Chapter One

Introduction

Background of the study

Richard Feynman, winner of a Nobel prize for his work in nuclear physics, was once asked in an interview whether an ordinary person could learn what he had learned. His answer was clear and definite.

> You ask me if an ordinary person, by studying hard, could get to be able to imagine these things like I imagine them? Of course. I was an ordinary person, who studied hard. There's no miracle people. It just happens they got interested in this thing and they learned all this stuff. They're just people. There's no talent or special miracle ability to understand quantum mechanics or miracle ability to imagine electromagnetic fields, that comes without practice and reading and learning and study. So if you say, you take an ordinary person who is willing to devote a great deal of time and study and work and thinking and mathematics and … then he's become a scientist.
> (Nebulajr, 2009)

This quote revealed several qualities that Richard Feynman encapsulated, not least of which might be seen as humility. But it is actually more profound and far reaching than that. Feynman articulated a belief that everyone is capable of significant learning, and that it is earned through constant effort, perseverance and problem-solving. It is a consequence of continued interest, curiosity, motivation, experiences and overcoming challenges. Feynman was known as being tenacious when faced with solving a puzzle or problem. He displayed resilience to setbacks and a lust for challenge, using creative methods to find solutions to difficult problems.

At another time, Feynman spoke about his thoughts on how one should learn, by focussing more on trying to understand than to memorise. He considered knowledge learnt based only on rote as "so fragile!" (Feynman, Leighton & Hutchings, 1985, p. 19). In another interview, he recalled when he was a child, watching his older cousin having considerable difficulty learning how to solve algebraic equations, something Feynman was able to do at the time. He observed that his cousin was trying to follow a set of rules without really understanding what it was that he was trying to do, which was evidence to Feynman as to why his cousin was not able to do it.

Rivalling his status as a scientist, Feynman was a renowned teacher, not only of students but also colleagues. It could be argued that his passion and positive attitude towards the subject, when combined with his belief in all people's potential to learn, was significant to his impact as a teacher. It is these qualities that serve as the starting point of this thesis, how they manifest and impact on preservice teachers' views and experiences of learning and teaching mathematics.

Teacher quality

Over recent years, there has been an increased focus on the quality and effectiveness of teachers. Politicians, researchers and the public have been wondering what are the qualities of an effective teacher? Teachers undoubtedly play a significant role in the development of their students and, in fact, recent research by Hattie and others (Hattie, 2009, 2012; Darling-Hammond & Lieberman, 2012) has shown that teachers are the single largest factor influencing student learning outcomes outside of the students themselves. This represents a greater impact than the effects of schools, principals, peers and the home. As well as the work from Hattie, the rising success of countries such as Finland and Singapore on international tests such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS), has contributed to a renewed focus on teacher quality. Pasi Sahlberg, the former Director-General of Finland's Ministry of Education and Culture, sees their success mainly resulting from the quality of their teachers. At the same time, Australia has slipped significantly in mathematical literacy, especially in the highest performing cohort. Consequently, many aspects of the schooling system are focused on improving these rankings, including teacher development in general and preservice teaching in particular. What are the underlying qualities of preservice teachers such as their skills, understandings and demeanours, that needs to be developed for them to become effective teachers?

Student-centred reforms

This recent emphasis on teacher quality has occurred in the context of decades-long reforms in mathematics education. Some of these initiatives have sought to make changes to the goals of students' learning experiences and the types of pedagogy to be used by teachers. In relation to the content, students are expected to achieve more than being fluent at mathematical procedures. Students are now also expected to demonstrate understanding, reasoning, problem-solving, and the ability to communicate these to others. This has meant that teachers are required to assess a broader set of criteria to determine a student's development, which has meant a shift in primary focus from what the teacher does to now carefully observing what a student can do. The emphasis is now on teachers to assess a student's individual development to determine necessary learning experiences for development and on meeting the needs of a large and diverse group of learners. These features of education have led to the use of the term ‘student-centred learning’, as it places the focus on the student and their needs. Despite many attempts to change, which began noticeably in the 1980s, teaching in Australian mathematics classrooms still significantly uses a teacher-centred approach focussing on the use of procedurally low-level, repetitive tasks with major focus on skills and fluency rather than developing conceptual understanding.

Effective teaching that meets contemporary goals is a real and important issue that teacher educators must address in their teaching of preservice teachers, in order to help ensure a high quality teaching community into the future. A cycle exists where students experience and learn within a significantly teacher-centred environment and believe that this is the only approach there is to mathematics education. Teachers are most likely to teach math just as they were taught (Ball, 1988). It is essential that teacher educators seek to break this cycle, by providing an opportunity for preservice teachers to question and critique their prior experience via a personal, student-centred learning environment; the aim is for the preservice teachers to develop deeper and richer understandings of the content and pedagogies associated with effective mathematics teaching. Understanding different types of preservice teachers and their experiences of teacher education approaches that potentially offers to break this cycle is worthy of investigation.

Beliefs and attitudes

Of special interest in this study was the affective aspect of preservice teachers and the role that beliefs, attitudes and prior experiences play in a person's view of learning and teaching mathematics. The predominant purpose of this study was to investigate how different beliefs and attitudes impact on their view of learning and teaching mathematics, and their teacher education experiences.

In relation to beliefs, research over a number of decades has seen significant developments in the psychology of learning. It has revealed the influence beliefs have on learning goals and consequently, behaviours in learning situations. These include one's belief about intelligence and the role it has as a causal factor of a person's learning goal – often a choice between either endeavouring to learn something or aiming to look smart to others. These two choices create two very different behaviours in a learning situation, especially when it is a challenging situation with a risk of failing. Students with mastery-oriented goals are more likely to seek out challenge, be resilient to failure and persevere. On the other hand, students with performance goals tend to avoid challenge, experience high levels of anxiety when facing failure and are less likely to persevere when times get tough.

Coupled with research on beliefs, there has been significant research interest in the attitudes of preservice teachers. A teacher's attitude, such as values and self-confidence, has an important influence on their practice, but also student affect. For example, a teacher with negative affect, such as a high anxiety towards mathematics, has a noticeable impact on students' affect. The importance of attitudes and beliefs were also recognised in the new 2012 NSW Australian K–10 mathematics syllabus. While some of the content objectives had changed from the 2002 syllabus, the values and attitudinal objectives did not. These objectives could be summarised as a positive attitude towards mathematics and a mastery orientation to learning. Specifically, these objectives encourage students to:

- *appreciate mathematics* as an essential and relevant part of life, recognising that its cross-cultural development has been largely in response to human needs
- demonstrate *interest, enjoyment and confidence* in the pursuit and application of mathematical knowledge, skills and understanding to solve everyday problems
- develop and demonstrate *perseverance* in undertaking mathematical *challenges*.

(emphasis added, Board of Studies NSW, 2012, p. 14)

The current state of mathematics teacher education in Australia is that many students entering preservice teacher education courses generally exhibit three common characteristics (Tobias, 2002). First, many express a negative attitude towards mathematics, experiencing strong feelings of anxiety and inadequacy when thinking about their ability to learn and teach mathematics. Secondly, students enter with different learning goals related to their implicit belief about the nature of intelligence. This belief refers to a view that intelligence is either primarily a fixed entity of a person that cannot be changed, or is something that can grow over time with effort and learning. These views of intelligence are particularly important in educational contexts as students who see intelligence as an emergent quality are more likely to be motivated, resilient to failure and achieve higher academic success than students who see intelligence as a rigid, non-developing quality. It is important to consider the role a teacher may play in the formation of a student's view of intelligence, as they spend a large amount of time together in learning environments. Thirdly, preservice teachers have more than likely had many experiences of a traditional, teacher-centred, didactic mathematics education, particularly in high school. These experiences involve learning with very little use of concrete materials, a rush to abstract representations, minimal opportunity to engage in discussion and collaboration, and a significant focus on skill acquirement and exam preparation. This is in stark contrast to the current student-centred reform movement that has been in existence since the 1980s. This reform asks teachers to adopt an approach that puts the students at the centre of learning, promotes a deeper understanding of the content, and creates experiences that lead students to have a positive attitude towards mathematics and its challenges. It is, therefore, important to understand teacher beliefs and attitudes, in an effort to improve teacher quality and student outcomes.

Problem-based learning

This study investigated the experiences of preservice teachers with differing views of intelligence and attitudes towards mathematics, and their experiences of a student-centred approach to a first-year mathematics teacher education subject. The semester-long unit utilised a problem-based learning (PBL) approach that focused on the use of student-centred pedagogies. These included the teacher acting as a facilitator rather than master, a focus on the role of assessment for learning in education, meeting the needs of the student, emphasis on group work, and development of student autonomy and independence.

Creation of the PBL unit began as a small 4-week pilot program in 2010 in anticipation of its greater use during 2011. It was created primarily by the researcher with contributions from other teaching colleagues. The researcher had the combined role of both the main developer of the unit and active participant in the teaching and research process. The unit used, as its central focus, analysis of four mathematics educational scenarios which served as the main stimulus for learning. These scenarios were complemented with other activities, such as mathematics content tasks, completed independently, and lectures. The research project reports on the preservice teachers' experiences of the PBL unit, along with how their beliefs and attitudes changed over the semester. Overall, the intent was to create broad and meaningful learning experiences in a student-centred environment, which challenged preservice teachers to explore and investigate educational situations in an educationally authentic and contextual manner.

Statement of the problem

Decades of reforms have pursued a shift from teacher-centred learning approaches to pedagogies more aligned with meeting the needs of individual students, commonly known as student-centred learning. This shift has not only been explored in primary and secondary schools but also teacher education at university, as an appropriate method for educating preservice teachers. The historical and, in many cases, the common method of teacher education in universities has been more aligned towards teacher-centred, lecture and tutorial approaches, and less towards meeting the needs of individual students. There are a number of reasons for this that are unique to higher education establishments.

These include far less teaching time than schools, sometimes very large groups, students studying by distance (off-campus) and staff workload constraints. This has the potential to possibly create a dissonance between the pedagogies preservice teachers are being asked to use in school and the learning experiences they have while at university (which is consistent with their school experiences).

The NSW Australian syllabus (2012) seeks that students have a positive attitude towards mathematics and mastery-oriented learning goals (as a consequence of an emergent view of intelligence), yet it is reported that many students entering preservice teacher education courses do so with a more varied combination of attitudes and beliefs about learning and mathematics. Many of these students express a lack of self-confidence, enjoyment and motivation to undertake mathematics, and experience feelings of anxiety and lack of willingness to persevere when confronted with challenging mathematical tasks. Undoubtedly, these attitudes and beliefs are a significant consequence of the many classroom experiences and personal encounters they had while at school or in other educational environments. This is, therefore, an important concern to the education community, with the prospect of preservice teachers entering the profession who have a negative attitude towards mathematics and performance goals, and significant experience of teacher-centre approaches to learning. Teacher educators need to better understand and address these differing preservice teachers' orientations in order to more appropriately meet their needs and model effective student-centred approaches that will be required when they begin their teaching.

This thesis represents a research opportunity to investigate the influence attitudes and beliefs have on preservice teachers' views of learning and teaching mathematics. Consequently, the following research questions were used to guide the study:

1. How do preservice teachers' attitudes towards mathematics, and beliefs about intelligence, relate to how they view the learning and teaching of mathematics?

2. How do preservice teachers with different beliefs about intelligence, and attitudes towards mathematics, respond to the qualities of the student-centred, PBL approach to learning mathematics education?

3. How does the student-centred, PBL approach affect preservice teachers' attitudes towards mathematics and beliefs about intelligence relating to mathematics education?

Each question seeks to understand more fully the relationship between preservice teachers' attitude towards mathematics, their view of intelligence and their response to a student-centred approach.

Purpose of the study

The main purpose of this study was to understand the past experiences of preservice teachers with differing attitudes and views of intelligence, and their experiences of learning in a student-centred mathematics education program. The study sought to identify the key themes in the participants' past experiences that may have influenced their current attitudes and beliefs, and how these played a role in their learning experience of the PBL unit. The intent of the unit was to help the students bring to the forefront an awareness of their own experiences and views on the teaching and learning of mathematics, and the role these play in their own learning and teaching of mathematics. The findings of the study were envisaged to assist teacher educators of mathematics to better understand the variety of students they teach and what the preservice teachers bring to their own learning and future teaching.

Thesis overview

Chapter 2 provides a review of the related research and theory relevant to this study. Namely, the three key elements of (1) attitudes, (2) views of intelligence (and learning goals) and (3) student-centred learning. First, a thorough summary and analysis is presented of the recent research on the state of primary teacher education in mathematics, and the role of the affective domain in preservice primary teachers of mathematics. It outlines the impact attitudes have played in educational contexts and the challenges faced by teacher educators in the area of mathematics. Continuing the theme of the affective domain, the next section of the chapter outlines the theories and research related to views of intelligence and learning goals, and identifies the limited research that has been done in the area of preservice teaching. It includes psychology research that investigated the impact motivation has on learning, such as learned helplessness. It also provides the fundamental ideas and studies underpinning the aspects relevant to the study, as well as the areas requiring further research. Finally, the chapter reviews the focus of student-centred approaches in mathematics education by providing research of its impact, the historical narrative, the defining aspects and its contemporary position in mathematics education. As well, this section provides a detailed description and examination of the research on problem-based learning (PBL), mainly from the field of medicine, then outlines the historical and theoretical background of PBL, and provides a summary of the qualities considered to define this specific type of pedagogy. Included in the section are reports on the benefits, criticisms and challenges of problem-based learning, and it also identifies the potential areas of further research.

Chapter 3 describes the methodology and methods used to frame and address the research questions informing the study. It outlines and justifies the use of a comparative case study format, and the role of the quantitative and qualitative methods in the data collection process. Acknowledged is the related research which also utilised similar methods and subsequently influenced the selection of the methods for this study. Included are descriptions of various quantitative and qualitative research components that were used to gather data to address the research questions. Quantitative data was gathered through surveying the preservice teachers in the unit, while qualitative data was collected through various methods, including a questionnaire and semi-structured interviews. These methods are discussed and justified in this chapter. In conclusion, the development of the unit is explained, including a minor pilot study looking at the implementation of the PBL unit which was conducted before the main study. A detailed description of the final PBL unit is provided, including the teaching and learning framework utilised for preservice teaching.

Chapter 4 presents the quantitative and qualitative results from the main study. The outcomes of the surveys are reported initially, followed by several key informant case studies that were used to capture a rich, contextual and varied account of the different learners entering teacher education and their experiences during the PBL unit.

Chapter 5 includes a description and analysis of the results presented in Chapter 4. The research questions presented in Chapter 3 are answered and relate to the impact attitude towards mathematics, and views of intelligence have on learning and teaching mathematics for preservice teachers. This includes preservice teachers' response to student-centred learning in a mathematics education unit that incorporated a problem-based learning approach. Finally, the chapter provides a report on the limitations of the study, which may have affected the results of the investigation, the implications and potential areas for further study.

Conclusion

This chapter provided a brief outline of the background and overview of this study. There are many challenges facing teacher educators as they attempt to best prepare future teachers for the inherent complexity of teaching, and at the same time, recognise the varied needs of the students who have chosen to become primary mathematics teachers. These include students with positive and negative attitudes to mathematics, performance- and mastery-oriented learning goals, and significant experiences of teacher-centred learning. The next chapter will go into these different aspects in detail with a review of the research literature.

Chapter Two

Literature Review

Introduction

This chapter evaluates the literature related to the affective domain and student-centred education in preservice education for primary school teachers. Specifically, the selected areas this study investigated were the preservice teachers' attitudes towards mathematics and their implicit theories of intelligence, and how these impacted on their experience of learning and teaching of mathematics. The outline of this chapter is structured in five main parts. First, an overview of the affective domain is provided, followed by a discussion of the prevailing theories, research findings and research opportunities that exist in the areas of attitude towards mathematics and implicit theories of intelligence. The final two sections look at the focus of student-centred learning within recent reform efforts, including an overview of problem-based learning as a potentially effective form of experiencing student-centred learning.

Affective domain

International interest in the impact of affect in mathematics education began in earnest during the 1960s (McLeod, 1992; Leder and Grootenboer, 2005), peaking in the mid-nineties (http://bit.ly/1VaCKP1). This has occurred alongside the rise of student-centred educational reforms starting at the same time, as a result of a more holistic approach to education (Lambdin & Walcott, 2007), as well as a focus on higher-order thinking (McLeod, 1992). McLeod indicates that the extensive behaviourist movement in the first half of the 20th century was a significant contributor to the delay in recognising the importance of the affective domain in learning. This stems from the behaviourist's reluctance to delve into the inner processes related to affect, and rely on data that is gathered through introspection or verbal responses.

The growing body of research in the last few decades has brought into focus the importance a student's affect has in their overall intellectual and emotional development. This importance has been affirmed with reference in official documents from organisations, such as the National Council of Teachers of Mathematics (NCTM) and the NSW Board of Studies (2002, 2012), who include positive affect objectives in the learning of mathematics. These include students seeing the value of mathematics, as well as enjoying and feeling motivated to take on the challenge of mathematics (Board of Studies NSW, 2012). Research found that emotions have important consequences to cognitive processing, such as biasing attention and memory, and activating action tendencies (Hannula, 2002; Di Martino & Zan, 2011).

The *affective domain* has been defined in various ways over the decades, with different emphasises being made on various factors. From the 1980s, there was an increasing view that the previous research of affect in mathematics education was in major need of greater clarity in theory and definition (Di Martino & Zan, 2015). In response, McLeod (1992) wrote an influential chapter, 'Research on affect in mathematics education: a reconceptualization' in the

Handbook of Research on Mathematics Teaching and Learning. Due to its impact, it is used as a key source in this section on affect.

The common theme throughout the studies on affect is the focus on the internal processes of a person (Martin & Reigeluth, 2013). The term, *affective domain*, as used in mathematics education research, is mostly understood to be a general term "investigating the interplay between cognitive and emotional aspects" (Di Martino & Zan, 2011, p. 1). It encompasses a number of subdomains, with varying degrees of cognition and stability. McLeod (1992) listed three subdomains (also called components and constructs) within the affective domain, as (1) *emotions*, (2) *attitudes*, (3) *beliefs*. DeBellis and Goldin (1999) included a fourth subdomain of (4) *values*, *ethics*, and *morals*. There has been, and continues to be, an ongoing challenge to encompass the complex interactions between the subdomains (Leder and Grootenboer, 2005; Zan, Brown, Evans & Hannula, 2006), as well as its relationship with the *cognitive domain* (White, Way, Perry & Southwell, 2006). McLeod (1992) suggests that these subdomains, as related to mathematics education, could be conceptualised as a continuum, with varying degrees of contribution from the cognitive and affective domains and varying degrees of stability (Leder and Grootenboer, 2005). For example, *emotions* can be considered as mostly affective, rapidly changing and with very little cognition, while *beliefs* are usually highly cognitive, stable with less affectivity than *emotions* and *attitudes* (Goldin, 2002). The two subdomains most relevant to this study are *attitudes* and *beliefs*. These details are shown diagrammatically in Figure 2.1

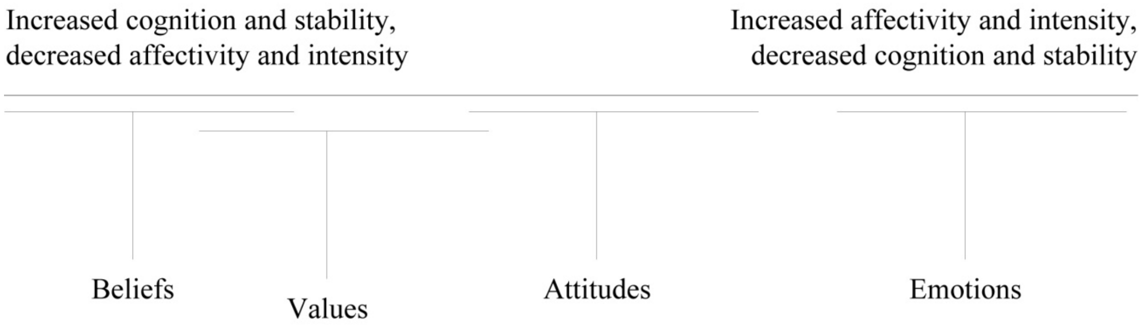


Figure 2.1 – Adapted from a model of conceptions of the affective domain (Leder & Grootenboer, 2005)

There is a growing acceptance of interrelationships between cognitions and feelings. Mandler (1984, 1989) approached the affective domain from a cognitive perspective using a constructivist paradigm. He proposed that most affective factors come about from a disruption to planned behaviours. Another way to express this phenomenon is that arousal is caused by an interruption to ongoing mental activity. McLeod (1992) explains that a plan of behaviour is activated by a *schema*, which can be thought of as mental structure of preconceived ideas. This schema then produces an action sequence or an intended set of behaviours. If these behaviours are interrupted, a physiological response or emotion occurs. To describe this phenomenon through example, consider a student who is required to complete a geometric proof that they expect to answer in a short amount of time, which is the planned behaviour. If the student is unable to complete the task in that short time, a physiological arousal occurs. This might include an increased heart rate, tensing of muscles and a feeling of frustration. The arousal, which in this case might be negative, acts as a mechanism to direct the student's attention towards action. The "subjective experience of emotion is a combination of visceral arousal and a cognitive assessment of the experience. Therefore it is not the experience itself that causes emotion, but rather the interpretation that one gives to the experience" (Di Martino & Zan, 2011, p. 5). The issue of concern is the impact of repeated negative emotions and reactions towards the task. The important aspect is to recognise the interplay between cognition and affect when learning and that "purposeful action is based on attention to both affect and cognition" (Martin & Reigeluth, 2013, p. 488).

Krathwohl, Bloom and Masia (1964) created a well-known 'affective taxonomy' based on the idea of *internalisation*, which refers to the extent to which an aspect of a person's affect, such as an attitude or value, becomes increasingly a part of a person. The amount of internalisation that has occurred is considered to be proportional to the amount that the affective aspect begins to guide and influence their behaviour. This study was interested in investigating participants who appeared to have greater internalisation of a particular attitude and belief, as seen by their relatively extreme scores on attitude and belief surveys.

Investigating the affective domain in mathematics education is of significant importance as observations have been made that clearly show that emotional nurturing supports intellectual and emotional health, as well as helping people master various cognitive tasks. Martin and Reigeluth (2013) see that:

> [R]ather than emotional development being separate from but equal in importance to cognitive development, it is an essential foundation for and component of development.
>
> (Martin & Reigeluth, 2013, p. 489)

The following sections will look at *attitudes* and *beliefs* separately, provide their definitions, and report on the recent research in mathematics education relevant to this study. It will include work from Australian researchers who, as a community, have also shown significant interest in investigating the issues of the affective domain in mathematics education. In fact, so much so that every four years, the Mathematics Education Research Group Australasia (MERGA), dedicates a chapter in the journal of *Research in Mathematics Education in Australasia* to summarising the research and trend of publications by the Australasian research community. Chapters have been written in 2004, 2008 and 2012. Di Martino and Zan (2001, 2009, 2010, 2011, 2015) also did significant work in the area of attitudes in mathematics, particularly from a theoretical perspective.

Attitudes

Theoretical perspective

Attitudes towards mathematics have been of interest to researchers from the mid-20th century (Di Martino & Zan, 2015). Sometimes referred to as *disposition* (Beswick, Watson & Brown, 2006), it is seen as an aspect of a person that has direct influence on one's behaviour and choices. Initial investigations in the 1960s rarely provided an explicit definition of attitude and simply implied 'the tendency [of a person] to behave in a certain way' (Di Martino & Zan, 2015, p. 53). During this time, research into attitudes was primarily quantitative and statistical, with a positivist paradigm. There was a significant focus and effort to identify causal correlations with other variables, such as achievement (Di Martino & Zan, 2015). It was observed that there was a clear correlation between a positive attitude and high academic achievement. Research has still failed to show a consistent, clear, causal relationship in the direction of attitude leads to achievement (Di Martino & Zan, 2015; White et al., 2006; Hannula, 2002). This focus on proving that achievement is a consequence of attitude was undermined by a lack of theoretical clarification, and dissonance between theory and methods. As they were using a positivist paradigm, which relies on clear definitions and isolating variables, it was not supported by a robust theoretical underpinning (Di Martino & Zan, 2015; Hannula, 2002).

Researchers recognised these limitations of the early research into attitudes in mathematics education. Leder (1987) described early attempts to measure attitude as using a unidimensional view of attitude, ignoring the various components which contribute towards the construction of attitude. Despite this lack of theoretical underpinning and measurement of attitude between the 1960s and 1980s, the abundance of results did reveal that mathematics learning was not only influenced by cognitive factors, but crucially and in combination with 'non-cognitive' factors (Di Martino & Zan, 2015). It changed the long-held view that mathematics learning was strictly a thinking activity and solidified the research of affective issues in mathematics as an essential branch of study.

McLeod's (1992) seminal chapter highlighted a number of issues at the time, some of which continue today. These include the use of terminology and definitions (Leder, 1987). The affective domain seems particularly difficult to define terms with complete clarity, as terms can have different meanings in psychology, as well different intensities. For example, in some studies *anxiety* meant fear, which is an intense emotion, while other researchers have used it to refer to more mild states such as a ‘dislike’ or ‘worry’ (McLeod, 1992). The definition of *attitude* in many studies was either absent or, if a definition was explicitly given, they did “not share a single definition” (Zan & Di Martino, 2009, p. 29).

There have been some commonalities and long-accepted aspects of the definition of attitude. These include that an attitude towards an object, a situation, a notion or a person:

- can be evaluated as either negative or positive
- has a certain level of stability, and
- is considered to have been learned from experiences

(Di Martino & Zan, 2015; White et al., 2006; Leder, 1987).

Di Martino and Zan (2001) considered two different views, referring to them as the ‘simple’ and ‘articulated’ definitions. These also begin to attempt to name the parts that contribute to attitude. The “simple” definition sees attitude as just emotional responses, while the “articulated” definition includes both emotional and cognitive contributions.

