. The questionnaire conducted at the end of for topic 1 (Table 7.5) shows Bernard’s responses for Research Question 3. Statements #2 and #17 will be discussed in 7.3.2 because they are a reflection of Bernard’s final view of the SMART system.
Table 7.5 - Responses to statements addressing RQ3 – topic 1 (linear equations)

<table>
<thead>
<tr>
<th>Likert questionnaire statement number</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. I gave some groups of student different activities because of the diagnosis</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Because of the diagnosis I could differentiate the curriculum</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. The diagnosis made it easier to discover student difficulties</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. I gave different student different tasks due to the diagnosis</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree

After topic 1, Bernard stated that he preferred to focus on the class of students as a homogenous group and felt it took an extraordinary amount of time to address individual student problems. This supports his response in topic 1 that the diagnosis did not make it easier for Bernard to uncover student misunderstandings (Table 7.5, #9).

Bernard stated that the diagnosis did not enable him to differentiate the curriculum, leading to neutral responses for statement #8 (Table 7.5 and 7.6). The reason for this response for topic 1 was that he wanted a homogenous class, he did not look for individual student difficulties and it was too late to differentiate for topic 2. Moreover, Bernard viewed differentiation of curriculum as students completing individual tasks every lesson rather than the definition stated in the literature review (section 2.3). If a clear definition of differentiation had been provided, Bernard may have responded differently.

7.3.2 Final Position

Bernard had changed his view slightly for topic 2 and recorded a neutral view for statements #9 and #17 (Table 7.6). He stated that although he could see the benefits of using the SMART system, there was too much to read on the diagnosis and found he continually referred between the student diagnosis and the explanation for misconceptions and developmental stages. This was his reason for the neutral response (#9).
Table 7.6 Responses to statements addressing for RQ3 - topic 2 (linear graphs)

<table>
<thead>
<tr>
<th>Likert questionnaire statement number</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. I gave some groups of student different activities because of the diagnosis</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>8. Because of the diagnosis I could differentiate the curriculum</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. The diagnosis made it easier to discover student difficulties</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. I gave different student different tasks due to the diagnosis</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree

At the end of the project, Bernard found that the diagnosis helped him to form students into groups at common developmental stages. He stated that after viewing the diagnosis, “you know where to address the skills and to then know what the common problem is before you attack it and deliver it.” This was a great help to his teaching as he was happy to have smaller groups working on different concepts. In particular, the student group working at a more advanced developmental stage were given explanations to enable them to progress to more complex tasks. Whilst the group of students working at an earlier developmental stage were given more detailed explanations in order to enable them to understand earlier concepts. The teaching practice of student groups working on different tasks was reflected in his responses in Table 7.5 (#2, #17). Bernard said that the diagnosis helped to him focus on the developmental stages with students rather than continuing with more complex concepts. Thus, he was able to give small groups of student’s different tasks to complete in order to overcome misconceptions.

Bernard spoke enthusiastically about the benefits of the SMART system for individual students. He stated that because he knew the developmental stages of individual students he could anticipate issues. Bernard was able to implement various tasks for students enabling him to differentiate the curriculum and improve student knowledge.

**7.4 Conclusion**

Bernard had a thought-provoking journey through this project. It is evident throughout the first topic that he saw the SMART system as another tool he could use to gain information about his class, yet felt the diagnosis only confirmed what he knew about general student knowledge. He made some significant changes to his teaching practice due to the use of the SMART system, especially in terms of differentiating the curriculum to address individual student needs. However, he was not enamoured by
the SMART system as he thought it provided too much information and he wanted a short concise overview of general student knowledge.

This feeling of ambivalence to the SMART system was carried through to topic 2 because he did not administer the SMART test until late in the topic, in the lesson before the summative test. It was possibly only due to reminders from the researcher that the SMART test was actually administered at all. Once completed, however, Bernard had a complete change of heart. Bernard’s class had struggled to make progress with linear graph concepts (topic 2). When Bernard’s students had completed the SMART test, he discovered the reasons why students had not made any progress. They were working at a much earlier developmental stage than he had thought. This is an example of Hattie’s (2009) visible teaching model. If Bernard had uncovered the misunderstandings earlier during topic 2, he could have addressed the students’ difficulties. Students may have then been able to develop their knowledge. He bemoaned the fact that he had not used the SMART system until late in the topic. Bernard felt he could have made a huge difference in progression of student knowledge if he had been armed with the information pertaining to student misunderstandings.
Chapter 8 Conclusion

8.1. Aim of study

The aim of this study was to examine teachers’ use of diagnostic testing in Year 9 mathematics classrooms, in particular the usage of the SMART system. The mixed method design of this study did meet its purpose although a few limitations became evident which are discussed in section 8.5. The project found that the SMART system offers teachers an efficient and easy way to uncover student misconceptions. The diagnosis highlights not only student misconceptions but also their developmental stage along a mathematical continuum. Teachers are able to use this knowledge to prepare appropriate activities to either address misconceptions or provide tasks at the correct developmental stage. Students are then exposed to activities or tasks that give them the opportunity to consolidate and develop a clearer understanding of concepts.

A short summary of findings can be found below. Refer to discussion chapters for more detail.