- A “simple” definition of attitude describes it as the positive or negative degree of affect associated to a certain subject. According to this point of view the attitude toward mathematics is just a positive or negative emotional disposition toward mathematics.
- A more “articulated” one recognises three components in the attitude: an emotional response, the beliefs regarding the subject, the behaviour toward the subject. From this point of view an individual’s attitude

> toward mathematics is defined in a more articulated way by the emotions that he/she associates to mathematics (which, however, have a positive or negative value), by the beliefs that the individual has regarding mathematics, and by how he/she behaves
>
> (Di Martino & Zan, 2001, p. 3).

It could be said that this "simple" definition of attitude is an example of Leder's (1987) criticism of analysing attitude unidimensionally, rather than adopting a multidimensional analysis. The 'simple' definition was discussed in McLeod (1992), who stated a hypothesis that attitude develops from repeated emotional responses. For example, if a student has repeatedly negative emotions towards geometric proofs, then this will create a negative attitude towards geometric proofs. The criticism of this definition is the omission of the role cognition and beliefs play in the construction of attitudes. It simply sees attitude as only an extension of continued emotional responses. This was despite McLeod referring to Mandler's theory of emotions (1984), which acknowledges the contribution cognition plays in the creation of an emotion. Mandler's theory is applied to the most frequent view of emotions, and emphasises the explicit component of cognition in emotions (Di Martino & Zan, 2011). Only seeing attitude as created from emotion also raises questions about its meaningfulness. Di Martino and Zan (2001) raised this concern in relation to the learning of mathematics:

> Accepting this definition, it is quite clear that 'positive attitude' means positive emotional disposition. It is thus important to question why a positive emotional attitude is meaningful in the context of mathematics education.
>
> … it seems to us that to promote a general positive emotional disposition toward mathematics is not very significant, if this disposition is not linked with an epistemologically correct view of the discipline. In other

> words an affective goal of mathematics education is to promote a 'view of mathematics as vibrant, challenging, creative, interesting, and constructive'
>
> (Silver, 1987, p. 57).

The "articulated" view of attitude, which this study adopts, seeks to define attitude as a construct involving emotional, behavioural and cognitive dimensions, in the form of beliefs. In this sense, it is important to consider emotions along with certain beliefs, which automatically involves a greater component of cognition (Di Martino & Zan, 2001). For instance, the belief statement "mathematics is one of the most important subjects for people to study", should be considered along with an emotional component, such as "and I like this" or "I don't like this" (Di Martino and Zan, 2011). It may be that this could be implied via another question, such as "mathematics is one of my most dreaded subjects". It is possible then for people to have a shared belief but a different attitude. Based on the work of Ajzen and Fishbein (1980), "attitudes must, therefore, be regarded as the result of all of the relevant beliefs the individual holds" (Beswick, 2006a, p. 37). It is important to note that the converse also holds, that two people may have the same attitude, but this could be the result of opposite beliefs. This is particularly important in this study, which investigates preservice teachers of similar/opposite attitudes towards mathematics and similar/opposite beliefs about learning and intelligence.

The "articulated" definition describes attitude as a multidimensional construct, which addresses Leder's criticism and offers a fuller view of attitude, but it also adds complexity and challenges. Di Martino and Zan (2001) raised concerns about giving a single score as an adequate measure of attitude, while viewing it as a multidimensional construct. They offer an alternative, which is to "probe" with qualitative methods, rather than attitude just being quantified by a score. Di Martino and Zan (2001) suggest to "give up 'measuring' attitude and describe it qualitatively with the pattern beliefs/emotions/behavior and the connections between them" (Di Martino & Zan, 2001, p. 5).

Hannula (2002) also used emotion and cognition as two central aspects to conceptualising attitude, seeing them as complementary aspects of the mind, but placed emotions as "more central to attitudes than cognition is" (p. 28). While cognition is neuron-based information processing, emotions include other physiological reactions. Emotions are seen as always being connected to personal goals, involve a physiological reaction (as distinct from non-emotional cognition) and are functional to human coping and adaptation. The basic set of emotions are: happiness, sadness, fear, anger, disgust and interest. Hannula (2002) says that "a student may express liking or disliking of mathematics because of emotions, expectations and values" (p. 30). This appears to view attitude as an interplay of emotions, planned behaviours, beliefs and values.

Definition

Based on the previous discussion regarding the different theoretical aspects of attitude, this study uses the term *attitude* to mean a multidimensional construct of a person towards an object, a situation, a notion or a person involving emotional responses, beliefs and behaviours. Attitudes are considered as being learned, have some degree of stability, have influence over behaviour and can be judged as either negative or positive (Leder, 1987; White et al., 2006; Beswick, Watson & Brown, 2006).

Research findings

Attitudes towards mathematics have a long history in research. The early studies investigated the link between achievement and attitude, due to its well-known direct correlation (McLeod, 1992; Di Martino & Zan, 2015). Namely, those with positive attitudes achieved more highly and undertook more difficult courses/units of mathematics than people with negative attitudes. There was an attempt to prove that attitude was the causal factor in achievement, implying that if a student could have a positive attitude, then achievement would follow. It was almost as though it was seen as the 'silver bullet' to achievement in mathematics. Research has since failed to show this clearly and consistently, suggesting that attitude and achievement are not dependent on each other, but that they do interact with each other in "complex and unpredictable ways" (McLeod, 1992, p. 582; White, Way, Perry & Southwell, 2006).

In recent times, there have been few studies conducted on attitudes towards mathematics in the Australasian region (Lomas, Grootenboer & Attard, 2012), especially related to preservice teachers. Some investigations have studied attitudes in the context of mathematical content. For example, Meaney and Lange (2010) conducted a study inquiring as to the affective responses of preservice teachers to being 'tested' on primary school mathematics content knowledge. They found that the focus on performance and content rather than mastering and understanding exacerbated "a reliance on procedural rather than conceptual understanding" (p. 399) and could have a negative impact on future teachers. Young-Loveridge (2010) studied the attitudes of preservice teachers towards both teaching and learning mathematics and found that preservice teachers can have different attitudes about these two notions. In some cases, this difference produced perhaps unexpected outcomes.

> Only 47% of the students were positive about both mathematics and the teaching of mathematics. However, students' reasons for their ratings revealed that a negative attitude towards mathematics sometimes resulted in enthusiasm about helping children to have better experiences than they themselves had had at school. Some students with positive attitudes towards mathematics worried about the responsibility of providing high quality teaching experiences in mathematics for children. The study showed that this issue is complex and attitudes towards teaching mathematics may be different from attitudes towards mathematics.
>
> (Young-Loveridge, 2010, p. 705)

A commonality among other teacher-related studies showed "that student learning was enhanced by the positive attitudes of teachers who were able to plan and modify tasks to suit specific student needs" (Lomas, Grootenboer & Attard, 2012, p. 28).

Research on attitudes has often been conducted along with beliefs, making it difficult to separate (McLeod, 1992; White et al., 2006; Beswick, 2006a). Despite this challenge, a number of studies have looked at attitudes and beliefs together.

Zan and Di Martino (2009) looked at learned helplessness, which is a perceived lack of control of an event, as an 'attitude' towards mathematics. Prior to this paper, learned helplessness had been studied in relation to student motivation and seen as a barrier to achievement (Zan & Di Martino, 2009). The study used a three-factor model of attitude towards mathematics: (1) view of mathematics, (2) emotional disposition towards mathematics and (3) perceived competence in mathematics. The researchers suggested that “the perception of lack of control on success in mathematics is associated with a ‘negative’ view of the discipline. In this case, a teaching intervention aimed at helping students overcome their low competence cannot go without modifying their view of mathematics” (p. 6). Essentially, people who believed they have a lack of control in their success did not have a positive view of mathematics. The researchers believed it was ineffective to only focus on improving competence, and a modification of their beliefs (helplessness in this case) was necessary. This finding raises a broader question about attitudes towards mathematics along with beliefs about learning and intelligence. Other research has established that learned helplessness is caused by a belief that will be discussed in detail later in this chapter.

In relation to preservice teachers, an extensive number of studies have investigated the affective aspects in relation to learning and teaching mathematics and have found a very significant number of students feel negative emotions and attitudes towards mathematics learning and teaching. These studies have included preservice teachers having high levels of anxiety, low levels of self-efficacy, and low achievement and performance levels (Cady and Rearden, 2007; Brown, Westenskow & Moyer-Packenham, 2012; Jackson, 2015; Riegle-Crumb, Morton, Moore, Chimonidou, Labrake, Kopp, 2015). Preservice teachers’ negative attitudes and anxiety have also correlated with their beliefs in their ability to teach mathematics effectively (Bursal & Paznokas, 2006; Bates, Latham & Kim, 2011).

In a study by Cady and Rearden (2007), it was found that nearly half of their 47 preservice primary education teachers admitted to feeling high to very high levels of anxiety towards mathematics. The preservice teachers in this study believed their anxiety was due to their prior experiences in mathematics and largely due to their teachers of the subject. Nearly all of these preservice teachers indicated that mathematics teachers influenced their belief about the subject, in either a positive or negative way.

Currently, there appears an area of research opportunity related to attitudes and beliefs about learning, particularly with preservice teachers. While some studies have looked at attitude and beliefs, these have mostly investigated it in the context of mathematical content, achievement or teacher practice. There is a place for a study of preservice teachers' attitudes towards mathematics and their belief about learning. Di Martino and Zan (2010) touched on similar ideas by focusing on learned helplessness. This study was broadened in focus to include more than learned helplessness by investigating its causes, which entailed beliefs about intelligence and achievement goals. The gap in the literature will become more apparent and is discussed in further detail in the following section, which considers beliefs from a theoretical perspective and the studies related to implicit theories of intelligence.

Beliefs

Theoretical perspective

Beliefs have been of interest to researchers of mathematics education for many decades. This is based on the premise that a person's behaviours and decision-making processes are underpinned by their beliefs (Piaget, 1928; Ajzen & Fishbein, 1980; McLeod, 1992; Di Martino & Zan, 2011) and seen as a “persuasive influence” (Grootenboer, 2008, p. 479) on teaching practice and pace of educational reforms (Handal & Herrington, 2003). As such, *belief* has been an integral part of recent reforms in mathematics education. It has been seen as a way to influence teacher practice, and is evidenced in the growing body of research mainly focused on exploring the relationship between a teacher’s beliefs, their practice and change in beliefs (Grootenboer, Lomas & Ingram, 2008). It is well documented, however, that beliefs are difficult to change, and that preservice teachers begin their university degree with firmly established beliefs regarding teaching and learning (White et al., 2006; Beswick, 2006b). Despite this, there is some evidence that change in preservice teachers’ beliefs about the teaching and learning of mathematics is possible (Tobias, 2002; Beswick, 2006a), but that these changes can be fragile and temporary when they begin teaching in schools (Tobias, 2002). These teacher beliefs have an impact on student performance (Bohlmann & Weinstein, 2013; Madni, Baker, Chow, Delacruz, Griffin, 2015) and influence preservice teachers’ interpretation of their teacher education program (Cady & Rearden, 2007).

Like many of the affective constructs investigated in the early studies, the term ‘belief’ was often not explicitly defined (McLeod & McLeod, 2002). A common aspect of the definitions provided is that *beliefs* are understood as anything that a person regards as true (e.g. Ashman & McBain, 2011; Beswick, 2007; White et al., 2006). For many studies, that is the extent of the definition provided, if at all. While it has a less ambiguous theoretical framework than attitude, there has been no clear agreement on the definition of belief. Based on the affective continuum of Leder and Grootenboer (2005), beliefs are considered distinct from *values*, *attitudes* and *knowledge*.

First, researchers have in the past used the terms *belief* and *values* interchangeably, due to the view that there is more in common between them than different (Philipp, 2007). In an effort to separate them, Clarkson, Fitzsimons, and Seah (1999) expressed the distinction between values and beliefs as values being "demonstrated in the actions carried out by a person, whereas beliefs can be verbally assented to, but do not necessarily lead to observable behavior in public" (p. 3). From this perspective, values are seen as enacted beliefs (Grootenboer & Hemmings, 2007). This thesis primarily looked at beliefs rather than values, as only a very small amount of data was obtained from observational methods.

Secondly, beliefs are distinct from attitudes due to the greater contribution of cognition and higher level of stability (Ajzen & Fishbein, 1980; McLeod, 1992; Di Martino & Zan, 2015). This has raised questions as to whether or not beliefs do belong in the affective or cognitive domain (Philipp, 2007; White et al., 2006). There appears a general acceptance, however, of it belonging more to the affective domain, particularly when studied with other affective aspects, such as attitude (Abelson, 1979; Speer, 2005; Philipp, 2007; Di Martino & Zan, 2011). McLeod and McLeod (2002) and others (e.g. Di Martino & Zan, 2011) see beliefs as the connection between cognition and emotion. Attitudes are nearly always judged as either positive or negative, whereas beliefs are "non-evaluative" (Beswick, 2006a, p. 37). Some studies take a different view, referring to beliefs as "positive" or "negative" (e.g. White et al., 2006). This study chose not to judge beliefs as "positive" or "negative".

Finally, beliefs are considered by many researchers as distinguishable from knowledge, mainly due to the different degrees of *conviction* and *consensuality* (Philipp, 2007; Thompson, 1992). First, beliefs are not all held with the same degree of strength, with some beliefs being more important than others. Knowledge on the other hand is considered to have much more certainty to a person. Secondly, beliefs are not consensual whereas knowledge is. The reason for this has to do with the ability to disprove. People may have different beliefs that cannot be disproved, but there is "general agreement about procedures for evaluating and judging its validity" when considering knowledge (Thompson, 1992, p. 130). Some researchers, however, see this distinction as unimportant for research purposes (Philipp, 2007), as "knowing" and "not knowing" is simply the same as "believing" and "not believing". This study primarily focuses on a person's view about their ability to grow their intelligence, which is seen in this study as a belief.

A belief exists as part of a system of beliefs. This section will describe briefly the three aspects of belief systems related to the work of Green (1971) and Thompson (1992), which are *structure*, *centrality* and *clustering*. First, belief systems are structured in a quasi-logical way, which Philipp (2007) framed as some beliefs being *primary beliefs* while others are *derivative beliefs*. Not all beliefs are of equal importance or influence and primary beliefs impact other beliefs. This implies that a primary belief will influence derivative beliefs, which consequently, impacts on behaviours. An example of this is a student who believes mathematics is valuable (primary belief) might believe they need to work hard in class (derivative belief). Another example is provided by Madni et al.:

> Beliefs and practices share a complex relationship in that beliefs and practices mutually affect one another. For example, if teachers have a more traditional view of education, they might believe that their role as instructor is to present information that students should store and remember. These teachers may engage in direct instructional practices and incorporate drill-and-practice activities. In contrast, if teachers have a more constructivist view of education, they might believe that their role is to guide discovery and model active learning. These teachers may develop a more student-centered curriculum that involves students working through authentic problems.
>
> (Madni et al., 2015, p. 59)

Secondly, is the concept of *centrality*, which refers to some beliefs being strongly held (central) while other beliefs are less strongly held and are more receptive to change (peripheral). Green argued that a primary belief might not be a central belief. Another way to think of these two concepts is that *primary* and *derivative* beliefs describe the architecture within the mind, while *central* and *peripheral* beliefs describe the intensity with which a belief is held. Last, beliefs are never held in isolation from other beliefs and are connected to other beliefs, often referred to as *clustering* (Ashman & McBain, 2011; Philipp, 2007). These clusters are seen as weakly connected, if at all, to other clusters, which creates the potential for contradictory or inconsistent belief systems when seen from an outside observer (Philipp, 2007).

Inconsistencies on beliefs

It seems appropriate to expect a person to behave in a way consistent with their beliefs, but it has been observed that there are inconsistencies between espoused beliefs and behaviours, bringing into question whether a person is actually articulating a belief. Like other affective aspects, beliefs are a part of an internal process which means “beliefs must be inferred and are therefore difficult to measure. Typically, data about beliefs are gathered using surveys, interviews or observations” (Anderson, Sullivan & White, 2004, p. 39). This can produce apparent inconsistencies.

As one example, Skott (2001) investigated early career teachers’ beliefs about school mathematics and teaching practices, revealing some inconsistencies. In one example, the teacher believed mathematics learning should be constructivist in nature, involving a focus on process, avoiding lecturing from the board, using hands-on tasks, valuing student responsibility for learning and a supportive role from a teacher who initiates and supports investigative activities. Simultaneously, the teacher also had broader, non-mathematical educational beliefs including students working towards becoming independent and self-confident learners. Skott observed two teaching moments in two consecutive lessons. The first was a moment where the teacher supported a discussion between two students working towards a solution. One student was stronger at mathematics while the other was weaker. During this exchange, the teacher actively and patiently listened to the weaker student’s incorrect idea for a solution, then moved the discussion towards the other student’s correct idea. In another episode in the following lesson, the teacher behaved in a highly teacher-directed way, telling two other students explicitly how to answer the question with a cognitively low-level, mechanical solution. Skott judged the first episode to be consistent with the teacher’s belief on learning and teaching mathematics and the latter as being inconsistent. When asked afterwards about the two episodes, the teacher responded by saying that he was comfortable with his behaviour, playing "different roles" (Skott, 2001, p. 15) in the two episodes.

On further analysis, Skott discovered that teachers have "multiple and sometimes conflicting educational priorities" (p. 18) and that, in this example, the competing priorities of managing a classroom and of broader educational issues, such as affect, took priority. In other words, what may look like inconsistencies is in actual fact, a restricted perspective. The research seemed to support the work of Hoyle (1992), who suggested that beliefs are situated. This implies that beliefs change based on the situation, but Skott disagreed with this, saying that it was not the teacher's beliefs that had changed, but "the teacher's goal for the particular activity changed, and after understanding the goal, the researcher could explain apparent contradictions between the teacher's beliefs and actions" (Philipp, 2007, p. 275). Philipp suggests that mathematics researchers should take the stance to attempt to resolve inconsistencies rather than simply accept them without further investigation. It is important for researchers to strive to understand the perspectives of their participants and, while inconsistencies may not be able to be explained, more progress will be made from this outlook.

Definition

This study adopted the following definition of belief:

> Psychologically held understandings, premises, or propositions about the world that are thought to be true. Beliefs are more cognitive, are felt less intensely, and are harder to change than attitudes. Beliefs might be thought of as lenses that affect one's view of some aspect of the world or as dispositions toward action. Beliefs, unlike knowledge, may be held with varying degrees of

> conviction and are not consensual. Beliefs are more cognitive than emotions and attitudes.
>
> (Phillipp, 2007, p. 259)

There is an increasing focus in the literature on *identity*, which Philipp (2007) defined as:

> …the embodiment of an individual's knowledge, beliefs, values, commitments, intentions, and affect as they relate to one's participation within a particular community of practice; the ways one has learned to think, act, and interact. (p. 259)

Collopy (2003) describes teacher's identity as as "the constellation of interconnected beliefs and knowledge about subject matter, teaching, and learning as well as personal self-efficacy and orientation toward work and change" (p. 289). This increasing focus on self and identity appears to be reminiscent of the early research stages of beliefs and attitudes. Lomas, Grootenboer and Attard (2012) provided a meta-analysis of the affective research in Australasia between 2008 and 2011. They observed that research is "starting to theorise on the concept of identity" (p. 23). There are aspects of this research study that have direct connections to identity.

Preservice teaching

This study looked at the preservice teachers' beliefs about learning mathematics in the context of their current attitude towards mathematics, and the impact it might have had on their experience of student-centred learning. It is crucial for preservice teachers to begin to understand their own beliefs and attitudes so that they may examine them explicitly as part of their own learning. Teachers' beliefs are one of the greatest influences on student achievement for which there is a possibility to influence (Hattie, 2012). For teacher educators, creating explicit and implicit opportunities for preservice teachers to reflect and challenge their own beliefs about the teaching and learning of mathematics can influence the core beliefs that make a difference (Tobias, 2002).

There are certain aspects related to the study of beliefs with preservice teachers that seem to be in agreement. These include:

- students enter teacher education programs with pre-existing beliefs based on their experience of school
- these beliefs are robust and resistant to change
- these beliefs act as filters to new knowledge, accepting what is compatible with current beliefs
- beliefs exist in a tacit or implicit form and are difficult to articulate

(White et al., 2006, p. 36).

The following section will discuss the theory and current research landscape related to people's different beliefs about intelligence and the thoughts and behaviours these influence. It looks at why some individuals love learning, seek out challenges, value effort and continue to problem-solve in the face of impediments, while others fear challenge, avoid failure, give up when tasks become hard and no longer try to find ways to overcome obstacles. Both of these types of learners exist in preservice teacher education courses and this section will look at the small amount of research that has been undertaken to date.

Beliefs of intelligence

The structure of this section will first describe the two different views of intelligence, the types of thoughts and behaviours caused by these views, including learned helplessness. Finally, there will be a discussion of the current research that directly relates to this investigation. Much of the theory is based on the research of psychologist Dr Carol Dweck, from Stanford University, who with others utilised two frameworks for understanding intelligence and achievement: Theory of fixed intelligence and Theory of malleable intelligence. These two views lie on a continuum (Figure 2.2) where individuals can be placed according to their belief of where ability comes from.

Fixed view of intelligence
Performance learning goals

Growth view of intelligence
Mastery learning goals

Figure 2.2 – People's views of intelligence lie on a continuum

There are a number of points that are important to keep in mind throughout this section. First, within the literature these two views of intelligence are sometimes referred to by different names. The view of "malleable" intelligence is often referred to as a "growth" or "emergent" view of intelligence and a "fixed" view of intelligence is sometimes referred to an "entity" view of intelligence. These views are also often called *mindsets*. Next, as people are frequently unaware of their own beliefs and they are unarticulated in a person's mind, these are referred to as *implicit beliefs* or *implicit theories*. Implicit theories are "schematic knowledge structures that incorporate beliefs about the stability of an attribute and organize the way people ascribe meaning to events" (Burnette, O'Boyle, VanEpps, Pollack & Finkel, 2013, p. 5.). Expressed another way, implicit theories "are essentially definitions; ideas or theories that laypersons or scientists have about some phenomena" (GarCía-Cepero & McCoach, 2009, p. 296). The term 'theory' in this context refers "to the ways that individuals think about the traits of themselves and others, rather than the scientific term 'theory,' which refers to a scientific explanation for phenomenon" (Wilson, C., 2015, p. 2). Finally, there are a number of common findings based on numerous empirical studies in this area across diverse populations that suggest, (1) fixed and emergent theories are approximately equal in size, (2) people can hold different theories in different domains and (3) theories generally do not correlate with other scales. This includes measures of self-esteem, confidence, optimism, religiosity, education, problem-solving ability, cognitive complexity, and personality traits such as extraversion and neuroticism (Burnette et al., 2013; Dweck, 2000; Molden & Dweck, 2000).

Implicit theories of intelligence

The theory of fixed intelligence is a hypothesis that intelligence is an inflexible entity that is innate and pre-determined in a person through genetics and cannot be changed through effort and environment (Burnette et al., 2013; Dweck, 2000; Hong, Chiu, Dweck, Lin & Wan, 1999). It has been observed that people with a belief in fixed intelligence are less inclined to persevere to overcome obstacles in challenging situations, report feeling high levels of anxiety and vulnerability, feel less motivated to learn, question their own abilities, exaggerate their past failures, minimise their past successes and misevaluate their chance of future successes

(Nussbaum & Dweck, 2008; Dweck, 2000; Hong, Chiu, Dweck, Lin & Wan, 1999; Mueller & Dweck, 1998).

The theory of malleable intelligence is a hypothesis that intelligence can be significantly changed through learning, meaning that a person's intelligence can incrementally grow due to effort and guidance (Dweck, 2000; Hong, Chiu, Dweck, Lin & Wan, 1999). Dweck (Happy & Well, 2013) addressed a number of misconceptions people can have about this view of intelligence. This theory does not deny that people learn things more quickly than others or that people know more than others. It also does not imply that all people can achieve the same level of intelligence. It is a simply a recognition that everyone can increase their intelligence and that people have some level of control in this process (Burnette et al., 2013). People with this belief about intelligence have been observed to seek out challenge, persevere through problem-solving when experiencing difficulties, accurately remember past failures and successes, and remain positive and confident.

Learning and performance goals

These two implicit theories often lead to different goals within an achievement situation. Incremental theorists tend to focus more on increasing their ability through learning and mastery. This is referred to as *mastery goals*. Entity theorists tend to have goals that involve documenting and demonstrating their abilities to others, in an attempt to gain favourable judgements. These are called *performance goals* (Blackwell, Trzesniewski & Dweck, 2007; Dweck 2000; Dweck & Leggett, 1988).

There are significant differences in the behaviours of these two groups, which is a consequence of two different sets of goals, and these are detailed in the following section. First, performance goals are discussed and their links to certain beliefs, values and behaviours, including learned helplessness. Finally, mastery goals will be introduced in detail and contrasted to performance goals.

Performance goals

An entity view of intelligence orients an individual to performance goals (Dweck & Leggett, 1988), and creates a collection of beliefs, values and behaviours common among people with this perspective. These include response patterns that occur when challenge is present and when failure occurs. The obvious response is a *helpless response*. As part of the discussion, a number of important studies will be elaborated on as examples.

As a consequence of an entity view of intelligence, an individual sees little use in persevering and applying effort to overcome obstacles in challenging situations since it is not seen as useful. In fact, it has the opposite effect. Challenging tasks only provide opportunities to get things wrong, and getting things wrong signifies insufficient intelligence to complete the task. To that extent, a challenging task is a threat to their self-esteem and confidence. It can also make a person obsess over trying to show others (and themselves) that they have been born with enough. The outcome is that they "must look smart and, at all costs, not look dumb" (Dweck, 2000, p. 3). From an educational perspective, entity theorists are threatened by challenging work and so pass up many meaningful learning opportunities. More demanding tasks are better for learning, but are far less effective if you wish to look smart. Instead, performance goals require a diet of easy successes. In fact, the most appealing situation for a person with an entity view of intelligence is succeeding with the least amount of effort at a task, but where everyone else struggles. In their mind, this success reaffirms that they have been born with a large amount of intelligence. The worst situation is applying effort without any success (Dweck, 2000).