8.2 Change in teacher knowledge

Research Question 1 asked whether or not teachers’ knowledge about student learning changed when their students use the SMART system. In some areas teachers’ knowledge did change when they used the SMART system. Their knowledge initially was formed from a general knowledge about their students, that is, knowledge that had been formed from prior teaching experience, observations of student difficulties with specific tasks. For some, a belief that some students always have difficulty with mathematical concepts so all maths will be difficult for them to comprehend. This knowledge changed to highly specific knowledge about each of their students. Teachers become aware not only of particular developmental stage that individual students may be experiencing, but also reasons why misconceptions occur, and activities that the teachers could provide to overcome these issues. For some the SMART system challenged the teachers’ conception of student learning. Students who experience many difficulties, are often viewed as students who cannot understand maths, instead may in fact have a misconception that is preventing that student from progressing. Once this misconception is addressed, students can move forward.
8.3 Change in teaching practice

Research Question 2 asked what changes in teaching practice occurred when teachers used the SMART system. In this study, teaching practice changed in a number of ways. Firstly, some teachers (Bernard and Jenny) were better prepared for class because the diagnosis highlighted issues and uncovered activities that could be designed to address misunderstandings. Secondly, teachers could review the diagnosis to discover misunderstandings between groups of students and then follow up with either a small group task for those students or, if it was a large group, conduct a class activity. Subsequently, some teachers reported feeling better prepared for class because they could provide appropriate activities for the developmental stage of students. Ideas for activities may be obtained from the SMART system. The teachers improved their teaching practice because of the information they received from the SMART system.

8.4 Addressing student needs

Research Question 3 asked whether the use of the SMART system helped teachers to address individual student needs. The diagnosis obtained from the SMART system aided teachers in differentiating their class. Rachael stated, “I was giving them different material to work with”. This supports the idea that differentiating occurs when teachers give different groups of students different activities to complete according to their particular learning needs (Wiliam, 2009). Participants reported that the diagnosis enabled them to see clearly which students had misunderstandings and the developmental stage of each student. Using this knowledge, some teachers were able to provide tasks for all developmental stages within their classroom. Teachers could then easily address misconceptions with the students in question.

8.5 Limitations of study

One limitation of this study was the small sample. There were nine Year 9 teachers at the study school of which six took part in the study. Due to the relatively small sample it is not possible to generalise to teachers in general. I chose to conduct interviews after participants had completed the questionnaire to gain a deeper understanding of participant responses on the questionnaires. To have a purely quantitative study with such a small group of participants would have given not only a
limited sense of how the SMART system affected teacher knowledge and teaching practice, but it also does not explain the reasons behind the responses. Another limitation is there was only one school involved in the project. The results obtained may be localised to this particular school. It was the researcher’s school, and even though the researcher was not in a position of power there is possibility of bias in the results.

The project was focused on only two topics. Research conducted over a number of topics and gathering data on end of topic tests may reveal whether or not student outcomes improve. The final limitation is the way in which data was collected. The interviews were a reflection of how teachers see their own teaching knowledge and practice rather than an objective, direct observation by the researcher. This means that teachers may not be explicit about the own teaching practice, which may lead to lack of depth in the data. To overcome this limitation, video could have been taken in order to closely examine changes in teaching practice, but this was outside the scope of the study.

In retrospect, the wording for some of the Likert statements could be changed to make them clearer. Although all statements were vetted and trialled with a teacher not linked to the project, there were statements that had different meanings for each of the participants. For example, statement #5 (the diagnosis caused me to investigate student misunderstandings further) and statement #18 (I researched student misunderstandings because of the SMART test diagnosis) were paired. However, teachers saw the words “investigate” and “researched” as completely different: “investigate” meant to talk to the students in the class and, “researched” meant using the Internet to find solutions. These Likert statements need to be more specific, such as, “The SMART test diagnosis caused me to investigate student misunderstandings with colleagues”. In this way the questionnaire would be clear for both participants and for data collection.

8.6 Further Research

There are many areas where further research could be conducted. The results collected as part of this study lead to further questions such as: How do the teachers relate the diagnosis to specific student activities? How do the activities that the
teachers use address the misconceptions the diagnosis has indicated? How do teachers actually use this diagnosis to differentiate their students’ learning? Are student outcomes improved if the SMART system is used throughout Years 7-9? Does student confidence in their mathematical achievement improve when the SMART system is used?

To complete this research effectively, a larger sample size and longer time period would be required, along with video evidence to gain an in depth view. Despite its limited scope however, the study does suggest that the use of the SMART system may lead to teaching that is more targeted towards specific misconceptions and developmental stages, which ultimately leads to better-prepared teachers. Bernard’s comments of “I can see where I can improve the teaching” and “It gives a bird’s eye view of where the students are at” depict the sentiments of the participants.
References


href1, Retrieved from www.smartvic.com


Steinle, V. (2004). Changes with age in students’ misconceptions of decimal numbers. *Thesis (Ph.D.)--University of Melbourne, Dept. of Science and Mathematics Education*


Appendices

Appendix 1 – Post-topic and follow up interview questions

Pre-topic interview questions
Teachers were posed the following questions:

• How do you currently become aware of the difficulties that student have about linear equations?
• What difficulties are you expecting?
• In what ways do you address these difficulties?
• Will this involve giving different tasks to some students? Why?
• Are you aware of these difficulties from your own experience or from other sources? Where?
• Did you teach linear equations last year?
• Compared to last year have you changed the teaching plan for this topic?
• How is it different to how you previously taught it?
• What are the specific changes that you have made?
• Why were these changes made?
### Post-topic interview questions

#### Research question 1: Does the teachers’ knowledge about student learning change when their students the SMART system?