Reaction to failure

Failure can be described as the inability to meet the desired or intended objective of a task. For a person who believes that intelligence is fixed, failure is viewed negatively and is to be avoided, rather than viewing it as an opportunity to learn something new or a sign that the correct strategy has not yet been found. This view of failure has been noticed in a number of studies and has subsequently provided a pattern of behaviours sometimes called the *helpless pattern* (Dweck, 2000). The most obvious response is a learned helpless response.

In 1978, Diener and Dweck undertook research with Year 5 students where they observed the students' reactions to failure while undertaking mathematical tasks. They separated the cohort into two groups based on a survey – those who are more likely to persevere when faced with challenge and those less likely to persevere. The task was created such that the first eight questions could be successfully completed, with some hints and guidance given if required. The last four questions were intentionally set well beyond their current level of understanding, in order to bring about a reaction to failure. The researchers observed the children's strategies during the two sections, as well as the expressed thoughts, feelings and actions. They noticed no difference during the success phase of the task. All participants in both groups were able to successfully complete this section using equally effective strategies. But they observed a clear distinction between the two groups when they encountered the challenge phase as an abrupt obstacle.

The researchers noticed that, when failure occurred, the two groups rapidly took on two distinct patterns. First, the students who were less likely to persevere exhibited a helpless pattern:

1. They condemned their intelligence almost immediately. They began to blame their intelligence and say things like "I guess I'm not very smart", "I never did have a good memory" and "I'm no good at things like this" (Dweck, 2000, p. 7) with complete absence of any positive.

2. They lost confidence in their ability. When the students were asked if they could again solve the same questions they had previously just solved during the success phase, one-third believed they no longer could.

3. They exaggerated their failures and minimised their successes. When asked to recall how many problems they had solved successfully (which was eight) and how many they had not solved (which was four), they replied with five successes and six failures. Expressed another way, they recalled more failures than successes.

4. They expressed a range of feelings including boredom, anxiety and self-doubt. Two-thirds of the group expressed a negative affect.

5. They engaged in task-irrelevant behaviour. Dweck and Leggett (1988) described that more than two-thirds of the students attempted to divert the attention of the researchers, where some students:

   > …attempted to alter the rules of the task, some spoke of talents in other domains, and some boasted of unusual wealth and possessions, presumably in an attempt to direct attention away from their present performance and toward more successful endeavors or praiseworthy attributes. Thus, instead of concentrating their resources on attaining

success they attempted to bolster their image in other ways.

(Dweck and Leggett, 1988, p. 257)

6. They showed a marked decline in problem-solving strategies and performance. Nearly two-thirds of the students began using completely trivial and ineffective strategies that Leggett and Dweck identified as likely to be used by 'preschoolers'. This was despite having just previously demonstrated they could all use mature and effective strategies earlier in the task (Diener & Dweck, 1978).

Overall, this group of individuals viewed difficulties as failures, indicating low ability, insufficient intelligence and challenge that could not be overcome (Dweck & Leggett, 1988). In subsequent studies, other behaviours and thoughts have been observed as part of a helpless pattern, including examples such as saying they would cheat next time instead of studying more (Blackwell, Trzesniewski & Dweck, 2007), and find someone else who did worse than they did in order to feel a high level of self-esteem (Nussbaum & Dweck, 2008).

The helpless nature of their response was first noticed in animal research in the late 1960s. The following section will identify the initial research that identified the factors that make one vulnerable to learned helplessness, then discuss of the signs of *learned helplessness*.

Learned helplessness

Previous to the work of Dweck and Reppucci (1973), research on *learned helplessness* was only done with animals by Seligman, Maier and Solomon (1971). Dweck and Reppucci (1973) adapted the word *helpless* to describe a view of failure, that once it occurs, "the situation is out of their control and nothing can be done" (Dweck, 2000, p. 6). Diener and Dweck (1978) extended the term to include all the reactions that these people showed when they met failure, including "denigration of intelligence, plunging expectations, negative emotions, lower persistence and deteriorating performance" (Dweck, 2000, p. 6). Mathematics appears to be particularly susceptible to learned helplessness as success and failure are highly salient and more obvious (Yates, 2009). One of the signs for the potential of a learned helpless response is a person's explanatory style.

Explanatory style

A pioneer of learned helplessness is the American psychologist, Dr Martin Seligman. His description of learned helplessness in his popular book *Helplessness: on development, depression and death* (1992) is as follows:

> Learned helplessness refers to three interlocked things: First, an environment in which some important outcome is beyond control; second, the response of giving up; and third, the accompanying cognition: the expectation that no voluntary action can control the outcome.
>
> (Seligman, 1992, p. xvii)

Seligman wished to better understand learned helplessness and how a person's explanation of the cause of one's failure or tragedy plays a significant role. This has become known as a person's *explanatory style*. Seligman discovered there were three main dimensions to a person's explanatory style – permanence, pervasiveness and personalisation (Seligman, 1992).

Permanence

People who give up easily often believe that the causes of the negative events are *permanent* and will continue to affect their lives. In contrast, people who are resistant to helplessness recognise that bad events and failure are *temporary* and will pass. Seligman acknowledges that everyone feels a moment of helplessness when they fail, but the length of time it takes for the feeling to pass is different (Seligman, 1992). For some, it is almost instant but for others, it can take days or even months for small setbacks to be overcome. For major defeats, some people never recover. Seligman offers some examples of these explanatory styles.

Permanent (pessimistic)	**Temporary (optimistic)**
"I'm all washed up."	"I'm exhausted."
"Diets never work."	"Diets don't work if I eat out."
"You always nag."	"You nag when I don't clean my room."
"My boss is a bastard."	"My boss is in a bad mood."
"You never talk to me."	"You haven't talked to me lately."

(Seligman, 1992, p. xxi).

Pervasiveness

Pervasiveness is the term used to describe the extent to which failure and negative events affect a person's life. People who have a *universal* explanatory style tend to give up on everything when a bad thing happens in one area of their life. In contrast, a person with a *specific* explanatory style may become helpless in one area of their life but carries on steadfastly in other areas. Seligman uses an example of two people who both lose their jobs. One person, with a universal style of explanation, lets the event affect him in many other areas of his life besides work. He stops seeing friends, disengages from his family and stops participating in everyday activities. In comparison, the other person remains optimistic and resilient to the setback. She continues to be a good family member, remains in contact with her friends and does not let the event affect other aspects of her life. Again, Seligman offers some examples to the two different explanatory styles.

Universal (pessimistic)	**Specific (optimistic)**
"*All* teachers are unfair."	"Professor Seligman is unfair."
"I'm repulsive."	"I'm repulsive *to him*."
"Books are useless."	"*This* book is useless."

(Seligman, 1992, p. xxii).

Personalisation

The last dimension that Seligman identified as contributing to learned helplessness is personalisation. This refers to the extent to which a person believes that they are responsible for the negative circumstance. It can be *internal*, where the person blames himself or herself, or it can be *external*, where the person blames outside factors like people or circumstances. People who blame themselves for negative events and failure suffer from low self-esteem as a result. They often report feeling worthless, unlovable and talentless. On the other hand, those who do not blame themselves but hold external factors responsible mostly respect themselves more. Seligman suggests that low self-esteem is often a result of an internal explanatory style.

Internal (low self-esteem)	**External (high self-esteem)**
"*I'm* stupid."	"*You're* stupid."
"I have no talent."	"I have no luck in poker."
"I'm insecure."	"I grew up in poverty."

(Seligman, 1992, p. xxiv).

Discovery of learned helplessness

It is when people view these three dimensions (permanence, pervasiveness and personalisation) in a pessimistic way that they are at risk of learned helplessness. But how does a person learn to be helpless? What have they experienced before that makes them fail to act in order to overcome challenge, adversity and failure? To best answer these questions, it is helpful to briefly examine the experiments that Seligman and others performed that allowed them to understand the required conditions to learn to become helpless.

In the mid-1960s, Seligman, Maier and Solomon (1971) discovered, by accident in fact, the phenomenon of learned helplessness. It was while experimenting on the relationship of fear and learning in mongrel dogs that they stumbled on the lack of response by certain dogs. The experiments involved repeatedly giving dogs a moderately painful electric shock while they were restrained in a hammock. This 'treatment' involved a dog being uncontrollably shocked up to 64 times with 5-second-long shocks of moderately painful intensity. The dogs were entirely unable to control the shocks because no voluntary action they made influenced the shocks. No tail wagging, struggling or barking made a difference to the onset, offset, intensity and duration of the shocks, and these four factors are what define helplessness or uncontrollability (Seligman, 1992).

Following this, the researchers wanted to train the dogs to escape a shock where they did have to the ability to avoid the shocks. The dogs were placed in a shuttle box (Figure 2.3), which is made up of two sides with a barrier in the middle approximately the height of the dog's shoulders. The experiment involved turning off a light in the shuttle box as a sign that an electric shock from the floor was imminent. If the dog jumped over the barrier to the other side, the shock was not given. If the dog did not jump the barrier, the shock was given until either the dog jumped the barrier or 60 seconds had passed. That means that for dogs that did not jump the barrier, they received the electric shock from the floor for 60 seconds.

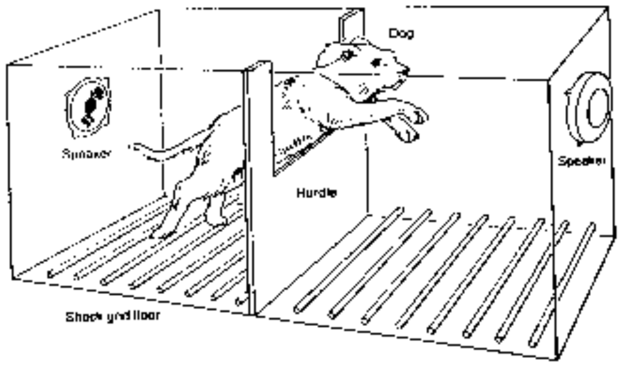


Figure 2.3 – An escapable shuttle box
http://www.flyfishingdevon.co.uk/
salmon/year2/psy221depression/psy221depression.htm

The researchers compared the reactions of two groups of dogs in the shuttle box experiments. One group of dogs had previously experienced inescapable electric shocks (pre-treated dogs) and the other group had never participated in any shock experiments (naïve dogs). The contrast between these two groups was stark. Seligman described the typical behaviour of a 'naïve' dog when they first experienced the shuttle box. On the first shock, the dog would run around frantically trying to escape the shock from the floor, until it accidentally jumped over the barrier, thereby turning off the shock. On the next trial, the dog would still move frantically but cross the barrier more quickly than the first time. After a few more trials, the dog efficiently jumps the barrier to avoid the shock every time the light is turned off.

In contrast, the reaction of the pre-treated dogs when placed in the shuttle box, was identical to that of the naïve dogs. They ran around frantically for up to 30 seconds, but then unexpectedly stopped, lay down and quietly whined. On the next trial, they ran around again but not for nearly as long. Rather amazingly, they seemed to give up and accept the shock submissively. On the subsequent trials, they failed to escape the shocks. Seligman describes this as 'the paradigmatic learned-helplessness finding' (Seligman, 1992, p. 22). Seligman also provided a succinct summary of the findings from the experiments. One of the most interesting points that follows is the inability for suffers of learned helplessness to learn from times when they do succeed and believe that the response worked.

> Laboratory evidence shows that when an organism has experienced trauma it cannot control, its motivation to respond in the face of later trauma wanes. Moreover, even if it does respond, and the response succeeds in producing relief, it has trouble learning, perceiving and believing that the response worked. Finally, its emotional balance is disturbed: depression and anxiety, measured in various ways, predominate. The motivational deficits produced by helplessness are in many ways the most striking.
>
> (Seligman, 1992, p. 22)

Some important factors to be aware of with relation to learned helplessness are summarised now. First, research has shown that learned helplessness is a condition found in many animals, such as dogs, cats, rats, mice and humans. It is not specific to dogs. Secondly, it is the trauma experienced with an inability to escape that causes the learned helplessness condition, not trauma alone (Seligman, 1992). This was discovered when Seligman set up an experiment that had two dogs connected to each other ('yoked') and both would receive identical electric shocks. The difference was that one dog could turn off the shocks, whereas the other was unable to escape. It was found that the dogs that had control over the shocks recovered from the experiments and never displayed a learned helplessness response, whereas the dogs that did not have control learned to become helpless. This confirmed that trauma alone did not lead to the helpless response. Although trauma is necessary for learned helplessness, it is not sufficient. It was not the trauma of being shocked that alone created the failure to escape, it was the trauma combined with the belief that they lacked any control in the situation.

Mastery goals

In contrast to an entity theorist, an emergent theorist believes intelligence can be developed and grown, which directs them to mastery goals (Dweck, 2000; Dweck & Leggett, 1988). The most significant consequence of this mindset is the desire to learn. They are not as interested in appearing smart to others and are not as motivated by external factors, such as grades and praise. When faced with a choice between simple tasks where they will be successful, they would rather undertake challenging tasks that provide the opportunity to master skills and acquire knowledge.

Continuing with the 1978 research by Diener and Dweck with the Year 5 students, the researchers observed a striking difference between these mastery-oriented students and the students with the helpless pattern. The following themes were observed from the students with mastery goals:

- They never denigrated their intelligence. They did not seem to view incorrect attempts as a reflection of their ability. In fact, it seemed to the researchers that they did not even see themselves as failing, but just undertaking a task that has not been mastered yet.

- They continued to use effective strategies, both cognitively and affectively. Examples of the students "solution-oriented self-instruction and self-monitoring" (Dweck & Leggett, 1988, p. 258) included them revising what they had learned about the problem so far. Some examples of children using motivational sayings included, "the harder it gets, the harder I have to try" and "I should slow down and try and figure this out" (Dweck, 2000, p. 9).
- They maintained an optimistic outlook that their effort will be worthwhile. The students said things such as "I did it before, I can do it again" (Dweck & Leggett, 1988, p. 258) and "I'm sure I have it now" (Dweck, 2000, p. 10). Almost two-thirds offered some sort of positive prediction of the outcome.
- They relished the challenge. Some showed elevated levels of positive affect, such as excitement and enjoyment. Examples of this included one student who rubbed his hands together, pulling in his chair and saying "I love a challenge", while another said cheerfully, "mistakes are our friends" (Dweck, 2000, p. 10).
- They maintained effective problem-solving performance. Four-fifths of the group maintained the same level of problem-solving sophistication they used during the success phase. Some students even actually solved the problems that were designed for them to fail.

Overall, Dweck and Leggett (1988) discovered that these two groups of responses and internal processes to challenge and failure were stark and rapid, and this was in the context of receiving identical tasks and achieving the same outcomes in the pre-failure phase. Dweck and Leggett (1988) summarised the discovery as:

> helpless children exhibited negative self-cognitions, negative affect, and impaired performance, whereas mastery-oriented children exhibited constructive self-instructions and self-monitoring, a positive prognosis, positive affect, and effective problem-solving strategies.
> (Dweck and Leggett, 1988, p. 258)

Table 2.1 provides an overview of the differences these two frameworks – namely, fixed and emergent views of intelligence – have on goals within an achievement situation.

Table 2.1 – Summary of mastery goals and performance goals in achievement situation

	Mastery goals	**Performance goals**
Motivations in achievement situation	Satisfaction working hard Learning new things Challenging work	Praise Positive feedback Looking smart Avoiding looking dumb Avoid challenge
Main goals in achievement situation	Understanding Mastering	Marks/grades Correct answers
Reaction to failure	Knuckle down Problem-solving	Negative self-cognition Negative affect Low perseverance Learned helplessness
Belief of intelligence	Intelligence is malleable	Intelligence is innate and fixed

Recent research

Research on implicit theories has been on the rise since the 1960s (http://bit.ly/implicit_theories). It has branched into multiple areas of achievement such as sport (Slater, Spray & Smith 2012), human resources (Junker & van Dick, 2014) and weight-loss (Job, Walton, Bernecker & Dweck, 2013), and included other aspects besides intelligence, such as personality and morals (Dweck, 2000).

From this growing field of research, a number of interesting findings have been made. Since the early research into the connection between implicit theories of intelligence and mastery/performance goals, there has been some work which has suggested that the link might not be as strong as first thought (Payne, Youngcourt, & Beaubien, 2007). This suggests that goals and implicit theories may be separate constructs (Wilson, 2015). Some researchers suggest there should be a relaxing of stringent assumptions about implicit theories and goals as it may open other opportunities for understanding (Tempelaar, Rienties, Giesbers & Gijselaers, 2015). Nevertheless, the connection is apparent from many studies. Dweck has investigated this aspect through her use of surveys that investigated implicit theories of intelligence, as well as surveys that looked at goal orientation and found no difference in the results (Dweck, 2000).

There is empirical evidence that shows that mindsets can change through targeted interventions (Molden & Dweck, 2000; Blackwell, Trzesniewski & Dweck, 2007; Burnette & Finkel, 2012; Shively & Ryan, 2013; Leith, Ward, Giacomin, Landau, Ehrlinger & Wilson, 2014; Romero, Master, Paunesku, Dweck & Gross, 2014). In Blackwell, Trzesniewski and Dweck (2007), a longitudinal study was conducted through an intervention with 7th graders (n=48) that looked at teaching an incremental theory of intelligence, learning goals and positive beliefs about effort, then compared this to a control group (n=43). They found over the two-year study, the control group "displayed a continuing downward trajectory in grades, while this decline was reversed for students in the experimental group" (2007, p. 246).

This 'mindset' work of Dweck and others has seen a massive interest outside of the academic sphere (Dweck, 2015; DeWitt, 2015). This adoption has been seen in many achievement spaces such as sports and business (Neneh, 2012). This has also seen a large adoption in thousands of schools across the world (DeWitt, 2015). There has been concern that the research has been interpreted in simplistic terms, with significant emphasis being placed on only parts of the theory. For example, Dweck (2015) provided an update on the "growth mindset" approach, having watched her work spread and become more and more popular. She had noticed "common pitfalls" and "misunderstandings" that were too common, the first of which is that a growth mindset is more than just *effort*. Dweck advised that the theory is about strategies, and people behaving in a way that is the complete opposite to helplessness. This also applies to teachers and not settling on the idea that a child is incapable of learning but rather doing everything possible to unlock the student's learning (Dweck, 2015).

> Students need to try new strategies and seek input from others when they're stuck. They need this repertoire of approaches – not just sheer effort – to learn and improve.
> (Dweck, 2015)

Dweck was also concerned that the theory is being misused as a way to build self-esteem, even if learning is not occurring. Teachers had been found to offer "comfort-oriented feedback" instead of "strategy-oriented feedback" (Rattan, Good & Dweck, 2012), the purpose of which was to try and improve students' self-esteem by making them feel good. It was done through praising effort, even if they were not learning, or saying "everyone is smart", rather than "telling the truth about a student's current achievement and then, together, doing something about it, helping him or her become smarter" (Dweck, 2015).

Other research has found "false growth mindset", where people proclaim themselves as having a growth mindset because they consider it the right thing to have, the right way to think (Sun, 2014), but in actual fact behave with a fixed mindset. Secondary mathematics teachers:

> …who endorsed a growth mindset and even said the words 'growth mindset' in their middle-school math classes, but did not follow through in their classroom practices. In these cases, their students tended to endorse more of a fixed mindset about their math ability.
>
> (Dweck, 2015)

Hattie's work has found that the *effect size* of a growth mindset is 0.19, which is below the 0.4 "hinge point" (DeWitt, 2015). The hinge point means that the influence of that intervention on learning is providing a year's worth of growth for a year's input. But rather than these two findings opposing each other, Hattie and Dweck appear to share many of the same ideas. While it may be that mindsets do yield a lower effect size, it may also be possible that the lack of ineffectiveness could be a result of poorly implemented interventions acknowledged by DeWitt (2015). Instead of embracing the entire emergent mindset, only parts are adopted or espoused, but actions still remain. Dweck (2015) writes that students need an opportunity to correct mistakes and Hattie has found that 40–50 per cent of the time when students make errors, the teacher corrects them (2012). They are never given the opportunity to struggle because teachers often give them the answer before it gets too hard (DeWitt, 2015). There are also external constraints such as time pressures, curriculum constraints and professional development. As of yet, Hattie has said that he will further explore and explain the meta-analysis that he used to find the effect size (DeWitt, 2015).

Teachers' implicit theories of intelligence research

Much of the research on implicit theories has been with students, and within the field of psychology (Dweck, 2000; Blackwell, Trzesniewski & Dweck, 2007), with significantly less on teachers' beliefs on intelligence (Jones, Bryant, Snyder & Malone, 2012; Sun, 2014; Madni et al., 2015). Dweck (2000) found that younger children are more likely to believe in an emergent view of intelligence until about the ages of 10 to 12, when some begin to take on more entity views. This finding has been challenged by results in other studies, where a large majority of students from Kindergarten to Year 11 in Germany and the United States continued to believe in an emergent view of intelligence (Kurtz-Costes, McCall, Kinlaw, Wiesen & Joyner, 2005; Jones, Byrd & Lusk, 2009). However, older children were more likely to link intelligence only to cognitive abilities, rather than non-cognitive (Kurtz-Costes, McCall, Kinlaw, Wiesen & Joyner, 2005). Other researchers have documented confirmatory evidence that an incremental view has been linked to students making more effort towards learning, having greater concentration, higher levels of motivation, deeper resilience to failure and significant use of study skills and problem-solving, than those with an entity view (Hong et al., 1999; Ommundsen, Haugen & Lund, 2005; Blackwell, Trzesniewski & Dweck, 2007; Shively & Ryan, 2013; Romero et al., 2014). Some researchers have asked if an incremental view of intelligence directly links to achievement (Gonida, Kiosseoglou & Leondari, 2006), or if achievement is mediated through goal orientation, such as learning goals (Leondari & Gialamas, 2002). Dweck (2006) has found both fixed and emergent mindsets across the spectrum of achievement. In particular, fixed mindsets have been observed in high-achieving girls (Dweck, 2006). Leondari & Gialamas (2002) also found that “implicit theories were not related to academic achievement”, but learning goals “had an indirect effect on achievement, which was mediated through perceived competence” (p. 279). These studies add evidence to the claim that mindsets and learning goals play a significant role in achievement. Another important aspect worth investigating is the implicit theories of teachers, “because teachers work closely with students during their academic learning, [so] it is reasonable to suspect that teachers could influence students’ implicit theories of intelligence” (Jones, Bryant, Snyder & Malone, 2012, p. 89).

There has been some recent research of implicit theories of intelligence with teachers, mostly focussing on the impact it has on their students through the teachers’ beliefs and teaching practices. There is still not a significant amount of research in the area of preservice and inservice teachers’ implicit theories of intelligence, and consequently this section will draw on a variety of research from around the world. Broadly speaking, the research findings could be grouped into (1) the impact on students’ own beliefs and (2) teaching practices as a consequence, at least in part, of the teacher’s implicit theories.

Research has shown that a teacher’s belief about intelligence can have an impact on the beliefs of their students. Pretzlik, Olsson, Nabuco and Cruz (2003) studied 10–11-year-old students (n=58) and two teachers from the UK, as well as 5–6 year olds (n=47) and two teachers from Portugal. The researchers asked the teachers to rank the students by their academic abilities from ‘best in the class’ to ‘weakest in the class’ (p. 579). They discovered that “teachers’ implicit conceptions of intelligence reflect a view of intelligence that is similar to what IQ tests measure” (p. 579). It also suggested that teachers have considerable effect on students' own beliefs about intelligence. In a recent quantitative study of seven science classrooms and two teachers, Schmidt, Shumow and Kackar-Cam (2015) found "significant teacher effects in the extent to which students' beliefs about mindset, students' mastery-oriented learning goals, and students' achievements were sustained several months" (p. 17) following an intervention. They found the teacher who achieved higher student outcomes placed greater emphasis on mastery goals, conceptual development and use of learning strategies than the other teacher. Georgiou (2008) compared the beliefs of novice and experienced teachers about school student achievement. It was found, after comparing 154 inservice teachers with 159 preservice teachers, that experienced teachers tended to credit achievement more to fixed qualities that cannot be changed, such as intellectual ability. Dweck (2008) and Boaler (2016) have noted that students tend to have more of a fixed view of mathematics skills than of other intellectual skills. This has also been found with teachers in a study by Jonsson, Beach, Korp and Erlandson (2012). They surveyed 226 Swedish teachers and found that "teachers from language, social science and practical disciplines had a significant preference for an incremental theory of intelligence compared to an entity theory of intelligence, while the teachers in mathematics did not. One of the conclusions was that entity theories of intelligence may be more pronounced among teachers in mathematics" (p. 1).

There is growing evidence that teaching practice seems to be influenced by a teacher's implicit theory of intelligence. Teachers with an emergent mindset were found to have higher levels of self-efficacy and a greater feeling that they were able to help students overcome difficulties (Leroy, Bressoux, Sarrazin, &

Trouilloud, 2007), which impacts positively on teacher effectiveness. Furthermore, in the Leroy et al. study (2007), they investigated how the teachers' implicit theories, their seniority, and their perceptions of pressures at work contributed to establishing an autonomy-supportive climate for students in their classroom. This is because student autonomy has been demonstrated to create high levels of student self-determination and intrinsic motivation. The study analysed 336 fifth-grade teachers randomly chosen from 269 schools in France and found that teachers with a fixed mindset caused a drop in the teachers' reported support for autonomy. Conversely, teachers with emergent mindsets preferred an autonomy-supportive climate. In another study, it was found that teachers with a fixed mindset about teaching skills were associated with less interest in professional development (Thadani, Breland, & Dewar, 2015). Rattan, Good and Dweck (2012) found teachers with an entity theory of mathematics intelligence more readily deemed students to have low ability than those teachers holding an incremental theory. Moreover, those "holding an entity (versus incremental) theory were more likely to both comfort students for low math ability and use 'kind' strategies unlikely to promote engagement with the field (e.g. assigning less homework)" (p. 371). The researchers then compared this "comfort-oriented feedback" given to students with "strategy-oriented and control feedback". They found the students receiving the comfort-oriented feedback both perceived the teacher's entity theory and low expectations for the students, as well as feeling less motivation and lower expectations for their own performance. Research by Sun (2014) found that teachers with fixed mindsets were: "(1) less likely to hold fixed views of the nature of math, meaning they were more likely to view math as a set of procedures, (2) more likely to have the expectation that some students would not make much progress or succeed in math and (3) less likely to report viewing mistakes as important for learning math" (p. 394). Research from Dweck (2014) reports that students of teachers with fixed mindsets achieve lower grades than those with teachers with a growth mindset, producing self-fulfilling prophecies. For teachers with fixed mindsets, low-achieving students remain low-achieving, whereas teachers with a growth mindset see all students improve.