<table>
<thead>
<tr>
<th>Likert Statement</th>
<th>SA/A</th>
<th>N</th>
<th>SD/D</th>
<th>Interview question based on Likert response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SA/A</td>
<td></td>
<td></td>
<td>• What type of misunderstandings did the diagnosis uncover?</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>N</td>
<td>SD/D</td>
<td>• What misunderstandings did students have that weren't shown in the diagnosis?</td>
</tr>
</tbody>
</table>
| 3                |      | N   | SD/D | • You wrote on the questionnaire that the diagnosis did not match your expectations in what way and why? [eg capable students had misunderstandings that wasn't expected. Weaker students more capable than expected]  
• Did the diagnosis help you in any way?  
• Were the misunderstandings uncovered the ones you were expecting? |
| 3                |      | N   | SA/A | • Did the diagnosis focus you on the problems student were experiencing?  
• You wrote in the questionnaire that the diagnosis made it easier to address student difficulties. In what ways? |
| 5                |      | N   | SA/A | • You wrote in the questionnaire that the diagnosis lead you to further investigate the misunderstanding, what resources did you use?  
• Did the diagnosis give you links to further investigate these difficulties? |
| 11               |      | N   | SD/D | • You said earlier that the diagnosis did not help you learn about student misunderstandings. Did you already know about them? |
| 13/15            |      | N   | SA/A | • Early you said that the diagnosis uncovered misunderstandings that you did not know about which misunderstandings? |
| 13/15            |      | N   | SA/A | • Early you said that the diagnosis uncovered misunderstandings that you did not know about, what were these in particular? |
Research question 2: what are the changes in teaching practice that occur when teachers use the SMART system?

<table>
<thead>
<tr>
<th>Likert Statement</th>
<th>SA/A</th>
<th>N</th>
<th>SD/D</th>
<th>Interview question based on Likert response</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>SA/A</td>
<td>N</td>
<td>SD/D</td>
<td>• In what ways did the diagnosis change how you taught linear graphs?</td>
</tr>
<tr>
<td>4</td>
<td>N</td>
<td>SD/D</td>
<td></td>
<td>• Did any other reasons lead you to change the way you taught the linear graphs?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• What were they?</td>
</tr>
<tr>
<td>6</td>
<td>SA/A</td>
<td></td>
<td></td>
<td>• You wrote on the questionnaire that you revised some linear graphs concepts because of the information from the diagnosis what were they and why?</td>
</tr>
<tr>
<td>7</td>
<td>SA/A</td>
<td></td>
<td></td>
<td>• In what ways did the diagnosis make it easier to see difficulties?</td>
</tr>
<tr>
<td>7</td>
<td>SD/D</td>
<td></td>
<td></td>
<td>• Did the diagnosis make it more difficult to find student misunderstanding?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• In what way?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Was the diagnosis too difficult to interpret?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• How could it be improved?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>OR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Did you use the diagnosis in any way?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Why?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• [eg was it too difficult to understand, take too long to run through the analysis, you didn’t understand the analysis]</td>
</tr>
<tr>
<td>16</td>
<td>SA/A</td>
<td></td>
<td></td>
<td>• You wrote on the questionnaire that you revised some other maths concepts because of the information from the diagnosis what were they and why?</td>
</tr>
<tr>
<td>16</td>
<td>N</td>
<td>SD/D</td>
<td></td>
<td>• Did you have a teacher lead revision session before final assessment?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Did you focus on particular concepts more than others?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Why?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• How did you gain the information that you needed to do this?</td>
</tr>
</tbody>
</table>

Research question 3: Does the use of the SMART system help teachers to address individual student learning needs?

<table>
<thead>
<tr>
<th>Likert Statement</th>
<th>SA/A</th>
<th>N</th>
<th>SD/D</th>
<th>Interview question based on Likert response</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>SA/A</td>
<td></td>
<td></td>
<td>• How did you feel that the diagnosis allowed you to give different students different tasks?</td>
</tr>
<tr>
<td>8/17</td>
<td>SA/A</td>
<td></td>
<td></td>
<td>• In what ways did you give different students different activities?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Do you think this is something you may continue in the future?</td>
</tr>
<tr>
<td>8/17</td>
<td>SD/D</td>
<td></td>
<td></td>
<td>• Did you give the students different activities because of a decision other than from the diagnosis?</td>
</tr>
</tbody>
</table>
Follow up interview questions

1. Have you continued to use the SMART tests in year 9 or with any other year levels?
   a. Why or why not?
   b. Which ones did you use and at which year levels?

2. What benefits did you see in these tests?

3. Are you happy with how the SMART test site works or do you think it could be improved?
   a. What type of changes would you like to see?

4. At what stage during the Linear Equations topic did you give your students the SMART test?

5. At what stage during the Linear Graphs topic did you give your students the SMART test?

6. At what stage during teaching a topic is the best time to give a SMART test?
   a. Does it change depending on the topic? Why?
   b. Does it depend on what your aim is for the SMART test? (eg new concepts finding out who hasn’t grasped them before final assessment, finding out previous knowledge)

7. Have the SMART tests helped you in guiding your teaching practice?
   a. In what way?

8. Overall do you think that by using the SMART test diagnosis student outcomes are improved?
   a. How does this happen?
Appendix 2 – Rachael

Pre-topic 1 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 1 (linear equations) began. The following is a summary of the interview, which has been paraphrased.

- Rachael uses SMART testing occasionally
- State use previous teaching experience of the topic as their main way for deciding on student knowledge or misunderstandings.
- Break problems into simple steps and teacher uses annotation and highlights each of these steps
- Rachael intends to extend and engage upper end students while consolidating the lower end students.
- Plan to give their students different tasks during their teaching of topic 1.
- Rachael intends to have extension and lower end students working on different tasks at times. To be able to extend the upper end students and consolidate knowledge for the lower end students.

Pre-topic 2 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 2 (linear graphs) began. The following is a summary of the interview, which has been paraphrased.