> This research shows that teachers with more fixed mindsets engage in more ability grouping and create more self-fulfilling prophecies when it comes to student achievement. Students whom they consider to be low in intelligence remain low achievers in their classroom. In contrast, low-achieving students often blossom in the care of teachers with a growth mindset.
>
> (Dweck, 2014, p. 10)

An increasing amount of research is demonstrating how a teacher's belief of intelligence impacts on the teaching decisions they make in the classroom. This includes messages, both implicitly and explicitly, that "teachers and schools constantly communicate messages to students about their ability and learning" (Boaler, 2013, p. 145). Boaler (2013, 2016) has investigated these messages and has identified a number of choices that are made by schools and teachers that can promote a growth mindset or fixed mindset. Some of the aspects she has identified include class grouping (ability or heterogeneous), response to student mistakes, teacher feedback and the types of tasks provided by the teacher. These parts come together to create a school and classroom culture of emergent or fixed mindset. Looking at ability grouping as an example, Boaler asserts that, "whether students are told about the grouping and its implications or not – students' beliefs about their own potential change in response to the groups they are placed into" (Boaler, 2013, p. 146). She goes on to say that:

> ability grouping as a practice rests upon fixed mindset beliefs – it is implemented by schools and teachers who themselves have fixed beliefs about learning and potential and it communicates damaging fixed ability beliefs to students.
>
> (Boaler, 2013, p. 149)

Overall, these findings have shown the significant implications teachers' beliefs of intelligence have on students and pedagogical practices. It appears that when teachers hold an emergent theory of intelligence rather than an entity theory, student affect is more positive and achievement levels are higher. There are questions that still remain unanswered within the literature. What is the impact of attitude in the context of these teachers' mindsets? What if a teacher holds an emergent view of intelligence, but a negative attitude? On the one hand they are likely to have mastery goals that value challenge and perseverance, but have an attitude that typically includes feeling unconfident, anxious, perhaps even frightened of mathematics. Do they still subscribe to mastery goals or does it lean more towards performance goals? And conversely, for teachers with fixed mindsets and positive attitudes towards mathematics – does their positive attitude persuade them to seek out challenge and persevere with learning when it is difficult? The combination of looking both at attitude towards mathematics and beliefs about intelligence would be interesting to determine what qualities come through when it comes to learning mathematics and prospective teaching of mathematics.

Preservice teacher education in primary mathematics

The final section of this chapter features the literature on preservice teacher education in the context of reform efforts in mathematics education. The theoretical frameworks underlying this research are consistent with the goals of mathematical education reforms pursued in Australia by national and state agencies. For more than a century, reforms have seen a pendulum-like motion shifting back and forth from a teacher-centred approach to learning, to a view that promotes the student as central to the learning experience. A brief analysis of these reforms, that have occurred as a trend both in Australia and globally, will show a constant tension between different mathematical educational priorities which are grounded in different theoretical learning perspectives. The reforms have made adjustments to the foci of mathematics education, and consequently provided an ongoing challenge for teacher educators, who often see preservice teachers entering courses with poor mathematical content knowledge, negative affect and vast experience of learning in teacher-directed classrooms. This consequently makes an important requirement on teacher change and modelling teaching practices consistent with reform efforts. Finally, the chapter will look at the implications of these reforms in teacher education and offer a direction for further investigation in preservice primary teacher mathematics education through the lens of attitudes and implicit theories of intelligence.

Mathematics education reforms

Since the early 20th century, there has been a number of reform efforts made in mathematics education. These have been well documented in the United States but have also occurred in Australia and elsewhere, as part of a global trend

(Tobias 2002; Simon, 2008). This is in part due to a fundamental ideological shift in the beliefs about how people learn, along with other factors such as research, cultural, technological and political influences (Lambdin & Walcott, 2007; Amit & Fried, 2008). Consequently, this impacts on what is required from teachers and how lessons are to be taught. Many teachers are suspicious of reforms and only change through sufferance, as research has found that teachers rely more on their beliefs than on current trends in pedagogy and research (Handal & Herrington, 2003). The challenge is that research shows that many of these teachers hold *behaviourist* beliefs, which has significant implications for *constructivist*-oriented reforms (Handal & Herrington, 2003). This provides a challenge to teacher educators to move preservice teachers, who are vastly experienced in pedagogies commonly aligned with behaviourist classrooms, to adopt a more constructivist approach to learning and teaching. The following sections will analyse and contrast these two approaches, not only to understand the differences but also provide the context in which this study was done.

Behaviourism

The current constructivist-reform has its beginnings in the 1950s, but despite these reform efforts, there is still a strong focus on low-level skill acquisition and algorithms in schools, with research showing a high proportion of Australian mathematics classrooms using problems with low procedural complexity, considerable repetition and lack of deductive reasoning (Hiebert et al., 2003; Vincent & Stacey, 2008). In the Trends in International Mathematics and Science Study (TIMSS) 1999 international video study, researchers analysed eighth-grade mathematics and science teaching in seven countries. They found in Australia that three-quarters of the problems provided were repetitions of preceding problems earlier in the lesson. This was the highest of the seven countries researched, which included Hong Kong SAR, Japan, Czech Republic, the Netherlands, Switzerland and the United States. This has been referred to as "shallow teaching syndrome" (Stacey, 2010). Along with this repetitiveness is the use of worksheets or textbooks in over 90 per cent of Australian mathematics lessons (Vincent & Stacey, 2008). Other features included:

- Of these 75 per cent of problems used by teachers that were rated as low procedural complexity, they required less than five steps to solve.
- Just over 25 per cent of mathematical tasks were designed to have a real-life context.
- Over 90 per cent of problems were presented to students as having only one solution.
- Approximately 35 per cent of the tasks per lesson were solved publicly by giving the answers only (no solutions).

(Hiebert et al., 2003)

The repetition of single solution, low-complexity, procedural tasks are often referred to as 'drill-and-practice' and is in contrast to current reform efforts, which does ask for skills, but also a focus on conceptual understanding through problem-solving and mathematically rich tasks (Board of Studies NSW, 2012). Conceptual understanding refers to "the mental connections among mathematical facts, procedures, and ideas" (Hiebert & Grouws, 2007, p. 382).

Drill-and-practice is a commonly recognised style of mathematical instruction that was the main method of teaching during the early 20th century (Kilpatrick, 2014). It came from the theory of *connectionism* from the work of

Edward Thorndike, and *behaviourism* from B. F. Skinner (Staddon, 2014). Both Skinner and Thorndike attempted to apply a scientific approach to learning on the basis that it was only possible to be scientific by making observations. This allowed only actions and behaviours to be studied, as it was not possible to observe and know what goes on in the mind. Thorndike argued that learning was the formation of ‘connections’ between stimuli (S) in the environment and responses (R) of an organism to that environment, known as SR bonds (Thorndike, 1927; Davey, 1972; Gibboney, 2006). The two theories asserted that through training and conditioning, specific responses could be tied with specific stimuli, and that the goal of the teacher was to connect the correct student response to a given stimulus (Lambdin & Walcott, 2007). Although many of these 'connections' between stimuli and response were determined at birth, new associations or habits could be 'stamped-in' according to conditioning, such as positive and negative feedback, and practice (such as repetition) to strengthen the bonds (Tomlinson, 1997). The teaching during the early 20th century was extremely rigid in its approach. Teachers did not permit mathematical tasks to be solved using unorthodox or novel solutions, for fear it would create an incorrect learned response in the student (Lambdin & Walcott, 2007).

A significantly important aspect to note is the role of the teacher and student within this learning approach. The teacher provides highly directed instruction, in a highly controlled learning environment and deters any sort of deviation from the set procedures. The theory saw students simply as passive receivers of knowledge and that the students’ actions were completely manipulable to regular positive reward when the correct response was given, and negative feedback when the incorrect response was given. Ernst von Glasersfeld described behaviourism as a very interesting way to teach *behaviours*, but that it did not teach *understanding*, because the theory of behaviourism excludes anything to do with cognition (Lombardi, 2010).

Teacher-centred learning

The type of learning that the TIMSS video study exposed had the same characteristics of an Edward Thorndike or B. F. Skinner approach of drill-and-practice, that is, a focus on low-level behaviours learnt through repetition; and aligns with a pedagogy often referred to as a *teacher-centred approach*. It is also sometimes referred to as 'traditional teaching', 'transmission teaching, 'talk-and-chalk' and a 'teacher-centred learning' (Dinham, 2013). It is a style of instruction that sees students passively accept information from the teacher, often in the form of a lecture or demonstration. Students are then expected to memorise the information, usually through repetition, and then repeat it back to the teacher when required (Lawrence et al., 2014). The use of teacher-delivered content to passive students, and the use of repetition and practice, are the primary sources of learning (van den Heuvel-Panhuizen, 2010). Barrows and Tamblyn (1980), who are identified as the creators of problem-based learning, described the typical characteristics of teacher-centred learning as the teacher who makes the decisions about what is to be learned, how it is to be learnt and at what pace. It usually relies on the teacher as the person who dispenses the knowledge through lectures and demonstrations.

As mentioned earlier, a teacher-centred approach is still very much recognised in today's mathematics classrooms, particularly in Australia, where the focus is on highly directed instruction, rote memorisation and breaking procedures down into small steps. However, this has been recognised as a significant cause of mathematics anxiety, recorded in students as young as five (Boaler, 2016). Nevertheless, teacher-centred learning continues to be used. Barrows and Tamblyn (1980) cited three reasons for its popularity. First, it is a time-efficient method for transmitting a large amount of content to a large number of students. The teacher can dispense the content knowledge in a very efficient way, such as a lecture. Secondly, the teacher can be guaranteed that the students have been exposed to the content thereby satisfying curriculum goals. And last, it is relatively cheap to administer as it only takes one teacher and very few resources. In summary, the benefits are mainly felt by the teacher.

A teacher-centred approach does, however, have a number of disadvantages. One of the disadvantages is that it is homogenous. It assumes that students have the same background, knowledge, experience and pace of learning, but the reality of a classroom is that this is never the case. Barrows and Tamblyn (1980) noticed that a teacher-centred approach also can erroneously lead both students and teacher to believe that once they have been exposed to this content knowledge and concepts, the students will recognise when to use the information, and know how to incorporate and apply it usefully in the future.

Another disadvantage of a teacher-centred approach is that the students' role is as a passive receiver of the knowledge. The teacher offers the knowledge to the students, which is then to be given back to the teacher when requested. This style of learning has a strong focus on memorising (Major & Palmer, 2001). The result is that the students see the teacher as the font of all knowledge and students show reluctance to question or critique the information they are receiving. This can lead to students believing that there are strictly right or wrong solutions and processes, and the goal is to memorise the right ones (Cady & Rearden, 2007).

Swan (2005) and Simon (1994) discuss some of the distinct features and implied assumptions that a teacher-centred approach advocates, whether intentionally or not, about learning.

Table 2.2 – Teacher-centred characteristics and assumptions about learning

Distinct features of a teacher-centred approach	**Underlying assumptions**
Students sit quietly, listen to the teacher and copy notes from the board.	The most effective way for people to learn new content is to have them passively accept it and memorise it.
Presentation of an abstract idea followed by application in specific contexts.	It is best to be presented the end product of an abstract idea, such as a formula or algorithm, at the beginning of the learning process.
The concepts discussed are presented by the teacher in his/her own language.	Students' understanding of language and its meaning is not recognised as important.
The validity of ideas is determined by the teacher or textbook.	Learning is about getting the right answer, as seen by the teacher or textbook, and not about students taking the lead to critique and analyse their solutions, with the assistance and guidance of the teacher.
The teacher does not assess the students' prior knowledge or ask questions, beyond clarifying that they understand what has been explained to them.	The students' prior knowledge and experiences are not applicable to learning new content.
Students do not contribute to the content.	The students' contribution is not required or considered useful for learning, resulting in learners' feeling they have nothing to contribute – 'just tell me what to do'.
Students are required to memorise facts and restate them in a summative assessment.	The content is more valuable than the actual process of recognising the need for the content and learning the skills required to find and use the content.

(Simon, 1994; Swan, 2005)

As an example of the impression left on students by a teacher-centred approach, Swan (2005) undertook a study to find out what students consider being their most frequent behaviour in a mathematics classroom. In his survey of about 750 students of mathematics from 30 universities and secondary schools, students described their most frequent behaviours in the following ways:

"I listen while the teacher explains."

"I copy down the method from the board or textbook."

"I only do questions I am told to do."

"I work on my own."

"I try to follow all the steps of a lesson."

"I do easy problems first to increase my confidence."

"I copy out questions before doing them."

"I practise the same method repeatedly on many questions."

(Swan, 2005, p. 3)

Swan describes that students' deep learning of mathematics is profoundly impeded and their attitude towards mathematics is greatly influenced by this style of mathematics teaching. There is an over-emphasis on product over process, with a lack of connecting knowledge. This has an important connection to performance over mastery goals from the previous section of this chapter.

> For these learners, traditional mathematics education is something that is 'done to them', rather than being a creative, stimulating subject to explore. It has become a collection of isolated procedures and techniques to learn by rote, rather than an interconnected network of interesting and powerful ideas to actively explore, discuss, debate and gradually come to understand.
>
> (Swan, 2005, p. 3)

The recent results from the TIMSS study suggest that many teachers still use a behaviourist approach to learning in mathematics classrooms, that could have appeared to come from an early 20th century classroom, when Thorndike's and Skinner's theories of behaviourism were the main theories used to teach mathematics. But instead it came from recent Australian mathematics classrooms where many of the incoming preservice teachers have had significant experience in this type of learning.

Constructivism

Constructivism has offered another approach to learning and has been the foundation of the student-centred approach. Over the past several decades, a large and growing body of research has suggested that what is taught by the teacher is not always what is learnt by students. The students' understanding does not mirror exactly what is provided by the teacher. There have been numerous studies that show significant qualitative differences in the understandings that students develop in instructional situations, and that these are often very different from those the teacher intended (Bodner, 1986; Cobb, 1994). The implication of this research is that we have a deeper understanding of how people learn and come to understand information. It was discovered that for understanding to take place, an individual could not be given information and it be immediately understandable and useful. Ernst von Glasersfeld, a philosopher, psychologist and a significant contributor to the theory of constructivism, describes the central tenet in constructivism:

> … you cannot transfer knowledge from a teacher to a student as though it were a commodity, that you can just transport from one head into another. They [effective teachers] realised that in some sense, the student has to always build his own knowledge or her own knowledge. And that is a very different process from the one that was assumed to be a reception of something that is ready made into the head.
>
> (Lombardi, 2010)

These findings have impacted the way educators view teaching and learning and are influencing educators to revisit the way effective, authentic learning is best designed and implemented. The previous few decades of education research have advocated a change of focus, from the teacher's delivery of content as the centre of the learning, to the student's activeness and participation in the learning process being at the heart of the learning experience. This change in focus has meant that reform educators do not initially focus on what the teacher says, but rather on what the students do through the expertise and facilitation of the teacher.

While behaviourism is the theory that informs a teacher-centred approach and drill-and-practice, it was during the 1930s to 1960s, when the Great Depression, World War II and the "space race" occurred, that people began to question the worth of doing these repetitive drills that only focused on fluency (Tobias, 2002). It was asked whether this sort of mathematics was of any practical use in this new and technological world. There was a desire and appeal for a more expansive and generous view of mathematics learning (Lambdin & Walcott, 2007).

Around this time, another strong voice in education was John Dewey, and he had a vastly different idea about how people learn and how teaching should be done. Unlike Thorndike and Skinner, who approached education from a behaviourist, animalist and purely scientific perspective, John Dewey approached education from a more philosophical and humanist perspective (Lambdin & Walcott, 2007). Dewey believed that people had a vast capacity for learning and critical thinking. Where Thorndike and Skinner valued quantitative test results as a key sign of learning, Dewey believed that the goal and measure of a good education should be to arouse a continuing interest in learning throughout the student's life (Gibboney, 2006). The implication of this is that the disposition of the student is critical in a 'good' education, and that there exist significant qualities in learning that are intangible and immeasurable by tests. Dewey valued children undertaking long-term projects where they would be immersed in everyday activities (Glassman, 2001). One of the most important aspects in Dewey's vision of education was the individual and the idea of *free inquiry*. For Dewey (1916) it was not the educational goals that mattered, it was only the process of inquiry that was important. Glassman (2001) described Dewey's educational vision, which sees:

> … [everyday] activities of the children will eventually coalesce around a topic that is of interest to them. The topic need not be of any relevance to the demands of the larger social community, or even have meaning or interest for the teacher. As a matter of fact, the teacher should step back from the process once children display a relevant interest and act as a facilitator rather than a mentor. It is the students who must drive the inquiry, based on their own goals. (p. 4)

Dewey's belief in a broad and democratic view of learning, combined with the world events in the middle of the 20th century, led to a blizzard of ideas for curriculum reform (Lambdin & Walcott, 2007). It was perceived that for a country to remain competitive, in an increasingly technological and changing world, the education system had to develop other skills in their students, besides being able to follow an algorithm. Such qualities like creativity and critical thinking would be needed and valued. The result was an unveiling of a new and different approach to mathematics education. Dewey (1916) believed that a formal, one-size-fits-all style of delivery, which involved communication only from the teacher to student, was like casting a mould, and "only when it [communication] becomes cast in a mold and runs in a routine way does it lose its educative power" (1916, p. 16).

It was during this phase in the mid-20th century that mathematics education changed focus, from algorithmic, rote-memorised, drill-and-practice style, to a much broader view of learning, involving higher-order thinking. The goal was not just skills, but the ability to 'understand' the mathematics, rather than just 'do' the mathematics (Lambdin & Walcott, 2007). Students' ability to understand concepts, work with real-life mathematical situations and have a grasp of the fundamental structures of the discipline were considered paramount in this reform. It would require students to become active participants in the educative process and less passive (Tigelaar, Dolmans, Wolfhagen, van der Vleuten, 2004).

In order to achieve this objective, a number of educational theories were employed. Alongside the contributions of Dewey, were two other theorists. The work of Jean Piaget and Jerome Bruner made profound contributions to the reform and many of their insights are still used today. The following section will look at these contributions separately, outlining how each concept influenced this new approach to learning mathematics. To recap, the constructivist theory asserts that learning is:

> the active construction of knowledge by the learner. The student is seen as an active, self-regulating learner, who creates meaning from his or her own experiences in a meaningful way.
>
> (Tigelaar et al., 2004, p. 254)

One of the most significant contributions to the theory of constructivism was by the Swiss biologist, philosopher and psychologist, Jean Piaget. His research investigated how individuals actually build their own knowledge and how these constructions are internalised. This was a significant difference from behaviourism, as it was an attempt to explain what goes on in the mind, which behaviourism excludes. Piaget asserted there were four main parts at play when a person learns – schemas, equilibrium, assimilation and accommodation.

Schemas

Piaget (1953) thought that individuals learn by building on top of logical structures or patterns, called *schemas*. Marin, Benarroch and Gomez (2000) cited a number of definitions of schema including:

> …a group of common and coherent concepts (Viennot, 1979), students' ideas which are coherent with their experiences (Watts and Zylbersztajn, 1981; Watts, 1983; Terry et al., 1985), perspective from which the students' answers to different questions can be predicted (Finegold and Gorsky 1991), a group of ideas which shows a certain consistency towards the same concept presented in different problem areas and contexts (Kuiper and Mondlane 1994), a network of relationships which constitutes the knowledge of facts and phenomena used by a child.
>
> (Ruggiero et al., 1985; Marin et al., 2000, p. 226)

Mental growth consists of moving from simpler to more complex structures (Bruner, 1997). Piaget was a constructivist and thought "no behaviour, even if it is new to the individual, constitutes an absolute beginning. It is always grafted onto previous schemes and therefore amounts to assimilating new elements to already constructed structures" (Piaget, 1970, p. 707). These structures are continually being revised and built on through experiences with the physical and social environments (Piaget, 1970). Each person has a unique framework due to the fact that schemas are based on experiences and prior knowledge, so therefore each person has a unique understanding of the world (Bodner, 1986).

The purpose of a schema is to help an individual interpret information (Bodner, 1986; Tigelaar et al., 2004). For example, a person may have a schema for ‘dog’ that includes some of the physical and behavioural features of a dog, such as fur, four legs, a tail, barking and licking. This schema will continue to be revised and built on with further experiences. For building or revising to occur though, an individual must be moved out of *equilibrium*.

Equilibrium

When an individual’s existing schema explains what is being perceived around them, the individual is in a state of mental balance, called *equilibrium* (Bodner, 1986). Piaget believed that knowledge is constructed and a person’s knowledge must "fit" a person’s experiences, but that “individuals are not free to construct any knowledge, but that their knowledge must be viable, it must ‘work’” (Bodner, 1986, p. 6) and this knowledge comes from their experiences.

Learning occurs when an individual is in *disequilibrium* (Piaget, 1970; Boaler 2016). This unbalance occurs when an experience cannot be made sense of by the individual’s existing schema. Expressed another way, “disequilibration occurs when we cannot assimilate our experiences into pre-existing schemes, when we encounter a problem because we cannot achieve our goals” (Bodner, 1986, p. 3). For example, a young child who has a schema for ‘dog’ but not one for ‘cat’ will be in disequilibrium because, while a dog and cat share many of the same features, a cat meows and a dog barks. Piaget believed the process of returning to equilibrium is self-regulating and once disequilibrium has occurred, the only way to return to cognitive stability is through a mixing of assimilation and accommodation (Gauvain & Cole, 2008).

Assimilation

Assimilation refers to the notion that an individual takes into the mind what makes sense. Piaget (1970) describes that assimilation as conservative, as no building is occurring, and subordinates the environment to the organism. Put another way, von Glasersfeld described assimilation as the process where:

> … you take out of a present experience what fits experiences that you've had before. You have a pattern and whatever fits that pattern, you are ready to take. The rest you discard, you don't know about it.
>
> (Lombardi, 2010).

It is only when disequilibrium occurs that an individual needs to accommodate new aspects of their experience.

Accommodation

The opposite of assimilation is *accommodation*. This is a process of learning where an individual returns their mental state to equilibrium. Piaget described accommodation as the "source of changes and bends the organism to successive constraints of the environment" (1954, p.353 cited in Block, 1982, p. 282). Ernst von Glasersfeld describes Piaget's accommodation.

> Accommodation is when you discover that a particular pattern you applied is not useful in that context. It doesn't work. It doesn't get you where you want to be. Then you may look at the situation anew and try to interpret it differently. If you revise what you see and it works then, you have a different scheme … Accommodation applied on its own, is again, making another pattern of your own that will fit this situation.
>
> Now if you recognise a situation, as the one in which a particular action was useful, then you carry out that action. But you expect the beneficiary effect at the end of the action. If it doesn't come, if the action doesn't produce

> what you want, then you have an incentive to
> accommodate, and that is to change your scheme.
>
> (Lombardi, 2010)

Put another way, Bruner describes in general terms, the process as follows:

> what was said to impel growth along this invariant course was disequilibrium, a process created by the relation between two component processes. Encounters with the world were either fitted into, assimilated to previous existing mental structures, or existing structures were changed to accommodate them. At one extreme, for example, there is the assimilation of play; at the other, the uncomprehending accommodation of imitation.
>
> (1997, p. 126)

Block (1982) states that accommodation is necessary for structural change and that that the transformation of the structures is a function of the experiences encountered. Piaget (1970) believed that assimilation and accommodation were products of an evolution, and an act of intelligence is characterised by returning to equilibrium through the mixing of assimilation and accommodation.

CPA and spiral curriculum

Also at this time in the mid-20th century, an American psychologist called Jerome Bruner made two major contributions. First, was the notion of a spiral curriculum and secondly, was the idea of discovery and student-ownership of the learning (Lambdin & Walcott, 2007). The spiral curriculum is based upon:

> an iterative revisiting of topics, subjects or themes throughout the course. A spiral curriculum is not simply the repetition of a topic taught. It requires also the deepening of it, with each successive encounter building on the previous one.
>
> (Harden & Stamper, 1999)

To assist the building of this knowledge in the spiral curriculum, Bruner used the stage-theory of Piaget and developed the notion that children move through three modes of representation as they learn (Lambdin & Walcott, 2007). So significant is this pathway of learning that Singapore, one of highest achieving countries in the international PISA scores (Thien, Darmawan & Ong, 2015), insists that the texts that are used in schools adopt this approach (Naroth & Luneta, 2015).

The first mode is the *enactive* mode, also known as the *concrete* mode. This means that a student's first learning experiences should be with objects that the student can manipulate. The second level is the *iconic* mode, also known as the *pictorial* mode. This involves the student working with images to represent objects. It acts as a step towards abstraction, as it is semi-concrete in the sense it has a real-life, concrete dimension, but the student is not able to manipulate the objects physically. This level plays an important part in preparing students to be able to work in the last mode, which was the *abstraction* or *symbolic* mode. Bruner observed that for students to have a firm sense of abstraction underlying what they were working with, they needed "a good stock of visual images embodying them" (Bruner, 1966, p. 66). Bruner saw the role of the iconic mode almost as a back up, so that the student would be able to rely on mental imagery "when his symbolic transformations fail to achieve a goal in problem solving" (Bruner, 1966, p. 49). The abstraction mode involves a student working entirely with abstract symbols, rather than objects or images.

An example of Bruner's modes in mathematics education would be the use of base-ten materials to understand the meaning of place value. Children would begin their learning by using base-ten blocks in the enactive mode, they would then work with images of base-ten materials in the iconic mode; and finally, they would simply work with the numerals in the symbolic mode (Herrera & Owens, 2001).