- Teacher relied more on their previous knowledge of teaching that particular topic to decide on where the student misunderstanding would be.
- **Note**: no diagnostic testing
- Show the students many examples
- Break problems into simple steps and teacher uses annotation and highlights each of these steps
- Rachael is going to approach the concept of finding intercepts differently but she is not sure how at the time of the pre-topic 2 interview.
- Intend to give different students different tasks but only the extension students.
- State that this topic is relatively new to the students and student knowledge in generally close together.
## Questionnaire results

Responses for the statements for topics 1 and 2

<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
<th>Blank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The diagnosis uncovered student misunderstandings</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I gave some groups of student different activities because of the diagnosis</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The SMART test diagnosis matched my own expectation of student knowledge</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. The diagnosis led me to change the way I taught some of the linear equations topic</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. The diagnosis caused me to investigate student misunderstanding further</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. The diagnosis led me to revise some linear equation concepts with my students</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Compared to last year it was easier to address difficulties because of the diagnosis</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Because of the diagnosis I could differentiate the curriculum</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. The diagnosis made it easier to discover student difficulties</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Due to the information I gain from the SMART test the students achieved a higher outcome on the end of topic test</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. I learnt about student misunderstanding through the diagnosis</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Student outcomes improved in comparison to last year</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I discovered misunderstandings that I previously had not thought about</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. SMART test diagnosis improved student outcomes</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. The diagnosis showed me misunderstandings that I did not know students could have</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. The diagnosis led me to revise some concepts, other than linear equations, with my students</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. I gave different students different tasks due to the diagnosis</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. I researched student misunderstandings because of the SMART test diagnosis</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. The diagnosis helped me to improve the way I taught linear equations</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 response for topic 1 2 response for topic 2
Post-topic 1 interview
See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 1 (linear equations) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

Knowledge
- Found different misunderstandings then they found in topic 1.
- Diagnosis did not match their expectation of student ability for topic 1.
- Rachael found that many in her class had trouble with pronumerals and on reading the diagnosis spoke to the class and very quickly ascertained that this was indeed true. After a short review she decided that her most student did have an understanding of pronumerals but they had forgotten from the previous year. Rachael put together a small revision presentation with a short activity and to address this issue. She reported back that it was a really good activity to do as all students now recall the concept of pronumerals and she could then move forward.
- Teachers that stated that the diagnosis did not help them learn about student misunderstandings said that they had been teaching year 9 long enough to be aware of specific misunderstandings surrounding this topic. They already knew who the lower level students were and the diagnosis only confirmed what they already knew about their individual students.
- The diagnosis uncovered misunderstandings they had not considered to be relevant or important for this topic. Both reported that knowledge they assume the students had the students in fact did not. It repercussions of this was they both did some revision work with students before moving forward.

Teaching Practice
- Rachael found that the diagnosis changed her teaching practice for topic 1
- During topic 1 she gave struggling students more visual references to aid their understanding of concepts as the diagnosis indicated that these students required extra help. These students were taught similar concepts but in a different format to help them consolidate the basics.
• Rachael found that the diagnosis did help her to revise concepts the were not topic specific however she was not explicit as to which concepts these were during the post-topic interview for topic 1.
• Disagreed that the diagnosis made it easier to focus on student difficulties.
• Found that the diagnosis confirmed what they already knew about their students as it highlighted those who were struggling. They both said it was great to have what they felt about their students confirmed.
• The diagnosis revised some topic related concepts while they were teaching the topic.
• The diagnosis helped them to improve the way they taught both topics.
• Gave struggling students slightly different work (not as hard), used more visual references with them
• Enabled Rachael to focus on particular concepts eg pronumerals
• Highlighted strugglers but ‘not an eye opener’
• Improved student outcomes by ensuring understanding of concepts esp. ones learnt in previous level

Post-topic 2 interview
See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 2 (linear graphs) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

Knowledge
• Teachers that stated that the diagnosis did not help them learn about student misunderstandings said that they had been teaching year 9 long enough to be aware of specific misunderstandings surrounding this topic.

Teaching practice
• Rachael found that the diagnosis changed her teaching practice for topic 1 but not topic 2.
• Rachael changed her teaching practice for topic 2 but it was not due to the diagnosis. However she did state that the diagnosis gave her the knowledge of
which concepts she needed to be thorough in and this helped her to ensure that students had a good understanding of concepts.

- For topic 2 Rachael revise other concepts due to observations she had made in the classroom rather than from the diagnosis.
- The diagnosis confirmed what they already knew about their students as it highlighted those who were struggling. They both said it was great to have what they felt about their students confirmed
- Rachael found the same with topic 2.
- Rachael found that she needed to revise the meaning of pronumerals, and making the link between x and y values.
- The diagnosis helped them to improve the way they taught both topics.

**Differentiation**

- Found diagnosis confirmed individual student misunderstandings
- Focus on student understanding
- Could focus on particular concepts if needed

**Follow up interview**

See Appendix 1 for the list of interview questions.

- Would like to implement SMART but has not due to lack of time
- Many benefits
- Good system
- Depends on topic where should use test but should be in first half to give time to address issues
- Has helped improve teaching practice by focusing more on student understanding rather than curriculum/content driven – more student centred?
- SMART test system only helps if teacher takes on board the diagnosis analysis and addresses any misunderstandings
Appendix 3 - Svetlana

**Pre-topic 1 interview**
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 1 (linear equations) began. The following is a summary of the interview, which has been paraphrased.

- Brainstorming with students to uncover prior knowledge
- Observation to find issues
- Evaluate problems in various ways
- Rephrase explanation if student doesn’t understand
- One-on-one help
- No changes (first year teaching maths)
- Only planning to give different tasks if a small group is having issues (first year maths)

**Pre-topic 2 interview**
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 2 (linear graphs) began. The following is a summary of the interview, which has been paraphrased.

- Gain knowledge by asking other teachers
- Teaching practice same as topic 1 but will spend more time on difficult concepts
- Will give some student extension work if needed
- Expressed that wanted to differentiate but had enough trouble getting head around course. Very daunting would do in future but try and start small now.
### Questionnaires

Responses for the statements for topics 1 and 2

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<td>5. The diagnosis caused me to investigate student misunderstanding further</td>
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1 response for topic 1 2 response for topic 2
Post-topic 1 interview
See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 1 (linear equations) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

Knowledge
• SMART test helped them to find misunderstandings
• That the diagnosis did not match their expectation of student ability for topic 1.
• Svetlana found that she had much higher expectations of student knowledge and was very surprised with the diagnosis as it showed many areas of weakness in particular basic algebra knowledge. She surmised that this was probably because she had not taught topic 1 previously.
• Agreed that the diagnosis change the way they taught topic 1 (linear equations). They both found that they had to start the topic with the basics of linear equations to revise/remind students.
• Svetlana also found directed numbers to be a source of difficulty during topic 1 but said he revised directed numbers more due to observations in class rather than the diagnosis but she did notice issues with directed numbers while students were completing SMART test for topic 1.

Teaching practice
• The diagnosis made it easier to focus on student difficulties for topic 1.
• Svetlana discovered that many of her students did not have or could not remember the basic concepts of linear equations. This meant that she had to start with concepts that would have been covered during lower levels (see previous data). Leading to the assumption that Svetlana could not assume that her class had consolidated concepts previously taught.
• Did not find the diagnosis specifically highlighted to them areas that needed to be revised that were topic specific. Questions were not asked for their reasons for this due to time constraints.
• Svetlana felt that the diagnosis helped her to teach topic 1
Differentiation

- Selected appropriate questions for groups of students; easier for strugglers, more advanced for extension
- Diagnosis made her start at beginning of topic
- Found diagnosis focus her on problems but did not give specifics for off topic
- Could see which students had gain competence
- Diagnosis made it quicker to see misunderstandings and multiple misunderstandings
- Could revise due to combination of test and observations

Post-topic 2 interview

See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 2 (linear graphs) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

Knowledge

- List of misunderstandings for topic 2 they found from the diagnosis. On the whole they were different misunderstandings than topic 1.
- Found different misunderstandings then they found in topic 1. It can be assumed that the issues students had in topic 1 had been addressed as there is much cross over of concepts between topic 1 and 2.
- Only Svetlana felt that she had to do some further investigation of student misunderstanding. Svetlana asked other maths teacher how they would approach each concept and taught in that particular way. She found the diagnosis difficult to interpret because this was her first year teaching maths and she reported that she struggled with some of the terminology on the SMART website. Svetlana got other teachers to help her interpret the diagnosis so she could address her students’ misunderstandings.
- It was found that Svetlana found it difficult to interpret the information she received from the diagnosis.
- Svetlana both said that the diagnosis uncovered misunderstandings they had not considered to be relevant or important for this topic. Both reported that knowledge they assume the students had the students in fact did not. It
repercussions of this was they both did some revision work with students before moving forward.

• Svetlana wrote neutral and on questioning said that she talked to other teachers to gain knowledge on how to deal with student misunderstandings and ideas on how to teach each concept. So even though she reported that she did not research in fact she did by talking to more experience teachers.

**Teaching practice**

• Svetlana experienced similar results for topic 2 where the diagnosis showed her the students had little or no prior knowledge of linear graphs. Again started the topic from early concepts.

• However for Svetlana directed numbers was not an issue in topic 2, which suggests that it had been addressed and students had consolidated this concept. Svetlana found that she had to revise substitution for topic 2 due to student questions.

• Svetlana felt that the diagnosis helped her to teach topic 1 but not topic 2.

• Although due to time constraints neutral or disagree responses were not subject to further questions it can be inferred that Svetlana was in her first year teaching mathematics and she had stated previously that she spent much of her time for topic 2 learning how to teach this topic that did not agree with this statement because of her own time limitations.

**Differentiation**

• Found it difficult to differentiate as students had not done topic so more at same level

• Had to revise coordinates with some, and substitution with some

• Even though students had no experience with topic diagnosis show that some students struggled with application, coordinates, substitution with was then revised with groups

**Follow up interview**

See Appendix 1 for the list of interview questions.

• Had not done SMART for other topics as forgot they were available

• Many benefits; see prior knowledge before topic starts, find out advanced students so can give appropriate work
• Had difficulty interpreting diagnosis need clearer instructions on how to read data this probably due to first time maths
• Do test at beginning and towards end to see if concepts have been learnt before final testing or if any concepts need to be revised
• Helped in teaching practice to find what students know
• Smart test diagnosis helps in teacher knowledge so therefore if addressed should improve outcomes.
Appendix 4 – Jenny

Pre-topic 1 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 1 (linear equations) began. The following is a summary of the interview, which has been paraphrased.

• From teaching experience had taught year 9 before
• Ask questions to get an idea of prior knowledge
• Changes are revise simplifying equations at start if topic
• Differentiation for strugglers only

Pre-topic 2 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 2 (linear graphs) began. The following is a summary of the interview, which has been paraphrased.

• Knowledge from teaching experience
• Use many examples to teach concepts using step by step instructions
• Focus on x and y intercepts
• One section has been removed from curriculum as should be covered in year 10 not year 9
• Differentiation only for extension students
### Questionnaires
Responses for the statements for topics 1 and 2

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1 response for topic 1 2 response for topic 2
**Post-topic 1 interview**
See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 1 (linear equations) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

**Knowledge**
- Diagnosis uncovered student misunderstandings
- Diagnosis identified areas of difficulties
- Could focus revision better
- However knew much of this through teaching experience

**Teaching practice**
- Jenny both agreed that the diagnosis change the way they taught topic 1 (linear equations). They both found that they had to start the topic with the basics of linear equations to revise/remind students. Jenny found that she emphasized steps that needed to be used more. Though she thought that some of the change might be due to previous teaching experience and knowing where students tend to struggle.
- Found the diagnosis did not aid them to revise concepts that were not topic specific rather it was through student questions and teacher observation. The common concepts difficulty being directed numbers, fractions and order of operations.
- Jenny both agreed that the diagnosis made it easier to focus on student difficulties for topic 1. Jenny found that she had to focus on fractions and directed numbers. She said that diagnosis made it quicker for her to see her students struggled with these concepts.
- Did not find the diagnosis specifically highlighted to them areas that needed to be revised that were topic specific. Questions were not asked for their reasons for this due to time constraints.
- Found the diagnosis helped them to improve the way they taught both topics.