Bruner believed that children could learn just about anything, if well-chosen problems were used with the guidance of his modes, to allow students to investigate and discover concepts, rather than being told the relevant concepts and expected to perform drills repeatedly (Herrera & Owens, 2001). Bruner's framework for instruction was adopted and the spiral curriculum was integrated into the new reform so that students would experience concepts repeatedly throughout their schooling. With each time students revisited the concepts, teachers would provide a greater level of complexity and abstraction, and assist the students to move through the enactive, iconic modes and finally work at the symbolic level (Lambdin & Walcott, 2007). The idea still has extensive use in today's curriculums within NSW's syllabuses, such as Arts and Music (see for example, Board of Studies NSW, 2009).

In the 1980s, there was considerable focus on the use of problems in mathematics education. It was intended that students would not only learn how to solve problems, by using problem-solving strategies like 'draw a diagram', but that students would learn through problem-solving (Lambdin & Walcott, 2007). It was argued that the benefit of problem-solving in mathematics is that students can develop deep mathematical knowledge and understanding (Anderson, 2008). In the United States, the NCTM explicitly made problem-solving a focus for learning in mathematics – that problem-solving is “not only a goal in mathematics but also a major means of doing so” (National Council of Teachers of Mathematics, 2000, p. 4). It was not completely new to use problems in mathematics, but traditionally it was placed during or at the end of the learning cycle, rather than the focus (Taplin, 2008). A satisfactory ‘problem’ would have the following characteristics:

- A situation that one finds a solution by a means that is not immediately obvious.
- A task that engages and develops important mathematical ideas that the student needs to learn about.
- The task must be ‘non-routine’ (Welch, 2007).

It is important to note that the term, ‘non-routine’, depends on the student, as what might be routine to one student, might not be routine to another student. With the expectation that students will undertake non-routine challenges before they know a solution that is not immediately obvious, educators needed a framework from which to guide the teacher’s new role. One educational theorist whose work was influential at this time was Lev Vygotsky and *social constructivism*.

Social constructivism

Particularly relevant to the use of problem-based learning is *social constructivism*, since the nature of the classroom is a social one, social constructivism has been “highlighted as a reform-oriented approach to teaching and learning mathematics. This form of constructivism promotes learning in a social context through problem-solving, collaboration and the negotiation of meaning” (Tobias, 2002, p.

14). Vygotsky was interested in the social and cultural aspects involved in constructing knowledge. Like Dewey, he believed that learning should be an active and context-specific process. But unlike Dewey, who strongly valued the individual in education, Vygotsky saw social and cultural goals as being integral to social pedagogy (Glassman, 2001).

Vygotsky applied the general theory of constructivism to a social context. While Piaget focused on the internalising and structuring of knowledge in the individual's mind, Vygotsky focused more on the value the role of instruction and society has on learning. Vygotsky did not, like Piaget, focus on the mind making logical structures, but rather the mind making meaning of its experiences (Bruner, 1997; Glassman, 2001). Vygotsky thought that the mind mediates learning and interactions, and "that other people – such as parents, teachers and peers – mediate learning and enculturation through cultural tools because knowledge and language pre-exist and are external to the individual" (Lerman, 2000, p. 213). He believed that isolated learning could not lead to cognitive development, meaning that learning always involves more than more person (Nyikos & Hashimoto, 1997).

Bruner (1997) makes the distinction that Piaget recognised the crucial role of logic-like operations in human mental activity, while Vygotsky noticed the dependence of the human intellectual ability on human culture and history as tools of mind. Piaget appeared to ignore *intersubjectivity*, which looks at how people know each other's minds, and know them sufficiently well to aid each other in constructing our knowledge of the world through negotiation, instruction and enculturation (Bruner, 1997). Bruner believes that Piaget's scientific background as a biologist meant that his approach to his work was framed as a scientist, and so therefore his absence of intersubjectivity, and culture altogether, was not inadvertent but principled and self-imposed.

Two major contributions from Vygotsky to teaching and learning are the *zone of proximal development* (ZPD) and the concept of *scaffolding*. Both have significant importance in a student-centred learning environment, such as problem-based learning.

The ZPD refers to the range of potential growth of an individual (Nyikos & Hashimoto, 1997). The zone, shown as the shaded area in Figure 2.4 is the range between where a student could complete a task with guidance, but could not complete a task even with guidance. In other words, a student is outside their ZPD when they are unable to complete a task, no matter what assistance they are provided, or if they could successfully complete a task unaided.

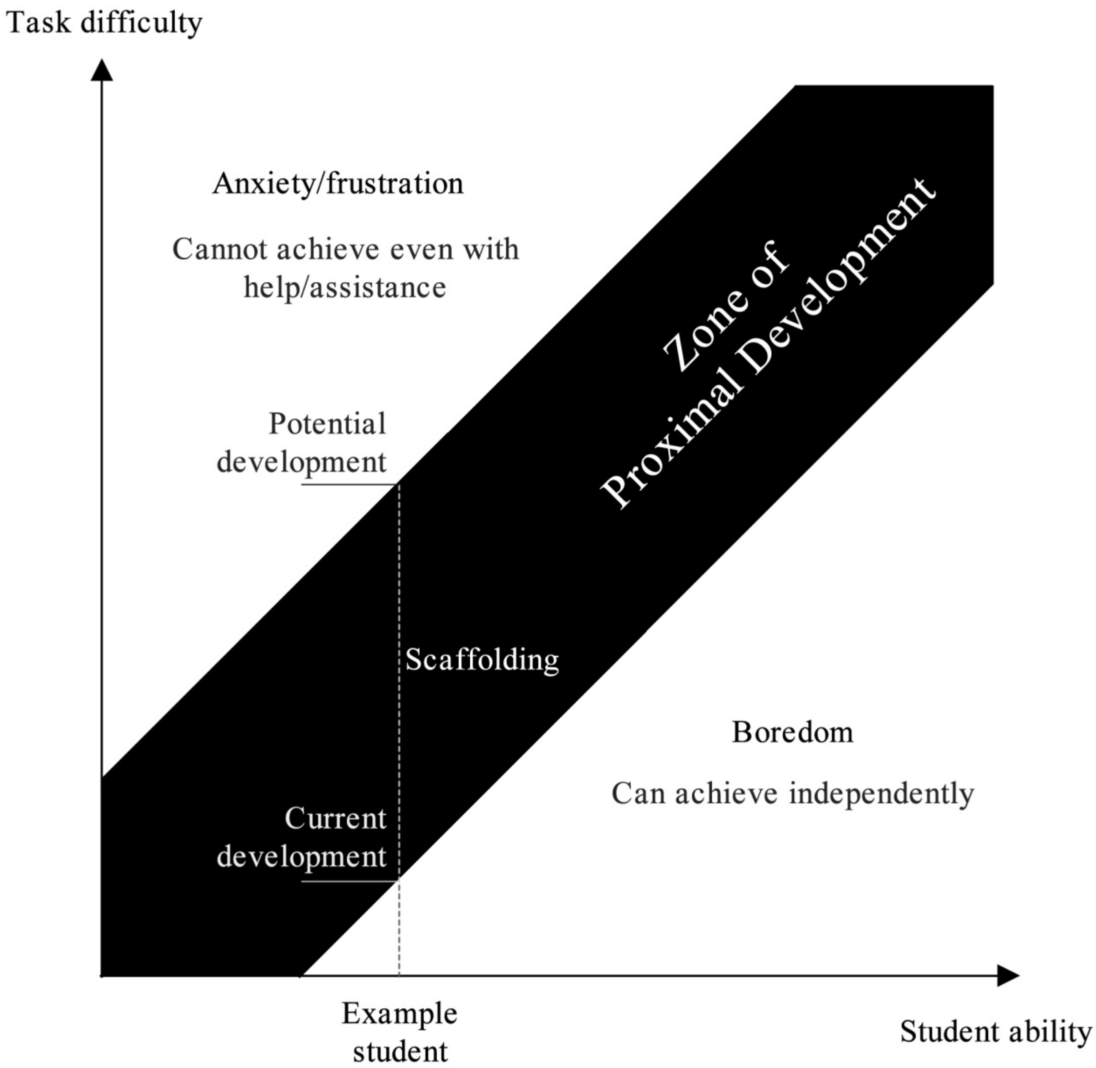


Figure 2.4 – Zone of proximal development (Leder & Grootenboer, 2005)

Vygotsky defined the ZPD as:

> the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers.
>
> (1978, p. 86)

To demonstrate by example, Vygotsky (1978) described two children, both aged twelve years chronologically and eight years developmentally. The latter implying that they could both deal independently with tasks up to the degree of difficulty of a standardised 8-year-old level. This is referred to as *current development* in Figure 2.4. Vygotsky suggested that people may imagine that the subsequent course for development of these two children will be the same, since they are both developmentally at the same level of eight years. But Vygotsky then described helping the children work through a task with his assistance. It was discovered that one child could successfully deal with a task at a 12-year-old level, while the other child up to a 9-year-old level. Therefore, it was determined that the children were of the same birth age, but not the same potential for mental development. As a consequence, the subsequent course of action for the two students would vary to a high degree. Vygotsky concluded by saying that “the difference between the twelve and eight, or the nine and eight, is what we call the zone of proximal development” (Vygotsky, 1978, p. 86).

Wertsch (1984) identified that Vygotsky’s phrase “problem solving under adult guidance or in collaboration with more capable peers” was not elaborated on by Vygotsky. He suggested there is a difference between the guidance that is behaviourist in nature and constructivist in nature, despite a task being completed correctly in both situations. The guidance or support in a constructivist environment takes on the form of a facilitator, rather than a lecturer. Interventions within a constructivist paradigm are done through *scaffolding*, also shown in Figure 2.4. The goal of scaffolding is more than assisting a student to work within their ZPD (Maybin, Mercer and Stierer, 1992). Scaffolding involves simplifying the learner’s role rather than the task and should be contingent upon the responses of the student (Daniels, 2001). Maybin, Mercer and Stierer (1992) suggested that scaffolding must (1) enable the learners to carry out the task which they would not have been able to manage on their own; (2) be intended to bring the learner to a state of competence which will enable them eventually to complete such a task on their own; and (3) have evidence of the learners having achieved some greater level of independent competence, as a result of the scaffolding experience.

Scaffolding can be done in a number of ways including reciprocal teaching (Daniels, 2001), as well as:

- assessing the learner's current knowledge and experience
- relating content to what student already knows or can do
- providing examples of the desired outcome and showing the learner what the task is as opposed to what it is not
- breaking a task into small, more manageable tasks with opportunities for intermittent feedback along the way
- offering students a chance to orally elaborate (“think-out-loud”) using problem-solving techniques
- use verbal cues and prompts to assist students in assessing their storage knowledge
- emphasising specific vocabulary that comes from the exploration
- regularly asking students to hypothesise or predict what is going to happen next
- allowing students time and opportunity to explore deeper meanings and relate it to newly acquired knowledge
- providing time for students to reflect and debrief on their learning experience and what worked and what did not (Silver, 2011, p. 31).

The qualities of social constructivism were summarised by Simon (1994) and contrasted with those of a traditional, positivist framework in Table 2.3. This was used as a framework for mathematical teacher education such that teachers were taught in a way that is consistent with reforms towards student-centred learning.

Table 2.3 – Social constructivist framework compared to positivist framework

Proposed Framework (Social Constructivist)	**Traditional Framework (Positivist)**
1. Situation for students to communicate mathematical ideas and engage in negotiation of meaning.	1. No situations for students to communicate mathematical ideas and engage in negotiation of meaning.
2. Problem solving in a specific context followed by abstraction/generalization of ideas.	2. Presentation of an abstract idea followed by application in specific contexts.
3. The concepts discussed are developed by students and expressed in their language.	3. The concepts discussed are presented by the teacher in his/her own language the language of the communities in which they belong.
4. The responsibility for determining the validity of ideas resides with the classroom community.	4. The responsibility for determining the validity of ideas resides with the teacher or is ascribed to the textbook.
5. Application is the exploration of new ideas or extension of ideas previously developed.	5. Application is limited to the practice and use of the general idea presented.

Simon (1994, p. 79)

Student-centred learning framework

The theory of constructivism developed by Dewey, Piaget, Vygotsky, Bruner and others, lies as the foundation of an approach to learning that places the student at the focus. It sees students as active participants rather than passive learners, and focuses on deep learning where connections are made and understood. It requires that students take on an increased level of autonomy and responsibility for their learning, and a more collaborative relationship with the teacher. Lea, Stephenson and Troy (2003) provided a framework for student-centred learning, and contrast this against a teacher-centred learning approach based on a positivist perspective. This framework and summary of the characteristics of a student-centred approach is provided in Table 2.4.

Table 2.4 – Characteristics of student-centred learning compared to teacher-centred learning

Aspects learning/teaching	**Student-centred approach**	**Teacher-centred approach**
Student body	Caters to heterogeneous student population and individual student needs	Caters to homogeneous student population and lowest common denominator
Mode of learning	Active – lectures more interactive, group work, flexibility in terms of choice of modules	Passive – lectured at, little group work, students replicate, what they have been told, lost from once regurgitated
Mode of teaching	Active – lectures more interactive, group work, flexibility in terms of choice of modules	Transmission – lectured at, little group work, little or no flexibility in terms of choice of modules
Feedback	Continuous, qualitative, teacher and student give each other feedback	Limited, quantitative, teacher gives student feedback
Assessment	Formative and summative, coursework and examination	Mostly summative, reliance upon end of module examination
Learning outcomes	Having a say in the learning outcomes, acquiring knowledge and skills, especially skills relevant and applicable to the real world	Having little or no say in the learning outcomes, acquiring knowledge and some skills
Student-teacher relationship	Respect for students, treated as adults, prior knowledge/ experience acknowledged, co-constructing knowledge, sometimes teacher learns from students	Paternalistic attitude, teachers as expert, student ignorant regarding process and content of learning

Aspects learning/teaching	Student-centred approach	Teacher-centred approach
Responsibility	Students more responsible for and in control of their own learning, become more independent, personal accountability, an empowering process	Staff responsible for making students learn, remains dependent on teacher

Adapted from Lea, Stephenson and Troy (2003, p. 327)

The following sections discuss the theoretical foundations that underpin the context and perspective this study utilised. The following section looks at one type of student-centred approach in the form of problem-based learning and was to both begin teaching the preservice teachers mathematics education, and serve as an example of student-centred education, using a social constructivist approach.

Problem-based learning (PBL)

This section introduces PBL as a method of teaching that utilises a constructivist, student-centred view of learning. This study adopted a PBL approach as a way of modelling the ideas to preservice primary teachers. The following part outlines the genesis of problem-based learning, the underlying theoretical framework and discusses why it appears particularly well suited, but not yet significantly used, in teacher education.

History of PBL

PBL is a fairly recent contribution to pedagogical approaches. Since its extensive use in the education of medical students at McMaster University in Ontario, Canada, which began in the 1960s, PBL has spread to many other fields of education including law, engineering, geology, psychology and architecture (Gijbels, Dobchy, Bossche, & Segers, 2005; Peters, 2006). The early pioneers of

PBL at McMaster University were Howard S. Barrows and Robyn M. Tamblyn, who described PBL in detail in their 1980 book, *Problem-based Learning: An Approach to Medical Education*. It was Barrows who observed that medical students who had passed a number of courses in basic medical knowledge (using a non-PBL approach), were not able to sufficiently transfer their knowledge when applying it to the assessment of a patient's condition (Barrows & Tamblyn, 1980). This was particularly evident when Barrows and Bennett (1972) investigated the way medical students performed an inquiry on a simulated patient. For the most part, the students would gather data procedurally and try to combine it all together later, or make a diagnosis based on a single symptom or sign, not even looking deeper for other possibilities.

Barrows' criticism of traditional lecture-based approaches, which continue today en masse in teacher education, was that students appeared to have a lack of ability to problem-solve and showed poor retention of relevant knowledge. This led Barrows to create a curriculum centred on the resolving of complex situations. The curriculum and definition of PBL were designed by Barrows and Tamblyn (1980) to "refer to a very specific approach to education in medicine". This approach revolved around two assumptions. First, that learning through problem-solving is much more successful in creating a body of useable knowledge in a student's mind, rather than memory-based learning. Secondly, that the most prized skill for physicians is to have problem-solving skills, rather than memory skills (Barrows & Tamblyn, 1980).

Barrows felt at this time that the current use of problems in the curriculum was misplaced. Problems were often given to students to solve only after they had been given the facts, concepts and principles, either as an example to highlight the importance of the knowledge they had just been given, or as an opportunity to apply this knowledge (Barrows & Tamblyn, 1980). Whereas Barrows believed a complex problem should be introduced, before the facts were known, as a focus for the study to be carried out. He believed that the application of this knowledge both helps enthuse students, teach problem-solving skills and aid in retention. Barrows asserts that knowledge used is better remembered (Barrows & Tamblyn, 1980).

Definition of PBL

It is important to note from the outset, as does Savin-Baden (2000), that not all learning that involves some kind of problem is PBL. PBL has certain, broad characteristics with the central one being that "the problem is encountered first in the learning process" (Barrows & Tamblyn, 1980, p. 1). Despite the obvious connection of Barrows and Tamblyn's work to medical education, the general elements they designed for PBL have permeated throughout large sections of the education community, particularly in the area of the professions. Even with the popularisation and major contributions of Barrows and Tamblyn to PBL, many researchers acknowledge the debate around what actually qualifies as PBL (see for example Boud & Feletti, 1997; Savin-Baden, 2000; Savery, 2015). Eng (2000) mentions that with the explosion in interest in PBL, concern has arisen that the concepts of PBL will be confused if any educational approach that uses the word *problem* will be seen as applying a PBL model. This concern has given rise to the question of what actually qualifies as PBL. What characteristics does the learning process need to have in order to be considered a genuine PBL approach? To what extent does the use of problem-solving have to be included in a course to have a genuine PBL status? What problems can be a classified as a 'problem-based learning-problem'?

Both Eng (2000) and Savin-Baden (2000) mention that it is not useful to be too strict or elitist in the classifying of PBL approaches. As well, Boud (1985) and Barrows (1986) support the view that PBL does not come in a single form. Boud (1985) also asserts that the nature of the discipline and learning objectives will influence the style of PBL. One reason to avoid too strict a definition of PBL and its processes is that this places narrow boundaries that tend to set traditional notions of learning, and reduce the perception of innovation (Eng, 2000; Savin-Baden, 2000). Another reason is that it tends to exclude the use of PBL in other areas of education, such as schools, distance education, online programs and non-vocational contexts (Eng, 2000). The latter is especially applicable to certain areas within the study of mathematics.

Despite this caution, Eng (2000) claimed that it is still important to be able to classify PBL characteristics and approaches for a number of reasons. There is a need to be able to validly compare evaluations and research, to understand the different interpretations of PBL and to have the ability to adopt appropriate and effective models to meet specific educational goals.

The following is a brief summary of the characteristics and processes of PBL, offered by a variety of researchers. The broad characteristics as laid down by Barrows and Tamblyn (1980) offer a starting point. Barrows and Tamblyn (1980) suggest that PBL is:

> … the learning that results from the process of working toward the understanding or resolution of a problem. The problem is encountered first in the learning process and serves as a focus or stimulus for the application of problem-solving or reasoning skills.
>
> (Barrows & Tamblyn, 1980, p. 18)

The authors go on to define a problem as:

> ... an unsettled, puzzling, unsolved issue that needs to be resolved. It is a situation that is unacceptable and needs to be corrected. Finding the answer to a question is not problem-based learning. The use of a known principle or solution to explain an observation or phenomenon is not problem-based learning.
>
> (Barrows & Tamblyn, 1980, p. 18)

This led to Barrows' (1980) characterisation of a model for PBL. It included that students are to work in small teams, students are responsible for their own learning, teachers take on the role of facilitators and problems must be based on complex, real-world situations and have multiple solutions. Many researchers agree that the characteristics of PBL as laid out by Boud (1985) are generally accepted as key features (Eng, 2000; Savin-Baden, 2000; Savery, 2015). They are:

- The presentation of a problem occurs at the beginning of the learning process, and that this process is in response to the problem
- The problem simulations must be ill-structured, allow for free inquiry and have value on the real world
- An emphasis on students taking the initiative and responsibility for their own learning
- More scope for the crossing of boundaries between disciplines and subjects
- A focus on processes rather than products of knowledge attainment

- Collaboration is essential. A more collaborative relationship between students and teachers
- An appreciation and accommodation of a student's knowledge and experience at the beginning of the learning process
- What students learn during their self-directed learning must be applied back to the problem with reanalysis and resolution
- Self and peer assessment should be carried out at the completion of each problem
- A greater attention to the communication and interpersonal skills so that students understand that in order to relate their knowledge, they require skills to communicate with others.

Boud (1985) also described one of the most important features of PBL, besides problem-centredness, is the learning from student-centredness. Barrows also advocated this characteristic as a key part of PBL. This is a primary reason why it was chosen for this study as a way of modelling and experiencing the approach by the preservice teachers. Barrows (1980) described the method of student-centred learning as:

> …the student learns to determine what he needs to know. Although the teacher may have considerable responsibility in the beginning, by providing the student with the necessary experience and guidance, it is expected that the student will eventually take full responsibility for his own learning ... The teacher is available for guidance as needed until the student gains full independence.
>
> (Barrows & Tamblyn, 1980, p. 9)

While certain criteria must be adhered to in order for an approach to be considered PBL, Savin-Baden (2004) argued that PBL is more than a set of characteristics used to define a teaching approach by referring to Boud's (1985) suggestion that PBL changes according to the nature of the field and the particular goals of the course. However useful it would be to have a set of easily recognisable characteristics for the PBL technique, it has been argued that context will affect learning outcomes. For example, Savin-Baden (2004) states "there are not narrowly defined characteristics of problem-based learning. Instead there are people working in contexts using problem-based approaches" (p. 19). She continues by adding that PBL is, "an approach to learning that is affected by the structural and pedagogical environment into which it is placed, in terms of the discipline or subject, the organisation and the staff concerned". Savin-Baden does admit there are possibilities of defining the "overarching features of curricula that use problem-based learning, from which it is possible to formulate broad models" (Savin-Badin, 2000, p. 19), but warns that simply listing characteristics is to ignore the complex and philosophical implications of PBL. Walton and Matthews (1989) have asserted that it is not just a teaching approach, but should be seen as a general educational strategy. Walton and Matthews do, however, offer three broad components that should be observed. In brief:

1. The approach is centred on the problem rather than the discipline
2. The teaching environment is student-centred and involves active learning
3. The approach is focused on developing overall skills for lifelong learning, as opposed to rote learning of facts.

With the use of PBL in so many different educational areas, the idea of a core model or form has given way to a mass of interpretations of PBL principles. Eng (2000) offered a classification approach that revolves around the question of whether or not PBL is being used as a delivery method, or as a way of reconceptualising a full educational approach.

Eng (2000) identifies a number of reasons why the form and application of "problem-stimulated" approaches can be influenced by:

- The objectives of those who make the decision to take the approach
- The limitations of available resources and expertise
- The opportunities and scope for change within the subject, course or program
- The constraint beyond the control of those who want to use PBL in their programs.

(Eng, 2000, p. 3)

Eng (2000) differentiated the use of PBL as a tool to that of an educational philosophy by suggesting that the former only makes adjustments to the educational settings in the delivery stage, with little or no change in the existing curriculum design or assessment practices. A model is provided in Figure 2.5. The assessments for EDME145 included a written report of a child who had undergone a Count Me In Too numeracy assessment. The other assessment was an examination that was stipulated by the University's teacher accreditation body. Therefore, there was a limitation imposed on the types of assessments that could be designed within the PBL unit.

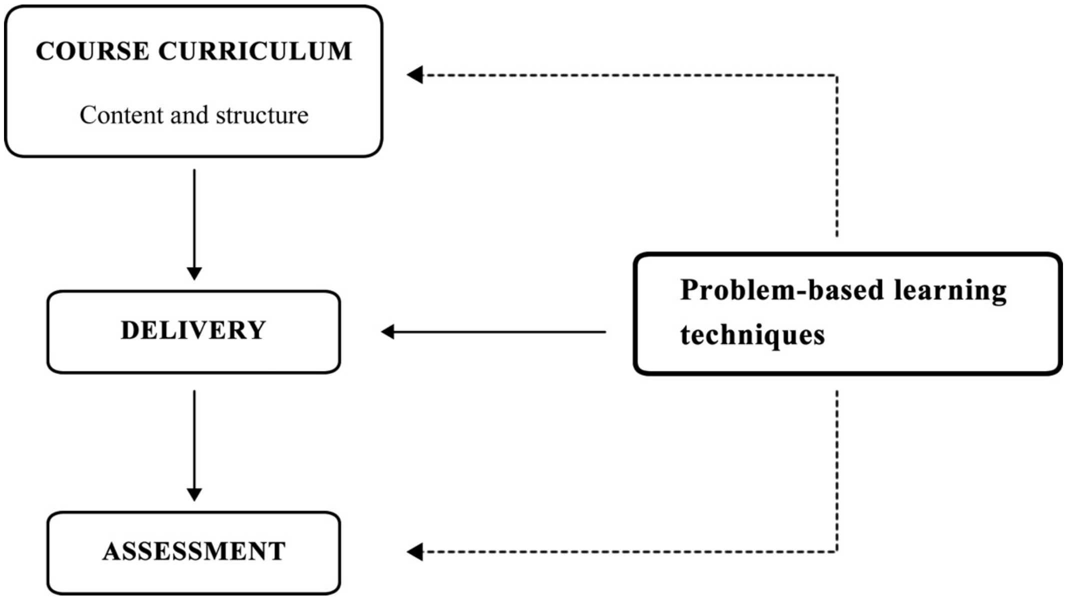


Figure 2.5 – Problem-based learning as an educational tool (Eng, 2000, p. 4).

This study's adoption of a PBL approach was similar to Figure 2.5, in that it impacted significantly on the delivery of the course content, with the use of small groups, ill-defined problems, learning targets and teachers as facilitators, but had only minor impacts on other parts of the unit, such as content.