**Differentiation**
- Gave different tasks due to teaching knowledge not diagnosis
• Started topic at basic due to diagnosis but also due to teaching experience
• Gave consolidating concepts to strugglers but due to both teaching experience and diagnosis
• Diagnosis made it easier to see difficulties
• Very easy to see concepts that needed to be revised
• Revised non topic content

Post-topic 2 interview
See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 2 (linear graphs) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

Knowledge
• All teachers gave a list of misunderstandings for topic 2 they found from the diagnosis. On the whole they were different misunderstandings than topic 1.
• Found different misunderstandings then they found in topic 1. It can be assumed that the issues students had in topic 1 had been addressed as there is much cross over of concepts between topic 1 and 2.
• Jenny said that their students had no idea about linear graphs and on further questioning discovered that students had had no real experience of linear graphing previous to year 9

Teaching practice
• Found that students had difficulty understanding graphs.
• Spent some time getting the students to interpret graphs. They approached this student misunderstanding differently but students were able to gain an understanding of the information that can be contained within a graph.
• Jenny also found the diagnosis changed her teaching practice with topic 2. Found that students could not interpret graphs so she researched some simple graphs to use with her class to improve their understanding of graphical information.
• Spent more time focused on any misunderstanding
• Could emphasize points of difficulty
• SMART questions of interest
• Revised concepts other than topic
• Students took on board important points (could be cohort)
• Improved teaching by focusing on difficulties and addressing them

**Differentiation**
• More students at same level
• Looked at interpreting graphs due to diagnosis
• Could emphasis difficulties and address with some students
• Used both diagnosis and teaching experience to give students different tasks

**Follow up interview**
See Appendix 1 for the list of interview questions.
• Have not continued to do SMART tests due to time factor and forgot
• Benefits; can quickly adjust teaching if needed
• Overall happy with website but found it difficult to analysis diagnosis
• Should do SMART test close to the beginning of topic
• However does depend on topic
• Has helped to guide teaching practice
• Adjust teaching according to diagnosis
Appendix 5 – Troy

Pre-topic 1 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 1 (Linear equations) began. The following is a summary of the interview, which has been paraphrased.

- Ask questions centring around an example
- Ask other teachers how they’re approaching it
- Focus on specific concept
- No specific changes
- Keep better track of individual students
- Small groups; planning to give groups of students’ different tasks
- Yes; previously taught year 9

Pre-topic 2 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 2 (linear graphs) began. The following is a summary of the interview, which has been paraphrased.

- Asking questions centring around an example
- Highlighting steps describing graphs
- Create some pod and vod casts for students to access
- Three groups of students; planning to give groups of students’ different tasks
## Questionnaires
### Responses for the statements for topics 1 and 2

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Post-topic 1 interview
See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 1 (linear equations) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

Knowledge
- Teachers found a variety of misunderstandings; these were problems associated with directed numbers, fractions, understanding pronumerals, and order of operations, terminology, and application style questions.
- Did not match their expectation of student ability for topic 1.
- Teachers that stated that the diagnosis did not help them learn about student misunderstandings said that they had been teaching year 9 long enough to be aware of specific misunderstandings surrounding this topic. They already knew who the lower level students were and the diagnosis only confirmed what they already knew about their individual students.

Teaching practice
- Diagnosis change the way he taught both topics
- He found that he was able to focus more on areas of difficulty; it also clarified the specific difficulties so he could target those difficulties.
- Troy both found the diagnosis did not aid them to revise concepts that were not topic specific rather it was through student questions and teacher observation.
- Diagnosis made it easier to focus on student difficulties.
- Troy found that the diagnosis confirmed what they already knew about their students as it highlighted those who were struggling.
- They both said it was great to have what they felt about their students confirmed.
- The diagnosis revised some topic related concepts while they were teaching the topic.
- Whereas for Troy the diagnosis highlighted that he had to revise application style questions with his students.
• Troy found the diagnosis helped them to improve the way they taught both topics.

**Differentiation**

• Used both diagnosis and teacher observation to give groups of students different tasks
• Diagnosis focused teaching on difficulties with groups of students
• Target teaching on topic concepts
• Diagnosis highlighted areas of difficulty for individual students
• Highlighted brighter students and areas of difficulty
• Could revise other concepts not of topic from diagnosis.

**Post-topic 2 interview**

See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 2 (linear graphs) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

**Knowledge**

• Troy found that while many of the student difficulties were new and pertaining to topic 2 there were some students that still struggled with basic maths skills.
• Troy found that the diagnosis did not directly help him to uncover student misunderstandings as many of the student difficulties were concepts that had been taught in previous year levels, particularly in primary school. But it did help him to begin to uncover where individual problems were.
• Found that students had difficulty understanding graphs.
• Troy found that for topic 2 that linear equations (topic 1) also became another difficulty.

**Teaching practice**

• Troy spent some time getting the students to interpret graphs. They approached this student misunderstanding differently but students were able to gain an understanding of the information that can be contained within a graph.
• Troy found that diagnosis change the way he taught both topics. He found that he was able to focus more on areas of difficulty; it also clarified the specific difficulties so he could target those difficulties. For topic 2 he had a similar experience to that of Jenny where students had difficulties interpreting graphical information. He too spent some time finding graphs so that students could practice analysing graphs. Troy found he changed the focus to more on interpretation and less finding gradient and intercepts.

• Troy found the diagnosis helped them to improve the way they taught both topics.