Criticisms of problem-based learning

The theory of problem-based learning is a significantly different way to learn when compared to more teacher-centered styles of learning, which often highly values the recall of accurate content. Barrows (1980) sees the purpose of problem-based learning as having two objectives. Firstly, there is the gaining of a body of knowledge that is related to the problem, and secondly, is the development or use of problem-solving skills. While there are a number of positives, PBL is not without its criticisms, which are acknowledged in this section.

One common criticism of problem-based learning is that students will not learn everything that they are required to know and at the depth needed (Barrows & Tamblyn, 1980), especially when students have no prior experience in the subject area. This seems like a genuine concern as there is evidence to suggest that the cohort's results of years of learning in a problem-based learning environment sometimes deteriorate over time (Moust, Berkel, & Schmidt, 2005; Tunny, 2007). Moust et al (2005) claim that this erosion in quality was due to various adjustments made to the curricula (intended and unintended) and the behaviour of staff and students, which was counter-productive to self-directed learning.

As Barrows & Tamblyn (Barrows & Tamblyn, 1980, p. 10) admit, problem-based learning does require maturity and discipline from the part of the teacher and the student. This approach does put a large responsibility and workload on the teacher to assess and account for the amount of prior knowledge a student brings to the problem. Barrows also places a tremendous emphasis on the teacher, who is required to use new skills and is now expected to act as a guide, facilitator and evaluator of the student as an individual learner.

Contradictory evidence also exists over the benefits of problem-based learning. Gijbels et al (2005) performed a meta-analysis of the influence of assessment on the reported effects of problem-based learning. They discovered that almost all of the claims about the effects of problem-based learning come from medical education. Their findings suggested that students in a problem-based learning environment possess a highly structured network of concepts and principles (Gijbels, et al., 2005, p. 46). There is also an advantage of the conventional education when it comes to knowledge acquisition, but this advantage disappears after the second year of study (Gijbels, et al., 2005, p. 46).

Kirschner, Sweller and Clark (2006) have made the claim that a student's cognitive load (also known as working memory) at the beginning of a problem-based learning process is too high in order for learning to be effective. To overcome this, the researchers call for a highly directed approach to teaching called "worked examples", where students are to watch an experienced person (namely the teacher) solve problems. They state that "minimally-guided instructions" are likely to be ineffective. They assert that the research over the past half-century demonstrates to them that, "minimal guidance during instruction is significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning" (Kirschner, et al., 2006, p. 76).

In contrast to Kirschner, Sweller and Clark's arguments against strategies, such as problem-based learning, Barrows (1980) and others explain that problem-based learning is not at all minimalist, nor does it leave the student without guidance during the learning process. Savin-Baden (2004) supports Barrow's explanations, in saying that the teacher plays a crucial role, particularly in the initial stages, in problem-based learning. The difference is that the teacher is asked to take a different role, rather as a guide and facilitator than a knowledge dispenser. The teacher is required to ask questions, summarise ideas, suggest alternatives, monitor progress and prompt and provide reflection on the learning process (2004, pp. 98-99).

Problem-based learning in mathematics teacher education

Problem-based learning in teacher education has been increasingly implemented over the last two decades, in part, to what many see currently as an overly theoretical approach to teacher education (Smith & Friel, 2008). The increased interest of PBL in teacher education has also come from exploring questions such as how PBL can help preservice teachers teach in contexts that is different to their own personal and practicum experiences? What aspects of PBL in teacher education can be transferred to the classroom for learning subject content such as mathematics (Nicol & Krykorka, 2016)?

When relating this use of a real-life, problem-solving approach with preservice teachers, Aldridge and Bobis (2001) suggested that the simultaneous combining of both theory and practice is crucial to a successful education of preservice teachers:

> …situating preservice teachers' learning simultaneously in university and practically-based contexts is considered crucial to the success of mathematics methods courses for preservice teachers. Simply relying on preservice teachers to enact upon new insights into knowledge and beliefs during their normal practice teaching components is not a satisfactory alternative.
>
> (Aldridge & Bobis, 2001, p. 48)

Schulman (1986) wrote about the apparent divide in teacher education between content and pedagogy, and that knowing one or the other is not sufficient for effective teaching. He argued that it is only a relatively recent development that these two domains have been split and offered separately in teacher education programs. Schulman proposed that teachers required advanced knowledge of two domains, namely mathematical content knowledge (MCK) and pedagogical content knowledge (PCK), and that high quality student learning occurs when teachers simultaneously consider both when teaching. Problem-based learning is particularly well-suited to this goal as it allows the teacher to engage students in appropriate tasks to match their abilities and understandings.

Three-Circle Framework for teacher education

A prominent concept throughout the learning of EDME145 unit was the integration of three domains of knowledge proposed by Lappan and Theule-Lubienksi (1992). Building on the work of Schulman (1986), Lappan and Theule-Lubienksi proposed an extra domain of knowledge in the form of the student. Teachers' work is often described as working within the union of different domains of knowledge. Lappan and Theule-Lubienski (1992) identified a visual model for teacher education that defines at least three kinds of knowledge that a teacher must have in order to teach effectively. These domains are represented visually in Figure 2.6. Darling-Hammond (2006) has also championed and developed a similar teacher education framework in the context of constructing a teacher education so newly entering teachers can successfully teach in and for the 21st century. The first aspect is *content*, which refers to a teacher's knowledge of the subject matter and curriculum goals. Next is pedagogy, which is the knowledge a teacher has of such things as assessment, catering to a wide range of learners and classroom management. Last, is the knowledge of the learners. This includes "knowledge of learners and how they learn and develop within social contexts, including knowledge of language development" (Darling-Hammond, 2006, p. 303).

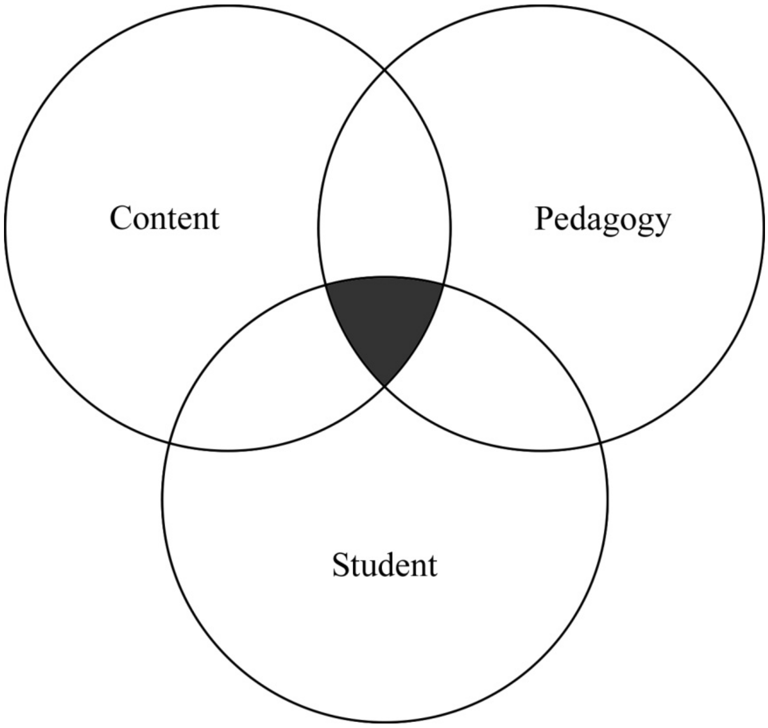


Figure 2.6 – Domains of knowledge required for effective teaching

Darling-Hammond (2006) described the qualities of a teacher in the 21st century as a person who is able to understand every child they teach and be able to find a way to nurture their development. To do this, teachers "need the skills to construct and manage classroom activities efficiently, communicate well, use technology, and reflect on their practice to learn from and improve it continually" (Darling-Hammond, 2006, p. 300). Teacher education has a genuine opportunity to support the development of these qualities in their preservice teachers so that they may undertake this complex job with a hope of success.

Conclusion

The history of mathematics education has many implications for teacher education. Teacher educators need to craft a course that not only prepares preservice teachers to be able to cope with teaching in today's classroom, but also the skills to adapt with the inevitable changes in the future. The increasing surge of technology in education is a case in point. It is a difficult and complex task to prepare teachers for the classroom, particularly with significant time and resource constraints faced in many tertiary institutions. A large number of students study off-campus via an online environment. These structural and institutional challenges are often compounded by the particular characteristics of many of the preservice teachers.

In mathematics education in particular, a large number of students enrolling in primary teacher education do so with low mathematical content knowledge, negative dispositions towards mathematics and a traditional, teacher-centred view of mathematics education. There is a cycle that exists, which sees preservice teachers enrolling into teacher education courses, having largely experienced teacher-centred learning. Once graduated, if they have not had sufficient experiences and persuasion towards student-centred learning, then they will most likely perpetuate teacher-centre learning. It is crucial for tertiary education courses to influence and expose their students to an alternative to a dominant and tempting approach to teaching.

The goal of a successful teacher education course should not only be focused on improving the preservice teachers' content knowledge, but also improving their dispositions towards the subject. A teacher's disposition towards mathematics appears to play an important part in the academic achievement and attitude of their students towards mathematics (Cady & Rearden, 2007; Morris, 2001; Tapia & Marsh, 2005). Recent research into the feelings, beliefs and attitudes of preservice primary teachers towards mathematics suggests that many experience a strong sense of anxiety when involved with mathematics (see for example Cady & Rearden, 2007; Hawera, 2004; Hughes, 2008), have an inability to relate mathematics to the real world, and a traditional view of how mathematics should be experienced (Beswick, Watson, and Brown, 2006).

Chapter Three

Methodology

Introduction

This chapter focuses on the methodological design and implementation devised to undertake this study. Initially, an overview is provided of the research questions and subsequent design, along with a theoretical justification. This includes details of the context in which the study was undertaken, the sampling procedures employed and ethical considerations. Next, details are provided of the methodological instruments that were adopted for the study. Finally, a brief section discusses the researcher's world view and a description of the mathematics education unit that adopted a problem-based learning approach.

Research design

In light of the research issues that emerged in Chapter 2, a study was designed that investigated how the attitudes, and views of intelligence, of first-year preservice students impacted on their perspective of learning and teaching mathematics. This included exploring their experience of a student-centred environment, in the form of a problem-based learning (PBL) mathematics education unit. As a consequence, the research design adopted was a case-study design using mixed methods.

Research questions

The following research questions were used to guide the study:

1. How do preservice teachers' attitudes towards mathematics, and beliefs about intelligence, relate to how they view the learning and teaching of mathematics?

2. How do preservice teachers with different beliefs about intelligence, and attitudes towards mathematics, respond to the qualities of the student-centred, PBL approach to learning mathematics education?

3. How does the student-centred, PBL approach affect preservice teachers' attitudes towards mathematics and beliefs about intelligence relating to mathematics education?

Case study

The methodology that was chosen to suitably answer the research questions was *case study*. Case study research refers to the methodology that investigates and analyses a single or collective case, intended to capture the complexity of the object of study (Stake, 1995). The goal of its application is to achieve a holistic, "thick description" that provides knowledge and understanding of a phenomenon (Campbell, 2010). Unlike other research approaches that attempt to remove context, the case study approach values context that produces a type of context-dependent knowledge (Flyvbjerg, 2006). A case study values rich contexts, which "are unique and dynamic, hence case studies investigate and report complex dynamic and unfolding interactions of events, human relationships and other factors in a unique instance" (Cohen, Manion & Morrison, 2000, p. 181). Cohen, Manion and Morrison (2000) describe the case study as a useful approach when the goal is to "understand and interpret the world in terms of its actors and consequently may be described as interpretive and subjective" (p. 181). The purpose of a case study is to "gain an in-depth understanding of the situation and meaning for those involved. The interest is in process rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation" (Merriam, 1998, p. 19). It is an approach that:

> facilitates exploration of a phenomenon within its context using a variety of data sources. This ensures that the issue is not explored through one lens, but rather a variety of lenses which allows for multiple facets of the phenomenon to be revealed and understood.
>
> (Baxter & Jack, 2008, p. 544)

Within the literature, three different approaches of case study appear (Yazan, 2015) – Robert Stake (1995), Robert Yin (1984, 2009) and Merriam (1998). All three approaches are conceived from a constructivist paradigm (Baxter & Jack, 2008; Yazan, 2015). Constructivism was discussed in detail in the previous chapter, but could be summarised with the following theoretical characteristics. Constructivism claims that people build understanding based on their previous experiences and knowledge, and as such, each person's mind is different. The construction of knowledge is a search for a "fit" with reality (Bodner, 1986). That is, a person's understanding of the world "fits" reality. The word "fit" is not synonymous with "match". It is not that a person's mind "matches" reality but that it "fits" reality, in the same way a key fits a lock. This means that a person may have knowledge that works in some contexts, but not in another (Lombardi, 2010). They would only become aware of this "misfit" when they have an experience where that understanding of reality does not work. Simply telling a person their understanding of reality does not work is not persuasive, they need to experience its misfit so that they can accommodate the new experience (Bodner, 1986). Consequently, it means that there are multiple "fits" to reality. Constructivism implies that an individual is not free to construct any knowledge, but only the knowledge that "fits" their experiences (Bodner,1986). So rather than rejecting notions of objectivity, constructivism values pluralism over relativism, in the same way that not any key will "fit" a lock, but that many keys of different shapes can "fit" the same lock (Baxter & Jack, 2008). Each person has a different "key" or view of reality. With this constructivist approach underpinning case study research, it enables an investigator to better understand a participant and their actions (Baxter & Jack, 2008).

Yin (2014) explains that case studies are appropriate for use when (1) "how" or "why" questions are being asked, (2) the researcher has little control over events, and (3) the focus is on contemporary phenomenon within a real-life context. Yin also states that the more a research question attempts to explain or provide an in-depth description of a phenomenon, the more relevant a case study methodology becomes.

Case study is not necessarily quantitative or qualitative (Stake, 2000). It can be used in many different ways, but often used for qualitative research, due to the depth of analysis demanded and the illustrative purposes of case studies (Stake, 2000; Wiersma & Jurs, 2009; Wyness, 2010).

A case study often involves an examination of a single unit, where the unit can be an individual, a group or even an event (Merriam, 1998; Cohen, Manion & Morrison, 2000; Stake, 2000). More broadly speaking, Stake (2000) defines case study not only as the object of study, but also as a process of inquiry about the case and the product of that inquiry. In defining a *case*, Stake (2000) says that not everything can be considered a case. While the characteristics of a case are not fully defined (Stake, 2000), there are guiding principles for what can be considered a case. The characteristics refer to a "specific, unique and bounded system" (Stake, 2000, p. 436). In this way, the single unit being studied has a pattern of behaviour, recognisable features and coherence, which are within the boundaries of the case.

It is this uniqueness that leads to the issue of respectability and legitimacy that Cohen, Manion and Morrison (2000) identify as an important aspect that case studies need to explicitly address. They also note that, like other research methods, it is important to demonstrate reliability and validity, but this can be challenging due to the uniqueness of the situations and so, by definition, may be inconsistent with other case studies or unable to provide a positivist view of reliability (Cohen, Manion & Morrison, 2000). On the contrary, it is the nature of case studies to see the situation from the perspective of the participant, which has a direct connection with the interpretive tradition of the research.

Like other ways of undertaking research, case study has both strengths and limitations. Some of the strengths include the ability to achieve high construct-validity, which is to say the "ability to measure in a case the indicators that best represent the theoretical concept" (Bennett, 2004, p. 34). This refining of concepts with a higher level of validity is a consequence of looking at fewer cases, with the cost of that being external validity, or the use of findings being applicable to a wider population of cases (Bennett, 2004). The following paragraphs will address the main concerns of case study design, particularly with qualitative methods.

Diefenbach (2009) wrote a particularly thorough and considered article that systematically addressed many of these concerns. A number of these related directly to qualitative research in general, while others were specific to case study. The issues related to the qualitative aspects of research are addressed in a later section, but the specific case study limitations will be addressed now.

First, is the concern that the selection of the unit of investigation does not happen systematically and objectively. This essentially is a concern about sampling and whether the selected unit is "typical" and "representative" (Diefenbach, 2009). In qualitative case studies representativeness, as it is thought of in quantitative studies, is not required, nor that the unit of investigation was selected "objectively" (Diefenbach, 2009). What is required is that the unit is "suitable" for the type of problem being investigated. This is done by providing all the relevant criteria and context, such as cultural background and personal circumstances (Diefenbach, 2009).

Another concern is that case studies cannot be tested or replicated due to their unique nature. Many researchers look at case study with circumspection for this reason (Gerring, 2004). However, case studies "primarily reveal and generate *specific* insights gained under specific circumstances" (Diefenbach, 2009, p. 887) and the case itself is at centre stage, not variables. Thus, the case study method is understood as a way of defining cases, not a way of analysing cases or modelling causal relations (Gerring, 2004). The "foremost concern of case study research is to generate knowledge of the particular" (Stake as cited in MacPherson, Brooker & Ainsworth, 2000, p. 52). In some instances, case study research can involve multiple cases.

Multiple-case case study

This study analysed more than a single case, and is therefore a multi-case design, with the benefit being the “evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust” (Yin, 2014, p. 45). Some fields of research, such as anthropology and political science, have considered multiple-case studies as a different methodology than single case studies. Researchers in those fields have rationalised multiple-case studies as a form of “comparative” studies (Yin, 2014). From the perspective of Yin, there are only two circumstances where the use of multiple cases is justifiable. These are either (1) a *literal replication*, where the cases predict similar results, or (2) a *theoretical replication*, where the cases produce contrasting results but for predictable reasons. The latter could be considered applicable for this study, as the implicit theories of intelligence dictates that students with similar beliefs would value and behave in similar ways within achievement situations. In that sense, different attitudes towards mathematics should not impact significantly on learning goals. If it turned out to be that cases with a fixed mindset were consistent and cases with an emergent mindset were consistent, these differences could be explained and the two frameworks for the implicit theory of intelligence strengthened by the results. For the alternative where meaningful discrepancies occurred, further research using other cases would be justified.

Case study was chosen for this investigation because the nature of the research questions related to *how* the preservice teachers’ attitudes towards mathematics and views of intelligence impacted their experience of learning and teaching mathematics. The goal of the investigation was to provide a thorough description of this phenomenon, including the preservice teachers' response to student-centred learning and any changes that may have taken place during the unit. To assist in providing a comprehensive, contextual description of this phenomenon, mixed methods were employed.

Mixed methods

The last decade has seen a significant increase in the use of mixed methods in applied research (Ivankova, Creswell & Stick, 2006; Fielding, 2010; Heyvaert, Maes & Onghena, 2013; Sandelowski, 2014), which involves the use of both qualitative and quantitative data. While case study is typically qualitative, quantitative data was incorporated into the study through the use of an *explanatory sequential design*. The motive for using mixed methods is the premise that neither sole use of qualitative nor quantitative data is sufficient to provide adequate context and richness of a phenomenon, which is a crucial aspect of case study methodology. Ivankova, Creswell and Stick (2006) define mixed methods as a:

> procedure for collecting, analyzing, and 'mixing' or integrating both quantitative and qualitative data at some stage of the research process within a single study for the purpose of gaining a better understanding of the research.
> (Ivankova, Creswell & Stick, 2006, p. 3)

The particular type of mixed method design adopted for this study was the *sequential explanatory design*. This approach features two distinct phases, namely the collection of quantitative data, followed by qualitative data (see Figure 3.1). The researcher collects and analyses quantitative results then subsequently collects and analyses qualitative data (Creswell, 2003; Ivankova, Creswell & Stick, 2006). The second phase of qualitative data collection is undertaken to build upon the quantitative phase.

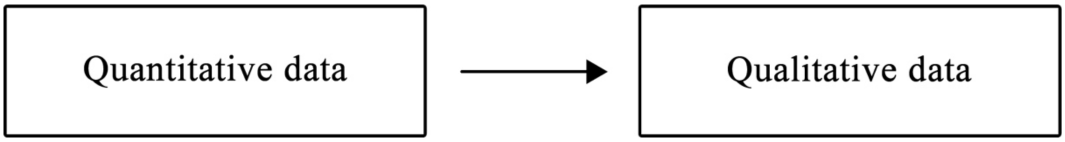


Figure 3.1 – Sequential explanatory design

Quantitative methods were used at the beginning and end of the investigation, with its primary purpose being a sampling technique to form groups that were later investigated using qualitative methods. Creswell (2011) states that an explanatory design is appropriate when the researcher seeks to "form groups based on quantitative results and follow up with the groups through subsequent qualitative research" (p. 82). Ivankova, Creswell and Stick (2006) describe the purpose of this second phase as a way to "refine and explain those statistical results by exploring participants' views in more depth" (p. 5). Creswell (2003) describes sequential mixed methods as one:

> ... in which the researcher seeks to elaborate on or expand the findings of one method with another method ... The study may begin with a quantitative method in which theories or concepts are tested, to be followed by a qualitative method involving detailed exploration with a few cases or individuals.
>
> (Creswell, 2003, p. 16)

The strengths and limitations of the mixed-methods design have been well discussed in the literature (Creswell, 2003; Wiersma & Jurs, 2009). The strengths are that mixing data sets can give a better understanding of the problem and yield more complete evidence. The investigator obtains both depth and breadth. The commonly cited limitations of mixed methods appear to be more practical in nature, such as involving the extra use of limited resources. Some have emphasised that the use of mixed methods does not automatically imply good research and still requires important consideration so that it meets the specific objectives of the study (Sandelowski, 2014). The goals and opportunities of using mixed methods lay in understanding their foundational and complementary nature and the type of knowledge they provide to the researcher.

Quantitative and qualitative data

This section is a further theoretical rationale for the use of both types of data in this study. The complementary nature of using mixed methods will be outlined by first understanding the epistemological foundation of each type of research method, then suggesting the benefits of using both in educational research. Quantitative research and qualitative research are grounded in quite different philosophies about knowledge claims (Creswell, 2003), and so have different understandings of the world (Wiersma & Jurs, 2009). Quantitative research is recognised as primarily using a positivist view of knowledge, and is interested in things such as cause and effect and reducing phenomena to specific variables. It does this by making strong use of measurement (Creswell, 2003; Hartas in Hartas, 2010). Quantitative research reflects a deterministic philosophy in which causes determine the effects and outcomes (Creswell, 2003). It also seeks to carefully observe and measure objective reality that exists in the world, thereby determining the laws and theories that govern the world (Creswell, 2003). For many people, “quantitative methods are considered to be reliable and valid, objective and clean, and oriented towards producing empirical outcomes that are generalizable across a variety of quite different school context" (MacPherson, Brooker & Ainsworth, 2000, p. 50).

On the other hand, qualitative research makes claims about knowledge using an interpretivist paradigm, namely, the multiple meanings of individuals' experiences. Unlike quantitative research, which is often interested in testing theories, qualitative research is often interested in developing theory or pattern (Merriam, 1998). According to Hartas (2010), a researcher must be wary to make the assumption that social reality can be investigated in comparable ways to the phenomena in the natural sciences. The problem is that qualitative research is grounded in the idea that social reality is shaped by people's actions and constructions of meaning, rather than the existence of a single, objective meaning. The social world is different to that of the natural world, due to the historical, political and cultural structures and the way these shape people's actions and constructions of meaning. Hartas (2010) also mentions that many researchers think that the concept of "truth" in social reality can be problematic and essentially irrelevant to understanding social reality. Qualitative research, therefore, seeks to understand people's perceptions and understandings of social reality. It often does this by relying on open-ended, context-rich, emerging data with the goal of developing themes from the data (Creswell, 2003).

The analysis of the qualitative data was undertaken through the process of identifying themes relevant to the research questions. This was achieved by first carefully analysing the qualitative data through the process of *coding*. This includes looking for actions, activities, concepts, differences, opinions or processes that are relevant to the research questions. The data included was a consequence of one or more of the following possibilities:

- The theme was repeated in several places
- The theme was unexpected
- The theme relates to previous research studies
- The theme relates to other theories or concepts

Specifically, the areas of interest are those related to the participants' experiences and how they connected to their attitudes and views of intelligence towards mathematics.

Both quantitative and qualitative research methods have strengths and limitations. As this study is primarily a qualitative study, these limitations are acknowledged. First, some academics are concerned that qualitative research is compromised by the investigator's existing theoretical position, prejudices, world view, implicit assumptions and political perspective, and as such, findings are inherently biased (Diefenbach, 2009). It has been argued by others (see for example Pyett, 2003) that this is true of quantitative research too, where it is incorrect to assume that "positivistic theories and models, formulas and diagrams imply an objectivity and truthfulness" (Diefenbach, 2009, p. 878), which is simply not the case. Nevertheless, subjectivity is inherent to case studies using qualitative research and the solution to overcome this potential downside is to manage the effect of researcher subjectivity. Diefenbach (2009) suggests making explicit the researcher's world view, implicit assumptions, interests, philosophical and political perspectives where possible. This chapter features a later section that outlines the relevant researcher's world view, in an attempt to help address this issue.

Increasingly, education research has utilised the benefits of both methods. Hartas (2010) cites the need for educational research that brings together both deductive and interpretive models, such as mixed methods. While there is a clear division in their epistemological foundations, both quantitative and qualitative methods seek out the same goals, according to Becker (1996), which is to understand the world. Becker states that in social science research, "both kinds of research try to see how society works, to describe social reality, to answer specific questions about specific instances of social reality" (Becker, 1996, p. 53). Hartas (2010) suggests the benefits of using both quantitative and qualitative methods in educational research is the possibility of:

> … giving voice to people who are directly affected by social and educational situations, and to encourage researchers to develop a capacity for reflection on both means and ends in education. Such a worldview is likely to bring together causal and interpretive models to examine the dynamics of complex systems where research practices are intensive and fine-grained to ensure complexity is mapped sufficiently.
>
> (Hartas, 2010, p. 50)

Hartas (2010) posits that mixed-methods research might offer the intellectual platform while bridging the different world views to combine methods that create a complementary form of educational inquiry. It also allows for the use of triangulation.