• Changed focus of topic

**Differentiation**

• Diagnosis did not show misunderstandings that were off topic but it then did allow teacher to work with those students to find initial misunderstanding e.g. order of operations when student cannot find intercepts

• Diagnosis allow teacher to see that interpreting graphs was a problem so worked on that

• Could focus on individual misunderstandings

• Allowed teacher to see that certain concepts needed revision

**Follow up interview**

See Appendix 1 for the list of interview questions.

• Has not continued with SMART tests because not yet a part of routine

• Will look at embedding it within program by making it part of outline of topic

• Benefit is finding gaps in student knowledge where within yr 9 or before

• SMART test website easy to use

• Should be doing test within the first third of topic though it may be topic dependant

• SMART has helped with teaching practice as could see that problems stem from problems with concepts from lower levels

• Yes outcomes improved would improve more if teacher had used the diagnosis more closely
Appendix 6 – Bernard

Pre-topic 1 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 1 (linear equations) began. The following is a summary of the interview, which has been paraphrased.

• Gain knowledge about student misunderstanding by asking questions to students and checking for misbehaviour
• Tend to do one-on-one help to address any difficulties
• Sometimes teacher gives students different tasks.
• Gives easier questions to struggling students
• Has taught year 9 before

Pre-topic 2 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 2 (linear graphs) began. The following is a summary of the interview, which has been paraphrased.

• Gain knowledge from previous teaching experience
• Changes include use of ICT, and step by step instructions, one section removed from curriculum
• Ideally would differentiate but feels not enough time to do this
## Questionnaires
Responses for the statements for topics 1 and 2

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1 response for topic 1  
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Post-topic 1 interview
See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 1 (linear equations) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

Knowledge
- Found a variety of misunderstandings these were problems associated with, understanding pronumerals, and application style questions.
- SMART test helped them to find misunderstandings
- Teachers that stated that the diagnosis did not help them learn about student misunderstandings said that they had been teaching year 9 long enough to be aware of specific misunderstandings surrounding this topic. They already knew who the lower level students were and the diagnosis only confirmed what they already knew about their individual students.

Teaching practice
- The diagnosis did not changed the way they taught either topic.
- Bernard stated that initially there was no change to his teaching of topic 1, he did change how he taught inequalities due to the questions the students’ asked. Through these questions he researched better or different ways of teaching this concept. Bernard found that student understanding improved through the use of more concrete materials.
- The diagnosis did not led them to revise concepts other than the particular topic.
- Bernard stated that he always concentrated on the major theory and structured revision around that and may do some other revision depending on student questions.
- The diagnosis made it easier to focus on student difficulties. They both said it was great to have what they felt about their students confirmed.
- Bernard likes focusing on the class of students rather than individuals as he felt it takes too long to address everybody’s problems. He found that the diagnosis helped him to group like students into smaller groups of common
misunderstandings. Bernard found this a great help as he was happy to have smaller groups working on similar concepts.

- Bernard found that the diagnosis revised some topic related concepts while they were teaching the topic. Bernard found that inequalities as an issues with some students and had to revise the number line.
- Did not agree that the diagnosis helped them to improve their teaching
- Diagnosis just another tool

**Differentiation**

- Advanced students given some group explanations so could move on
- Struggling students given easier work with explanations
- Diagnosis help to focus on groups of students with similar misunderstandings
- Found diagnosis not well organised with too much info.
- Helped to focus on major theories with students

**Post-topic 2 interview**

See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 2 (linear graphs) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview, which has been paraphrased. The interview has been divided into sections relevant to each research question.

**Knowledge**

- Bernard did not do the SMART test for topic 2 until the end of the topic, done for part of the revision. This made it difficult for him to address any misunderstandings before the final assessment. His students completed both the linear graphs test and re did the linear equations test. This is where he found that his students were still operating at backtracking level and had not moved on to inverse operations in dealing with linear equations. He said that this is why he got bogged down during topic 2 and students were moving very slowly through the concepts and found them extremely difficult to understand.
  Bernard said that if he had done the SMART test earlier he could have addressed this issue and students may have found topic 2 easier to comprehend.
- Teachers that stated that the diagnosis did not help them learn about student misunderstandings said that they had been teaching year 9 long enough to be
aware of specific misunderstandings surrounding this topic. They already knew who the lower level students were and the diagnosis only confirmed what they already knew about their individual students.

- Reported that the diagnosis had uncovered misunderstandings they had not considered for topic 2.
- Bernard said that he realised that students were still operating at backtracking, which he was surprised at as topic 1 dealt with inverse operations.

**Teaching practice**

- Unfortunately Bernard did not complete the SMART test for topic 2 until very late in his teaching so diagnosis could not change how he taught this topic.
- Bernard found different misunderstandings then they found in topic 1.
- The diagnosis did not lead them to revise concepts other than the particular topic.
- Although Bernard completed the SMART test for topic 2 late he found that he needed to revise directed numbers with his students.
- Not agree that the diagnosis helped them to improve their teaching.
- Although due to time constraints neutral or disagree responses were not subject to further questions it can be inferred that because Bernard did not complete SMART test for topic 2 until late so implies that the diagnosis would not be helpful, as he could not address any issues that came to light.

**Differentiation**

- Completed diagnosis too late to be of any use
- Too many misunderstandings to successfully group students
- Did revise other concepts due to diagnosis

**Follow up interview**

See Appendix 1 for the list of interview questions.

- Have used SMART tests for year 8 planning to extend this
- Benefits are; it gives you where students are at and you can see the common problems/misunderstandings with the topic
- Diagnosis could be improved by being more concise
- Best to do test at the beginning of topic
• Helped in teaching practice as more prepared for class
• Know where students are at and what problems to expect
• Not sure if helped with outcomes but improves teacher preparation
• Great advantage
Appendix 7 – Chen

Pre-topic 1 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 1 (linear equations) began. The following is a summary of the interview, which has been paraphrased.

- Uses previous knowledge of student misunderstanding
- Asks questions of students to find out prior knowledge
- Focuses on terminology, step by step, work habits
- Changes; more focus on terminology, teach basic skills (revise)
- Use some concrete materials

Pre-topic 2 interview
See Appendix 1 for the list of interview questions. This interview took place before the teaching of topic 2 (linear graphs) began. The following is a summary of the interview, which has been paraphrased.

- Uses previous teaching experience
- Uses many examples to demonstrate theory
- Change to curriculum to an MAV PD
- Using more ICT
- Only extension students will do different work
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Post-topic 1 interview
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Knowledge
• Found a variety of misunderstandings these were problems associated with directed numbers, fractions, understanding pronumerals, order of operations, terminology, and application style questions.
• Chen states the SMART test was too hard and could not gain an accurate picture from the analysis so difficult to determine the specific misunderstandings his students had.
• Said that the diagnosis did not match their expectation of student ability for topic 1. Chen was neutral about if the diagnosis matched his expectations as he found the test much too difficult for his students to the point where any the more capable students could not do the test.
• Teachers that stated that the diagnosis did not help them learn about student misunderstandings said that they had been teaching year 9 long enough to be aware of specific misunderstandings surrounding this topic
• Chen who did not like the test at all stated that the diagnostic and the SMART test web site gave him some ideas surrounding linear equations misunderstanding to consider when he was teaching. He reported that he looked at them carefully so he could include explicit teaching around the common misconceptions.
• Chen said that their students had no idea about linear graphs and on further questioning discovered that students had had no real experience of linear graphing previous to year 9.

Teaching practice
• The diagnosis did not changed the way they taught either topic
• Chen found both the SMART tests were too difficult for his students and found they had limited value for him. He thought that it could have been due
to the students having no experience with the style of questions. He did find realise that for both topic he had to start with early concepts.

- The diagnosis did not led them to revise concepts other than the particular topic. Chen had a similar view that the teacher knew they had to revise the major concepts but he also stated that the SMART test website gave him concepts to think about. That it showed him the concepts that students had difficulties with and the reasons why so he could include that in his revision.
- Chen disagreed that the diagnosis made it easier to focus on student difficulties. They both said it was great to have what they felt about their students confirmed
- The diagnosis helped Chen by highlighting that his students had either forgotten or not consolidated knowledge from previous years leading to their difficulty in completing the SMART test. This indicated to him that he had to start both topics from very early concepts.
- Chen did not find the diagnosis specifically highlighted to them areas that needed to be revised that were topic specific. Questions were not asked for their reasons for this due to time constraints.
- Chen did not agree that the diagnosis helped them to improve their teaching. Chen previously stated that the test was too hard for his students so it was of limited value, as he had to start the topics at the very beginning.

**Differentiation**

- Class work at same pace
- As all students at same/similar level.
- Test too hard
- Had to start at the beginning of topic
- SMART gave idea of common misunderstandings and some ideas to investigate/take note of

**Post-topic 2 interview**

See Appendix 1 for the list of interview questions. This interview was conducted at the conclusion of teaching of topic 2 (linear graphs) approximately 30 minutes after the questionnaire had been completed. The following is a summary of the interview,
which has been paraphrased. The interview has been divided into sections relevant to each research question.

Knowledge

- Chen reported that the test was too hard and found that the students had no understanding of linear graphs. He had to start from the very beginning of the topic.
- However Chen found that the SMART test for topic 2 was too difficult for students, as they had had little experience of this topic previously. This is a diagnosis in itself as if students cannot complete the test it gives the teacher an idea of the lack of knowledge in this particular topic and that they cannot assume any prior knowledge.
- For topic 2 Chen found that students had difficulty understanding graphs.
- Chen trialled a new approach that he had seen at the MAV conference at the end of 2011. This approach had a completely different sequence of teaching linear graphs to what had been previously done at this school. It began with hands on activities looking at gradient, then went on to introduce the concept of drawing a graph from the gradient.

Teaching practice

- Chen found both the SMART tests were too difficult for his students and found they had limited value for him. He thought that it could have been due to the students having no experience with the style of questions. He did find realise that for both topic he had to start with early concepts. Chen change completely the way he taught topic 2 and this was due to attending a lecture at the annual Mathematics Conference for teachers (MAVCon) run by the Maths Association of Victoria. He said he trialled this new or different way of approaching linear graphs and found it very successful.
- Neither Chen found that the diagnosis did not lead them to revise concepts other than the particular topic. Chen had a similar view that the teacher knew they had to revise the major concepts but he also stated that the SMART test website gave him concepts to think about. That it showed him the concepts that students had difficulties with and the reasons why so he could include that in his revision. Chen had a similar experience with topic 2.
The diagnosis helped Chen by highlighting that his students had either forgotten or not consolidated knowledge from previous years leading to their difficulty in completing the SMART test. This indicated to him that he had to start both topics from very early concepts. Svetlana also found this for topic 2. Chen used ideas of student misunderstanding to focus revisions sessions before final assessment of topic 2.

**Differentiation**

- SMART test too hard so all students at same level
- Used some of the ideas from website to guide teaching of concepts.

**Follow up interview**

See Appendix 1 for the list of interview questions.

- Have not continued to use because tests too hard
- If teacher looks might use a lower level test or use at year 10
- Has lots of benefits though
- Website good to use once you have used it once – some initial problems
- Use SMART at beginning
- Depends on topic where to use, depend on what teacher is using it for – i.e. test knowledge learnt for topic or finding gaps in prior knowledge
- SMART has helped in guiding teaching
- More mindful of common misunderstandings
- SMART improves students outcome but only if teacher acts on the information received
Author/s:
QUENETTE, JACQUELINE

Title:
Diagnostic testing and changes to teaching practice in Year 9 mathematics classes

Date:
2014

Persistent Link:
http://hdl.handle.net/11343/43027

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