Triangulation

Triangulation describes the use of two or more methods of data collection in a study to explain more fully the richness and complexity of human behaviour (Webb, Campbell, Schwartz & Sechrest, 1966; Cohen, Manion & Morrison, 2000). Triangulation has two purposes. First, in the natural sciences, a single observation is normally sufficient and unambiguous, but this would be a limited view that only provides a thin depth of understanding into the complexity of social human behaviour (Cohen, Manion & Morrison, 2000). Secondly, the goal of this process is to look for similar findings and check that the results are not simply some bias in the particular method of data collection. This bias can be somewhat overcome by combining the findings from interviews and the investigation of other data. This cross-checking adds an extra level of verification and validity to the data (Mertens & Hesse-Biber, 2012).

In this study, the data used to triangulate findings came from the surveys, the pre-study interviews, the mathematical task observation and the Critical Moments questionnaire. This triangulation makes use of a number of different methods. Triangulation is particularly useful in case studies, where a particular example of complex phenomena is being investigated and a rich description is sought (Cohen, Manion & Morrison, 2000; Wyness, 2010).

Context

This section provides a detailed outline of the contextual issues related to the study. It includes the geographical location and selection of the participants in the study.

Geographical location

The geographical context of this study is the University of New England (UNE) in Armidale, NSW, Australia. It is a rural, inland city with a population of approximately 25,000 people and is known for its cultural community, educational diversity and surrounding national parks. Armidale is situated halfway between Sydney and Brisbane and only two hours from the coast. It is particularly known for its strong focus on education and, for its relatively small population, boasts a university, a TAFE, and a large and diverse number of primary and high schools.

The University of New England

The UNE is the oldest regional university in Australia and has a strong tradition of distance education and fully residential colleges. The largest school at UNE is the School of Education, accounting for approximately a quarter of the students who are mostly enrolled in undergraduate and postgraduate teaching courses. The School of Education has been involved in undergraduate teacher education since 1988, when it amalgamated with the Armidale Teachers' College (ACAE). It currently caters for on-campus and off-campus (online) admissions and offers a large number of undergraduate and postgraduate scholarships and degrees.

Participants

This study involved the on- and off-campus, first-year preservice primary teachers who were enrolled in the Bachelor of Education (Primary). This course is an initial primary teacher education program, which was created to meet the requirements of a beginning primary teacher in Australia. It was also created to meet the accreditation requirements of the NSW Institute of Teachers (NSWIT), now known as the Board of Studies and Educational Standards NSW (BOSTES NSW). The course is offered both on-campus and online, with typically 80 per cent of UNE students studying online. The entire course has approximately 250–300 on-campus students, and approximately 1,000 online students. Approximately 80 per cent of the cohort is female. The completed course takes four years studied full-time and up to ten years studied part-time.

There are a variety of ways to gain entry into the Bachelor of Education (Primary) course, but there are some overarching requirements. First, a student must have an adequate ability and experience in the English language. Secondly, they must have demonstrated a satisfactory level of achievement in both mathematics and English at a Year 12 high school level. This standard, for both literacy and numeracy, requires candidates to have achieved a certain level or higher – at least Band 4 (out of 6) in the lowest NSW mathematics and English courses. A level of Band 4 places the candidate in the top 50 per cent of the state, in the lowest level of that subject. If the candidate studied in the higher levels of the subject, any level of achievement meets the requirement.

This specific level of achievement in mathematics and English does pose a challenge for many people wishing to gain entry to the Bachelor of Education (Primary). It is often either due to (a) the student achieving lower than a Band 4, (b) the candidate finished school before that particular measure of achievement was introduced, or (c) that the candidate finished school over ten years ago, after which it is considered too long ago. For those candidates, they may still enrol in the Bachelor of Education (Primary), but are required to apply for admission into the university's teacher education enabling courses. This involves the student taking the courses that they require, namely mathematics and/or English. Successful completion of one or both of these content units is considered to have met the Band 4 requirement. At present approximately 60 per cent of enrolling students do not meet this requirement on entry to the Bachelor of Education (Primary) and must undertake one or both of the enabling units.

Sample selection

The initial quantitative stage of this study involved participation of students enrolled as on- or off-campus, first-year Bachelor of Education (Primary) cohort studying at UNE. The only age condition was that they were over 18 years of age. The students who chose to participate (n=237) completed an online survey that measured their attitude towards mathematics and their views of intelligence (in terms of emergent or fixed). The scores from these data allowed each participant to be placed on a scatter graph, which positioned them according to their attitude towards mathematics and their views of intelligence, summarised in Table 3.1.

Table 3.1 – Definitions of clusters

	Attitude towards mathematics	**Theory of intelligence**
Cluster 1	Negative	Fixed
Cluster 2	Positive	Fixed
Cluster 3	Negative	Emergent
Cluster 4	Positive	Emergent

Using the median score for both axes, it was possible to split the cohort into four clusters of students, whose characteristics were defined in Table 3.1. Any respondents whose scores were on the median were not placed into any cluster, and subsequently removed from the rest of study. Since the median was used to divide the cohort into these four clusters, they were approximately equal in size. In this research project, each cluster was considered a *case* to study.

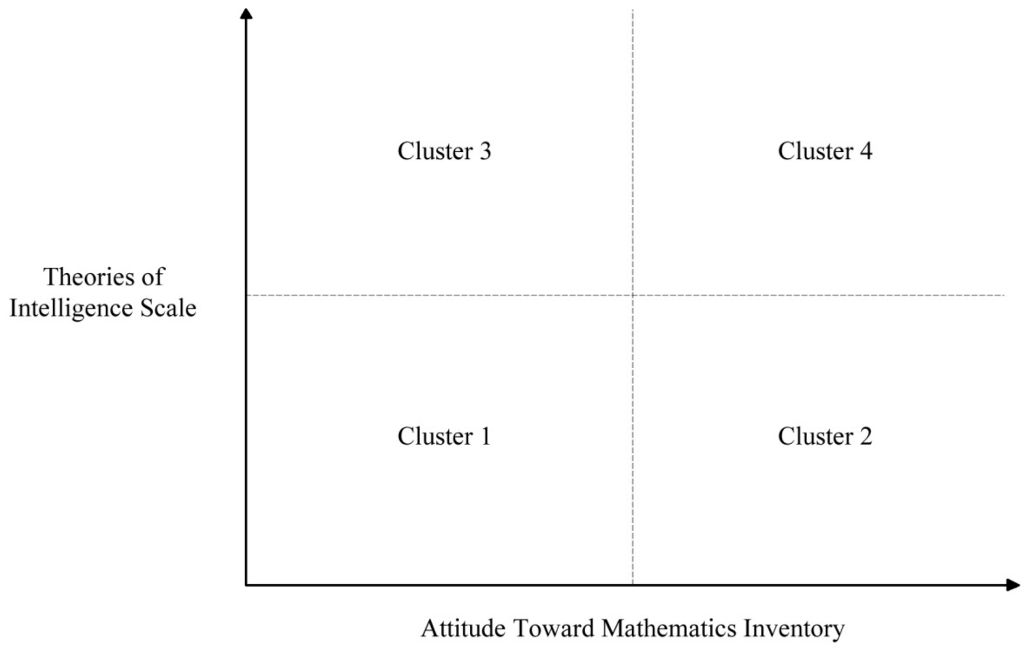


Figure 3.2 – Implicit theories of intelligence vs Attitude toward mathematics inventory

Key informants

After the initial surveys were completed, scores processed and analysed, two students from each cluster (*n*=8) were purposefully selected and invited to take part in the next stage of the study. These pairs became *key informants* for that cluster. While the study was mainly looking at the various clusters, some diversity within the key informants was included, such gender and mode of study. The criteria for key informants were broad and included the following characteristics for each cluster:

- participants who were at least one standard deviation away from the mean for both the Implicit Theories of Intelligence (ITI) and Attitude

Toward Mathematics Inventory (ATMI) surveys, as highlighted in Figure 3.3. These surveys will be discussed in more detail later in this chapter.

- one male and one female
- an on-campus and an off-campus student.

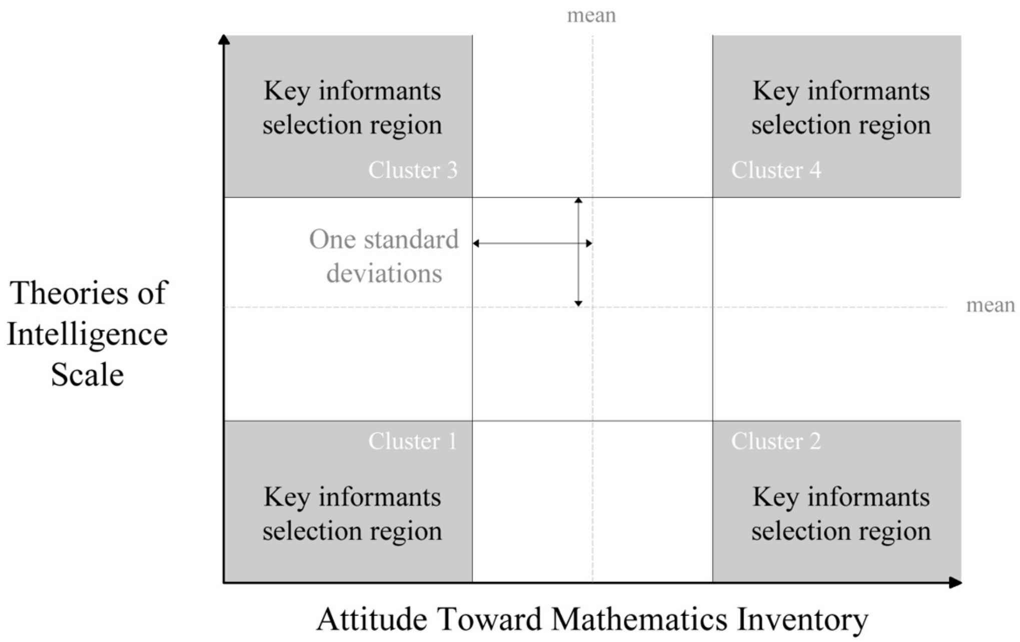


Figure 3.3 – Key informants' selection region

The sampling type was *purposive sampling*, which describes a type of non-probability sampling technique. It sees participants being chosen based on a judgement of the researcher. It is important to note that case studies that involve qualitative data inherently require purposive sampling and are not designed for random selection of participants (Palys, 2008). Specifically, *extreme sampling* (Palys, 2008; "Purposive Sampling", 2012) was used because it offers "the purest or most clear-cut instance of a phenomenon" (Palys, 2008, p. 697). This study sought to gain significant and deep insights into the phenomenon between the relationship of attitudes, beliefs on intelligence and the subsequent impact on the learning and teaching of mathematics. The relatively extreme scores offered a potential for higher level of purity of this phenomenon, since the affective issues of beliefs and attitudes were thought to likely be well-internalised, as evidenced by their relatively extreme survey responses and behaviours.

Two standard concerns with purposive sampling are the risk of *researcher bias* and lack of *generability* (O'Leary, 2004). Researcher bias refers to the "in-built tendency to see the world – and hence to interpret data – in a particular way" (Barbour & Schostak, 2005, p. 344) and lead to samples that are not representative of the population. A subjective and selective process for sampling can be susceptible to researcher bias, especially in comparison to other sampling methods such as random selection ("Purposive Sampling", 2012). Barbour and Schostak (2005) state that it is important to eradicate bias or at least understand it through a process of reflexivity, along with accounting for it. As such, this chapter includes a section on this researcher's world view, so as to make explicit the lens through which the decisions were made and the information interpreted during the study. The risk of researcher bias within purposive sampling is mainly significant when "such judgements are ill-conceived or poorly considered; that is, where judgements have not been based on clear criteria, whether a theoretical framework, expert elicitation, or some other accepted criteria" ("Purposive Sampling", 2012). This study adopted clear criteria, supported by theory (Saldana, 2011). The key informants displayed strong views towards their affective characteristics, as identified by their survey scores. Therefore, participants were selected deliberately and strategically based on the criteria.

Another potential issue with purposive sampling is generalisability, or the ability to apply research findings to other situations. Generality is always at tension with complexity, but it is worth taking a broader view of the study and what its goals were. Ragin (1987) argues that use of case study methodology sees "the goal of appreciating complexity … given precedence over the goal of achieving generality" (p. 54). Generalisability also depends on obtaining representativeness of a population when sampling (Lewin, 2005), whereas many researchers who collect qualitative data are not looking for representativeness, but a rich understanding that can come from the few rather than the many (O'Leary, 2004).

The participation of key informants involved collecting qualitative data, such as being observed undertaking a mathematical problem-solving task, and semi-structured interviews at the beginning and end of the teaching period. The aim was to have two participants in each cluster and, where possible, a male and female as well as an on- and off-campus student.

Methods

Research instruments

The following sections move from the theoretical underpinnings of the study towards the operational aspects of the study. It describes the research instruments used to collect information from the participants, along with the research schedule. Table 3.2 describes which participants provided data, the instrument used and time it was administered.

Table 3.2 – Participants involved in the data collection throughout the study

Instrument	Participants	Time
Attitudes Towards Mathematics Inventory	All participants	Pre- and post-study
Theories of Intelligence Scale	All participants	Pre- and post-study
Unit website interaction (e.g. forums)	All participants	Throughout semester
Critical Moments questionnaire	All participants	Pre-study
Mathematical task observation	Key informants only	Pre-study
Semi-structured interviews	Key informants only	Pre- and post-study

A variety of instruments were used to provide the rich and contextual description required by case-study methodology. As the study involved eight key informants along with the researcher teaching the unit, there was a consideration of the needs of the study along with the needs for teaching a large unit (~n=700), both on- and off-campus. It was thought that these instruments, along with a focus on pre- and post-study timings, would meet the needs of the study and teaching requirements.

Attitudes Towards Mathematics Inventory (ATMI)

The ATMI by Tapia and Marsh (2005) was used to collect quantitative data about the participants' attitude to mathematics (see Appendix 1). While other instruments have been more popular in the past, such as the Mathematics Attitude Scale (Aiken, 1976) and Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976), recent studies have shown that the ATMI has demonstrated content and construct validity when tested with new university students, as well as school students (Tapia & Marsh, 2005; Majeed, Darmawan &

Lynch, 2013). The Fennema-Sherman Mathematics Attitudes Scales has been the most popular instrument in research about attitudes towards mathematics. However, it is approaching 40 years old, has 108 items and takes 45 minutes to complete, and has been questioned at times about its validity and reliability (Tapia & Marsh, 2005). The ATMI has been used for both college students and high school students. A confirmatory factor analysis conducted by Tapia and Marsh (2002) evidenced that it was a valid and reliable instrument for American college students (Tapia & Marsh, 2005), having also successfully been used with high school and middle school students (Tapia & Marsh, 2000, 2002). Majeed, Darmawan and Lynch (2013) tested the instrument with South Australian school students and confirmed it to be a "viable scale to measure students' attitudes toward mathematics" (p. 122). They achieved very high Cronbach alpha coefficients for the overall instrument (0.963) and all the subscales. The results were comparable to Tapia and Marsh's (2004) results for validity and reliability.

The instrument features 40 questions that use a Likert scale with six possible responses ranging from 0: Strongly Disagree to 5: Strongly Agree. Eleven items are reversed to be negatively worded. This has been taken into account in the scoring of the instrument, which is calculated by the sum of the ratings. According to Tapia and Marsh (2002), the four factors that have been determined to measure the participants' attitude to mathematics are self-confidence, value, enjoyment and motivation.

Fifteen items are assigned to the *self-confidence* factor, with five statements reversed. Some examples of the statements are "Mathematics does not scare me at all" and "Studying mathematics makes me feel nervous". The *value* factor was constructed from ten items and featured no reversed statements. Sample statements from the ten items linked to the value factor are "Mathematics is a very worthwhile and necessary subject" and "Mathematics courses will be very helpful no matter what I decide to study". Ten items measured *enjoyment*, with one question reversed. The statements investigated participants' attitudes towards "enjoying mathematics, the challenge of solving new problems, the comfort level in participating in discussion in mathematics, and feeling of happiness in the mathematics classroom" (Majeed, Darmawan & Lynch, 2013, p. 127). This factor includes items such as "I really like mathematics" and "I have usually enjoyed studying mathematics in school". The *motivation* subscale consisted of five items with one item reversed. Sample statements from this factor are "I am willing to take more than the required amount of mathematics" and "The challenge of mathematics appeals to me".

The participants completed the online questionnaire during the first and last week of the semester. Written instructions were provided with the survey, which outlined the basic steps to assist the participants complete the survey.

Implicit Theories of Intelligence Scale

The Implicit Theories of Intelligence Scale (see Appendix 1) is a collection of measures created by Dweck and others (see Dweck, Chiu, & Hong, 1995; Levy, Stroessner, & Dweck, 1998; Levy & Dweck, 1999). The collection looks specifically at the domain of intelligence and not at other implicit theories people have, such as personality or moral character. The measures ask participants to report their theories about their own intelligence (Dweck, 2000). It has been shown to have a high level of reliability and validity (see Dweck, Chiu, & Hong, 1995; Levy, Stroessner, & Dweck, 1998; Levy & Dweck, 1999). For example, in Dweck, Chiu and Hong (1995), their results for statistical significance (α) ranged from 0.94 to 0.98 and the test-retest reliability over a 2-week period was 0.80. Initially, the scale only included entity theory items and not incremental theory items. It was found that these items were simply too compelling for people which revealed people would endorse both entity and incremental theory items, creating low correlation (Leggett, 1985; Dweck, 2000). There was a development of the scale in the late 1990s that saw the inclusion of both entity and incremental items that were not as appealing, and showed a high negative correlation with the entity theory items (Dweck, 2000). This most recent version was used for this study.

There was a choice available to use the Implicit Theories of Intelligence Scale as a measure of "self" or "other" form. The "self" form phrases the statements for participants to answer about their own intelligence, such as "You have a certain amount of intelligence …", while the "other" form asks the participant about implicit theories of intelligence in general, such as "Everybody has a certain amount of intelligence …" (Dweck, 2000). The form used in this study was the "self" form, as the study was mainly interested in the participant's own self-goals, self-judgements and helpless- vs mastery-oriented responses. The "other" form has potential use for teaching, but since this study was with first-year students who are in the earliest stages of becoming teachers, the study was more interested in how the participants viewed themselves rather than others.

The Implicit Theories of Intelligence Scale was composed of eight items and used a 6-point Likert scale ranging from 0: strongly disagree to 5: strongly disagree. The items were scored between 0 and 5, with 0 aligning to most entity view of intelligence and 5 aligning to most with incremental view of intelligence. Four items were phrased with an entity view of intelligence, for example “You have a certain amount of intelligence, and you can’t really do much to change it”, while the other four items were phrased in terms of the incremental view of intelligence, such as “You can always substantially change how intelligent you are”.

Along with the Implicit Theories of Intelligence Scale, there were also extra items added in this section related to implicit theories of intelligence and goal orientation in the form of mastery or performance goals. The purpose of these was to provide further insight into the views and beliefs of the participants, as well as for use to confirm consistency or irregularities in responses. The items were found throughout the writings in Dweck’s *Self-Theories* book (2000) and had been used within her studies.

First, participants were asked to complete the question “I define intelligence as …”. The purpose was to offer another opportunity for the participant to reveal their implicit theory of intelligence as fixed or emergent in an open-ended format.

Secondly, an item asked “Who is more intelligent? Those who work hard or those who don’t have to work hard”. Like the previous item, this question was asked to probe their implicit theory of intelligence and whether they see intelligent people need to work hard, or whether working hard is a sign of low intelligence.

Lastly, was a goal-choice measure, which investigated the participants’ goal-choice when undertaking a task. This study was interested in not only the participants’ implicit theories of intelligence, but also their goal types in the form of mastery or performance. The connection between one's implicit theory of intelligence is seen as the causal factor of one's goal orientation (Dweck, 2000), but the link has not always been shown to be synonymous, as some research has suggested (Payne, Youngcourt & Beaubien, 2007). Nevertheless, the overwhelming bulk of research suggests the connection between these two phenomena is very strong. Dweck (2000) does mention that there have been a number of scales in the field that have been designed to measure learning and performance goals directly and independently of implicit theories of intelligence. Dweck revealed that her own use of these goal-orientation scales often found "no difference between entity and incremental theorists" (p. 184). Both groups say they seek to demonstrate their ability or doing well, and are interested in learning new things. It is only when measures of performance and learning goals are *pitted* against each other that a clear relation with students' theories of intelligence and their goals in an achievement environment is disclosed. For that reason, this measure was added that asked participants to make a choice between learning and performance goals. Namely, when asked to decide, would a participant prefer a task where they are challenged and learn new things, at the risk of failing, or prefer an easy task where they can demonstrate their high ability or avoid showing an inability? The possible options in the measure intentionally pit mastery goals against performance goals, and ask students to make a choice between looking smart or taking on a challenging learning task. These data offered extra information that was used to triangulate findings from the Theories of Intelligence Scale and other instruments used in the study, such as the mathematical task observation.

Website contributions

Throughout the semester, students could post comments, questions and answers to the online unit website, Moodle. These could cover any topic related to the unit, as well as personal information, such as introductions, personal anecdotes and reflections. The purpose of this instrument was to obtain, with permission, unsolicited feedback relating to the unit, for instance, the implementation of PBL, as well as contributions by key informants.

Mathematical task observation

The task was based on a similar idea performed by Diener and Dweck (1978) that involved upper primary-aged students undertaking mathematical questions with difficulty levels that started simply, then abruptly became exceedingly challenging. The findings of this research study were described in detail in Chapter Two. Essentially, the task was structured to observe and examine the participants' reactions to abruptly facing challenge and failure.

Specifically, the task in this study involved completing three KenKen puzzles (Appendix 2). A KenKen is a special type of mathematics puzzle involving logic, similar to the very popular Sudoku puzzle, but different in that it also involves basic arithmetic. The key informants were asked to complete three KenKen tasks and express what they were thinking in their minds, both about problem-solving and how they were feeling. The first two KenKens were considered to be at a beginner's level and quite simple to complete. These two KenKens were given to learn the rules of KenKen and act as a simple task that every participant would successfully complete with ease. The third KenKen was a larger and significantly more advanced level. No participant was expected to complete this task in the time allowed. It was during this time that participants entered the challenge phase of the task.

Based on Diener and Dweck's (1978) results, a collection of behaviours characterised and distinguished the students into two types of responses. Either a helpless response or a mastery response. These characteristics listed in Table 3.3 provided a lens that was used to view and interpret incidences collected throughout this mathematical problem-solving task.

Table 3.3 – Framework of behaviours based on Diener and Dweck (1978) response types

Characteristic	**Mastery response**	**Helpless response**
Mindset	– Believes in a growth mindset	– Believes in a fixed mindset
Challenge	– Embraces challenge – Put off by simple tasks	– Avoids challenge – Prefers tasks where they'll be successful
Failure	– Accepts failure as part of learning	– Avoids failure at all costs
Self-talk	– No denigration of intelligence – Positive, encouraging – Strategy-focused	– Denigrate intelligence – Attempt to distract observer – Psychological projection
Resilience	– Will persist in the face of setbacks – Reasonable estimation of something being too difficult – Continues using effective strategies despite setbacks	– Easily discouraged by failure – Problem-solving strategies evaporate quickly – Takes time to recover from failure
Goal-seeking	– Primarily wants to learn and achieve	– Primarily wants to look smart and receive praise

The instrument was administered before the pre-study interviews within the first week of the teaching period. This particular task was undertaken to assist and strengthen the results of other data collected from the surveys, as well as provide a stimulus for questions within the pre-study interviews.

Semi-structured interviews

Theoretical considerations

Interviews are a very common method in qualitative research, with an estimated 90 per cent of social science investigations exploiting interview data (Denzin, 2001). They have been demonstrated to be a valuable method for gaining interpretive data (Mason, 2004). The general purpose of an interview is threefold. First, it can be used as the main instrument to gather information with a direct connection to the research objectives. These include where depth of meaning is important and the researcher seeks to gain insight and understanding (Gillham, 2003; Barbour & Schostak, 2005). An interview provides access to what an individual knows, prefers, values and believes (Cohen, Manion & Morrison, 2000). Its use implies a value on personal language as data and is considered essential in gaining the intended insight into the participant's perceptions and values (Barbour & Schostak, 2005). Secondly, an interview can be used to test a hypothesis or suggest a new one and lastly, interviews can be used in combination with other methods in an attempt to validate or follow unexpected results (Cohen, Manion & Morrison, 2000).

Interviewing is a method that sees knowledge not as something that is external to individuals, but knowledge that is produced between people, often through communication and talking (Cohen, Manion & Morrison, 2000), consistent with a constructivist paradigm. The purpose of an interview is to allow participants and researchers to discuss their interpretations of the world they live in, the experiences they have had and how they regard situations from their own perspective (Cohen, Manion & Morrison, 2000; Barbour & Schostak, 2005). It is due to this interaction that interviews are seen as neither subjective or objective, but rather *intersubjective* and a shared experience (Cohen, Manion & Morrison, 2000; Denzin, 2001). Gubrium and Holstein (2000) describe intersubjectivity as "a set of understandings sustained in and through the shared assumptions of interaction" (p. 489). In that sense, an interview "is literally an *inter-view*, an *inter-change of views* [emphasis added] between two persons conversing about a theme of mutual interest" (Kvale, 1996, p. 14). Kvale (1996) described the general qualitative interview as a "construction site of knowledge" (p. 2) and it typically has the following distinctive characteristics:

- One-on-one basis and in-person, involving a single interviewer and a single interviewee
- The use of open-ended questions
- Less structure and offers freedom to the interviewers to present questions in a less specific, predetermined manner and order.

(Hobson and Townsend, 2010, p. 224)

There are a number of different types of interviews, which vary both in structure and process. It is important to consider these diverse characteristics in light of the study's research questions and the advantages and disadvantages of using a particular type of interview as a research tool. One of the most popular types of interviews lies on a continuum between the extremes of structured and unstructured interviews, and is known as a *semi-structured interview* (Hobson and Townsend, 2010).

The characteristics of semi-structured interviews include a moderate level of formality, where the interviewer develops and uses an interview guide (Mason, 2004; Bryman, 2012). This guide usually consists of a list of questions, topics, themes, or areas that will be addressed during the conversation, most often in a particular order. While a fully structured interview would see an interviewer follow a strict list of questions to be asked in the same way of all interviewees, a semi-structured interview permits the interviewer some freedom to follow topical trajectories in the conversation that may stray from the guide when he or she feels it is appropriate (Mason, 2004; Cohen & Crabtree, 2006; Bryman, 2012). Semi-structured interviews are best used when a researcher will only have very few chances to interview someone (Cohen & Crabtree, 2006). That was the situation with this study, where there were only two interviews with key informants at the beginning and end of the teaching period.

Considerations

Interviews provide a number of important benefits, including the opportunity to probe to a greater depth than other methods of data collection, and clarify any misunderstandings that may occur (Cohen, Manion & Morrison, 2000). At the same time, it is important to be aware of potential weaknesses and limitations and, where possible, eliminate or minimise the effects as much as possible.

Reliability and validity

One consideration is the effect of interviewees being influenced by the interview situation and the interviewer, resulting in it not being a valid and reliable source for information (Diefenbach, 2009). This is a part of a general effect known as the *Hawthorne Effect*, which refers to the alteration of behaviour by the subjects of a study due to their awareness of being observed. A lessening in reliability can occur as a consequence, often unintentionally, due to leading questions, transcription and coding errors (Kvale, 1996; Bryman, 2012). Diefenbach (2009) and Mason (2004) acknowledge that interviewing is a social interaction, where the interviewer is an active part of these interactions and that “there is no such thing like a neutral, non-intervening and non-existent interviewer” (Diefenbach, 2009, p. 880). The interviewee can be influenced to make certain statements that he or she would not make otherwise as a consequence of the interviewer. Leading questions is a common example (Kvale, 1996), but it is sometimes the case that leading questions are sometimes necessary as a way to check the reliability of the interviewee’s responses. One such example is of Piaget’s interviews with children regarding their understanding of physical objects. Leading questions were deliberately used in wrong directions to test the strength of the child’s understanding of the concept, such as length. The fundamental issue is not whether to lead or not, but where the interview should lead and if the direction is producing new, important and interesting knowledge (Kvale, 1996).

There is also the possibility that the interviewee will consciously and deliberately mislead the interviewer, such as providing answers that the interviewee assumes the interviewer wants to hear or which are socially acceptable (Diefenbach, 2009). It may be a consequence of a power or social status (McNeill & Chapman, 2005; Bryman, 2012). Responses of this kind are often difficult to determine whether the interviewee has said what they mean and mean what they have said. Therefore, it is important for researchers to always treat interview data critically and with some distance, as well as triangulating with other data (Mason, 2004; Diefenbach, 2009; Bryman, 2012).

> Criticisms that it produces data that cannot permit comparisons between interviews because they are not standardized are misplaced, because it uses a logic where comparison is based on the fullness of understanding of each case, rather than standardization of the data across cases. However, semistructured interviewing alone can produce only partial interpretive understandings and can be usefully supplemented by other methods, such as those that can extend the situational dimensions of knowledge, including participant observation and visual methods.
>
> (Mason, 2004, p. 1021)

Kvale (1996, p. 148) offers guiding criteria that is likely to lead to successful interviews, which produce rich knowledge that is valid, reliable and ethical. A summarised version is provided:

1. *Knowledgeable*: thoroughly familiar with the interview theme and can conduct an informed conversation about the topic.

2. *Structuring*: introduces a purpose for the interview, outlines the procedure in passing and rounds off the interview by briefly telling what was learned.

3. *Clear*: poses clear, simple, easy and short questions.

4. *Gentle*: allows participants to finish what they are saying and let them proceed at their own rate of thinking and speaking.

5. *Sensitive*: listens actively to what is said, how it is said and what is not said. Shows empathy towards the interviewee.

6. *Open*: is flexible to new aspects that are introduced by the interviewee and listens to topics that are important to the interviewee.

7. *Steering*: the interviewer knows what he or she wants and controls the course of the interview.

8. *Critical*: questions critically what is said and tests the reliability and validity through challenging inconsistencies and using data methods.

9. *Remembering*: relates what is said to earlier statements.

10. *Interpreting*: clarifies and extends the meanings of the interviewee's statements without imposing meaning on them.

Interviews play a very important role in research, where the outcome is a co-production of the interviewer and subject (Kvale, 1996). This study utilised semi-structured interviews as a way to know how participants viewed mathematics in the context of different attitudes and implicit theories of intelligence. The following section outlines the operational aspects of the interviews that were undertaken during the study.

The interviews

The key informants were invited to participate in two interviews at the beginning and end of the teaching period; namely, a total of eight participants with positive/negative attitude toward mathematics and fixed/emergent view of intelligence. An interview guide was designed with questions clustered together thematically. The interviews were audio recorded with the permission of the participants and later transcribed by the researcher. On-campus students were all interviewed face-to-face, while off-campus students were all interviewed over the telephone.

Pre-study interview

The pre-study interviews were conducted within the first two weeks of the teaching period and involved all eight participants from the four clusters. These interviews were used to provide additional information and insight to supplement the Critical Moments questionnaire, the quantitative data collected from the ATMI and ITI responses. It was proposed that this data and ability to probe previous responses would provide a more detailed and informed perspective on the key informant's view of their learning goals and view of mathematics education.

Post-study interview

The post-study interviews were all conducted in the last week of the semester, before their final examination had taken place. The purpose of these interviews was to reflect on their recent mathematics education learning experience, in the context of the student-centred approach in the form of PBL, as well any changes in their attitude toward mathematics or their view of intelligence. A potential risk was participants being unavailable for the post-study phase of data collection. To attempt to prevent this, key informants were asked if they would be available during the post-study phase, to which they all agreed.

Critical Moments questionnaire

Theoretical considerations

Questionnaires are highly valued by researchers and commonly used (Rowley, 2014). They are often compared and contrasted to interviews as they have a number of similarities (McNeill & Chapman, 2005; Bryman, 2012). They both seek to solicit information from respondents that is designed to be useful for analysis (Babbie, 2010) and share some of the same strengths and limitations. In the context of case-study research, a questionnaire fits with the view of the case subject being a reflexive social agent and the questionnaire acting as a reflexive practice (Wyness, 2010).

Questionnaires are often used with large populations, in combination with closed-ended questions (Babbie, 2010; Rowley, 2014). This sees respondents completing closed-ended questions, where there is only a select list of possible answers that they can choose. This allows for uniformity and easy processing (McNeill & Chapman, 2005; Babbie, 2010). Some researchers from an ethnographic tradition are wary of this approach (McNeill & Chapman, 2005). Interpretivist researchers argue that pre-coded answers reduce the complexity of respondent's opinions, attitudes and experiences. It also lowers the chances of revealing certain meanings underpinning actions and behaviours (Foddy, 1993; McNeill & Chapman, 2005). When people choose the same option in a list of possible answers, their meanings may still not be uncovered as people may not share the same meaning for the option. Closed questions can reflect and impose the researcher's personal values and priorities on respondents, and assume that researchers know all possible answers. Consequently, respondents may feel compelled to choose a response that they do not entirely agree with (McNeill & Chapman, 2005).

Questionnaires can also be used with open-ended questions, which allows respondents to provide their own answers, in a similar way to interviews. Among some of the strengths are the ability for respondents to express themselves in their own words, it does not suggest answers to respondents and allows for complex influences and frames of reference to be identified (Foddy, 1993; McNeill & Chapman, 2005). On the other hand, some researchers see open-ended questions tending to produce data that is extremely variable, of low reliability and difficult to code (Foddy, 1993; McNeill & Chapman, 2005). Many social researchers find a compromise position and devise questionnaires that use a combination of open- and closed-ended questions to combine both factual and attitudinal data (Foddy, 1993; McNeill & Chapman, 2005).

Like other research methods, questionnaires have strengths and limitations. Many of these have already been discussed in relation to interviews, such as biases and types of questioning. These include generally avoiding leading questions, keeping wording short, to the point, and free of jargon (Rowley, 2014). Unlike interviews, questionnaires can be completed independently of the researcher. Self-completed or self-administered questionnaires see respondents complete the questionnaire by themselves and can produce absence-of-interviewer effects (Bryman, 2012). This is a consequence of minimal interaction with the researcher, and thus, less opportunity for biases caused by such things as power positions, social status, or ethnic or gender biases, which can weaken the validity of the data (McNeill & Chapman, 2005; Bryman, 2012). There is also greater opportunity for the respondent to ponder their response in a self-completed questionnaire rather than an interview.

Questionnaire overview and administration

This study used a questionnaire called the Critical Moments questionnaire that was developed by the researcher, with its purpose to provide a fuller context into the key informant's previous experiences to obtain greater depth and understanding of the origins of their attitude toward mathematics, and their view of intelligence. This study adopted a constructivist perspective that views people's current understanding as a consequence of accommodating previous experiences. Therefore, there was significant worth in looking at the key informant's past and the moments they viewed as critical during their schooling, as it was a significant time in their mathematical learning.

The Critical Moments questionnaire was a very minor assignment and the first assessable task of the unit (see Appendix 3). Worth five per cent of their final grade, the questionnaire was marked on a pass/fail basis and completed in the first two weeks of the semester. Students who completed the assessment were awarded full marks otherwise they were given a zero mark. The questionnaire asked students to reflect on their mathematical learning experiences, both positive and negative, prior to beginning university. In this reflection they were to consider three aspects and how they each played a role in their experience of learning mathematics. The aspects were obtained from the teacher education framework proposed by Lappan and Theule-Lubienksi (1992), which proposed teachers have professional knowledge in the domains of pedagogy, mathematical content and the student. Specifically, respondents were asked to describe any positive or negative critical moments in their mathematics education and how this affected them. The preservice teachers were asked to describe their own critical moments openly and as a personal reflection, with reference to:

- the part mathematics teachers play in their learning (pedagogy)?
- the content of the mathematics being learnt (content)?
- their experiences as a learner of mathematics (student)?

The word limit guide was 250–500 words for each of the positive critical moments and the negative critical moments. The responses were collected using online survey software, Qualtrics, and the data from the task were used to triangulate with other research instruments.

PBL Experience questionnaire

A questionnaire was created for all participants in EDME145 and administered at the end of the teaching period. Its purpose was to gather data related to the preservice teachers experience of PBL, the impact on them of learning about implicit theories of intelligence and learning goals, and if they had experienced any change of feelings or beliefs towards learning and teaching mathematics over the semester (see Appendix 4).

Participants were asked general question about learning in EDME145, such as "What aspects of the unit do you feel have been helpful to you?" There were specific questions related to PBL, such as the value they saw in working through rich, complex scenarios used in PBL, such as "What 3 things have you most valued about learning through these types of questions?" These were also asked in terms of growth and improvement possibilities in the unit and the implementation of PBL, such as "What has been challenging about learning using the PBL approach?" and "What could be improved to assist learning using the PBL approach?".

As the questionnaire was administered at the conclusion of the unit, and analysed after teaching had concluded, the questionnaire asked for participants' details such as their name and student number. This was so they could be linked to their ATMI and ITI scores from the beginning of the semester. The questionnaire was completed online using the survey software, Qualtrics.

EDME145 unit and teaching evaluations

Two university-level questionnaires were administered via online software at the conclusion of the teaching period. Offered to all students enrolled in EDME145, these two questionnaires asked respondents to anonymously evaluate the unit and teaching staff. On-campus and off-campus students completed separate questionnaires for both the unit and teaching staff (see Appendix 5 and 6).

The unit evaluation featured two open-ended responses that asked respondents "What were the best aspects of this unit?" and "What aspects of the unit are most in need of improvement?". There were also eight items that asked respondents to rate various aspects of the unit on 5-point Likert scale. The eight items were:

1. The learning outcomes of this unit were made clear to me
2. The unit enabled me to achieve the learning outcomes
3. The unit was intellectually stimulating
4. I found the resources provided for the unit (e.g. online, print) to be helpful
5. I received constructive feedback on my work
6. The feedback I received was provided in time to help me improve
7. The overall amount of work required of me for this unit was appropriate
8. Overall, I was satisfied with the quality of this unit.

The teaching evaluation was an individual evaluation of the researcher and had a similar structure as the unit evaluation. The two open-ended questions were "Indicate the major strengths of the lecturer that you have seen or experienced this semester" and "Indicate any weaknesses or areas for improvement that you feel the lecturer could work on developing into strengths". As both these questionnaires were anonymous, it was not possible to link the comments with particular clusters, but it did offer the opportunity to provide a richer context when used with different data from other methods.

Researcher's perspective

This section focuses on the researcher's perspective of mathematics education and its role in this investigation. The conveying of a personal perspective is an attempt to provide a world view and epistemological approach through which data was collected and reported.

The researcher's world view

A researcher's world view, also referred to as a paradigm (Willis, 2007), is the fundamental models or frames of reference one uses to organise their observations and reasoning (Babbie, 2010). Often implicit and difficult to recognise, they allow for a better understanding of the different views and actions of others. A world view also influences a researcher and the study that is conducted. Pyett (2003) acknowledges that "a researcher's theoretical position, interests, and political perspective will affect, if not determine, the research question and the methodological approach" (p. 1172).

For this study, I, as the researcher and mathematics education lecturer for the EDME145 PBL unit, adopted a constructivist paradigm. Constructivism has been discussed in some detail in Chapter 2 and this chapter, but as a summary, the essential tenets can be described as:

> Meaning is not discovered but constructed. Meaning does not inhere in the object, merely waiting for someone to come upon it … Meanings are constructed by human beings as they engage with the world they are interpreting.
> (Crotty, 1998, p. 42–43)

Knowledge is therefore seen as being socially constructed and coming from people's social interactions. Social reality is generated and constructed by people and exists mostly within people's minds. The study was therefore primarily qualitative in nature. Merriam asserts that interpretation is an essence of qualitative social research.

> The researcher brings a construction of reality to the research situation, which interacts with other people's constructions or interpretations of the phenomenon being studied. The final product of this type of study is yet another interpretation by the researcher of others' views filtered through his or her own.
> (Merriam, 1998, p. 22)

This study primarily focused on the preservice teachers' current understanding and perspective of learning and teaching mathematics. Tobias (2002) recognised the complex perspectives of preservice teachers and the multitude of influencing factors contributing to their views. Therefore, the "primary interest of qualitative researchers is to understand the meaning or knowledge constructed by people" (Yazan, 2015, p. 137) and how they make sense of their experiences. Qualitative researchers must have a large tolerance for ambiguity, sensitivity to context and good communication skills (Merriam, 1998).

My own background, experiences and beliefs played a significant part in the creation of this study. Having struggled with mathematics over nearly the entirety of my schooling, I would have likely continued to dislike mathematics and believe that intelligence for mathematics is fixed, except for the impact of a single teacher at the end of high school. This teacher helped me make significant gains in the learning of mathematics, along with a love and enjoyment of mathematics as an experience. It is these experiences and beliefs that motivated me to design a study that investigated preservice teachers' mindsets and attitudes towards mathematics and how it may change over time.

My role as lecturer of EDME145 was for preservice teachers to reflect on their past learning experiences, identify their own values and beliefs on learning mathematics, and challenge these views with the use of a student-centred approach in the form of a PBL approach.

Ethical considerations

This research, like any social research, has a number of ethical considerations that needed to be taken into account. The main concern was the researcher's participation in the EDME145 unit in the role of unit coordinator and lecturer. Many of the considerations related to ensuring potential participants felt free of coercion or penalty. This was obtained by involving another researcher for the sole purpose of administering the consent process. This permitted the researcher to only know the identity of participants where it was necessary to do so, such as key informants.

The involvement in the study was with informed consent. Participants were provided with a cover letter with information about the study, such as what data will be collected and that an individual is free to withdraw from the study at any time; and that the collection of data will have the assurance of confidentiality and appropriate use of the data in the collecting, analysing and distribution phases.

First, there is the issue of dependence around the process of informed consent. The *National Statement on Ethical Conduct in Human Research* (2007) describes dependence as a pre-existing relationship between the researcher and participants. In this case, it is the researcher as lecturer and the students as participants. The concern is that this pre-existing relationship “may compromise the voluntary character of a participant's decision to be involved, due to the unequal status of the researcher and participants. The researcher is in position of influence and authority over the participants” (Australian Research Council et al., 2007, p. 59). To remove the impact of this effect, during the consent phase the on-campus students had the consent process administered by a non-researching academic, while the researcher was absent. The colleague made it clear to the participants that involvement was completely voluntary and no reason was required or penalty imposed for withdrawal. The consent forms were kept in a locked cabinet and inaccessible to the researcher during the period of the teaching intervention. This strategy meant that the teaching researcher had no knowledge of who were the on-campus participants.

For the off-campus students, an information page was placed on the unit’s website and was accessible always during the study. The information page described the research project, and listed the data that was to be collected, how it would be stored and used, as well as the standard information about research procedures at UNE (e.g. complaints, counselling). The contact details of the non-participant researcher were also on the information page so potential participants could contact him at any time if there were any queries or concerns (see Appendix 7 and 8). Again, the consent process was designed in such a way that the participating researcher had no knowledge during the teaching intervention of who participated in the study.

Whenever online data was collected, a university-accepted statement of implied consent was placed at the beginning of the collection process. This form required the participant to tick one of two boxes, indicating their involvement. Essentially either "Yes, I agree to participate in this study" or "No, I do not wish to be a part of this study". The researcher was not present during the administering of the survey and would have no knowledge during the entire teaching period of who participated in the study. This was to ensure no student would gain or be penalised as a consequence of not participating in this research study.

Mathematics education unit EDME145

Goals

EDME145 was designed to achieve two overarching goals. The first was to have preservice teachers' critique their views on mathematics education, in an attempt to contrast traditional teaching methods with more student-centred teaching methods. It included developing the requisite knowledge and skills to plan for and manage learning programs for students. The second goal was to help engage preservice teachers' with the development of their attitudes and learning goals towards mathematics.

To achieve the first goal, it was necessary to provide preservice teachers with an effective student-centred, social-constructivist learning experience, consistent with current educational expectations, such as the NSW syllabus, while teaching student-centred teaching strategies. It was decided by the researcher to use a problem-based learning approach for the first time in 2010. The particular design was chosen because of the two-pronged effect of being both a student-centred approach to learning, and requiring preservice teachers to perform student-centred tasks, such as through assessments of school student scenarios. These involved making informed judgements on individual student mathematical assessments and planning further activities for the school student's development.

The second goal required building a learning environment that valued effort, problem-solving, perseverance and learning. A week of the unit was dedicated to activities that introduced preservice teachers to implicit theories of intelligence, learned helplessness, and performance and mastery goals. The nature of learning within a PBL environment offered an important contribution to achieving this goal. PBL relies deeply on students becoming self-directed learners, learning from mistakes and being proactive in asking questions in new situations. In other words, succeeding to learn in a PBL environment requires students to act in a way that is completely opposite to learned helplessness.

Background

As development of EDME145 began in 2010 no other examples could be found online and in research articles where PBL had been used for other mathematics education PBL units. Consequently, there were no examples of units in this particular field on which to model or learn from. As no previous examples of PBL in mathematics teacher education could be found, particularly rich and complex student scenarios, it was necessary to imagine and create a PBL unit from the very beginning. This involved designing unit-level assessments, followed by progression of content throughout the semester. To do this, the researcher attended the university's medical school, which used a well-developed PBL curriculum, based on the PBL course from The University of Newcastle in NSW. The researcher/lecturer also attended several PBL tutorials and met with a number of PBL tutors, support staff and lecturers.

Based on the information gathered from those meetings a number of structural aspects from the medical PBL curriculum were adopted for the EDME145 unit. Two of these were significant details. The first was the use of scenarios (sometimes called *learning problems*), which are seen as the core element to a PBL curriculum. In the case of medicine, the scenario would typically be about one or more patients. In mathematics education, the scenarios were about school students. While details varied among scenarios in terms of size and content, they all serve the following roles:

- as a stimulus to resolve real-world problems
- use existing knowledge and experience
- practice an analytical logical approach to teaching problems
- identify further knowledge required to solve the problem
- promote teamwork
- practice breaking problems down into parts.

The goal was to implement a PBL approach into a mathematics education unit, as a means to promote the qualities just mentioned. This included providing students with higher levels of autonomy, problem-solving, group work and practical situations directly related to teaching children in schools.

Development of EDME145

The following section discusses the specific structure and content of EDME145. It includes details about the basic design iterations of the PBL curriculum, the topics and timeline.

Content

The first-year mathematics education unit, EDME145 (Primary Mathematics 1: Numeracy), was a crucial part of this research study. The unit was created in 2010 to meet new requirements from the then accrediting body, NSW Institute of Teachers (NSWIT). This coincided with this pilot study and the trial of a PBL approach. In 2010, the unit was designed to trial PBL for the first term of the semester (five weeks) with the expectation that it be extended throughout the unit in 2011. The use of PBL would see scenarios as the major driving force in the learning, supplemented with smaller mathematics education activities and lectures.

For content, EDME145 provided experiences for preservice teachers to improve their content knowledge of mathematics that is relevant to a primary school teacher, and introduce students to the concepts and ideas of student-centred mathematics teaching. Some examples included understanding and applying assessment for learning strategies, and using developmental learning frameworks for planning. The mathematics content was in line with the, then current, NSW Board of Studies mathematics syllabus (2002). EDME145 looked at all five content strands (Number, Patterns and Algebra, Data, Measurement, Space and Geometry) and the one process strand (Working Mathematically). The Working Mathematically strand overarched all the content strands, and looked at a students' development in the areas of questioning, reasoning, applying strategies, communicating and reflecting.

The first five weeks of the EDME145 in 2010 saw students undertake four scenarios, approximately one a week. They were entirely focussed on the content of Number and extensively used the Count Me In Too learning framework (Board of Studies, 2002). Each week involved a one-hour lecture followed by a two-hour tutorial with the following content foci:

- Week 1 – Early number
- Week 2 – Counting strategies
- Week 3 – Addition and subtraction
- Week 4 – Place value
- Week 5 – Multiplication and division

The expectation in 2011 was to include more scenarios from the other content strands in the second semester, such as measurement and geometry. It was discovered on reflection of the 2010 trial of PBL that more time was required to complete scenarios, allow for sufficient research, learn the relevant information and share with the group. As well, extra help would allow for more students to receive feedback in a reasonable amount of time. Therefore, in 2011 the PBL would be team-taught by two lecturers.

PBL scenarios

The Open

The Open referred to the tutorial where students were introduced to the scenario. Information about the scenario was divided into two or three packets called Triggers and were provided at different points throughout the tutorial. These packets would describe the context of the scenario, as well as offer details about the student. For example, some academic detail from the student, such as a classroom artefact, a description, or video of the student doing a task like recognising numerals or performing calculations; or personal information, such details about the students affect. Once the information had been exhausted, another packet of information was provided. This new information was usually more comprehensive and revealed further detail about the scenario's context, and insight into the student's mathematical situation.

The broad goal of the Open was for the preservice teachers to immerse themselves in the scenario, deliberate on the information provided and always work towards making an action plan. The scenarios were designed such that a complete resolution of the scenario would not be possible during the Open. It was designed so that there would be several aspects of the scenarios where the preservice teachers would not yet have the required knowledge or understanding to move forward. Identifying these areas of need for their own learning was one of the key learning goals of PBL, as well as developing lifelong learners. At the end of the Open, approximately six to eight of these areas requiring investigation were identified. These were called Learning Targets and each group member was usually assigned one specific Learning Target. Examples of these Learning

Targets could be to answer questions such as “What do children need to learn to count rationally?” or “What resources are available to help teachers to teach counting?”. The role of the tutor is also important to consider during the tutorials. Instead of giving content, the facilitator’s purpose was to help the students work through their ideas and guide the development of the Learning Targets. The preservice teachers then took their Learning Target and privately studied it in the week’s break between tutorials. In the next week, they reported their findings back to the group, and this was called the Close.

The Close

The essential aims of the Close were to share the information that had been learnt throughout the previous week from the students’ private study. Then, as a group, they would reflect on the scenario and bring it to a resolution. While the final action plan is important, PBL’s main goal is on the learning that had occurred, which is what partly separates it from project-based learning.

Supplementary activities

The other structural aspect that was adopted in EDME145 was the use of supplementary activities, such as lectures and directed activities. These were included as a means to support students in completing their scenario work and assist in their learning of what was considered core content. These included mathematical activities and lectures about mathematical concepts, teaching ideas, and learning frameworks such as Count Me In Too. A lecture was given once a week, with the content being directly relevant to that week’s scenario. At the time the lecture was delivered, the preservice teachers had already gone through that week’s Open but had not yet completed the Close.

Example scenario

The following example is included to provide greater detail about the PBL scenarios and the type of work students were expected to undertake. Scenarios were intentionally designed to be ill-defined and broad in nature. The former was to allow students to experience and gradually become more proficient at dealing with unfamiliar situations. The latter was included to more readily mirror real-life situations and allow enough content so that each member of the PBL group could have their own Learning Target.

This PBL scenario used a combination of text and videos, which were split into Triggers. A Trigger took approximately 20 to 30 minutes to exhaust discussion before moving onto the next Trigger. The scenario was developed from a combination of real experiences that were had by the two teaching lecturers.

This example was the first PBL scenario the students experienced. As the students were in their first mathematics education unit and for most students, their first experience with scenarios, the facilitator provided significant support in terms of guiding discussion, modelling problem-solving behaviour and coaching effective study habits.

> Trigger 1
>
> It is the start of the teaching year and you are required to undertake the last NSW *Best Start* numeracy assessments with a couple of new kindergarten students.
>
> Clinton
>
> A parent currently has a child enrolled in your kindergarten class and another child in a different grade. After school, as parents are picking up their children, a parent walks into the classroom with the older child and says, “I'm worried that I shouldn’t have sent Clinton to

> school this year. He can't count so he will probably fail
> the test.
>
> (Schmude, 2011)

This was then followed with Trigger 2, which was a video clip of Clinton completing two tasks. The first involved him rote counting forwards from one and the second clip recorded counting a small set of counters, to which he said, '99'. This scenario focused on learning about the Kindergarten entrance literacy and numeracy assessment, *Best Start*, along with learning about the five principles of counting, resources to assist teachers with assessment and best practices for interacting with parents.

Comparison with medical PBL scenarios

There were structural aspects from the medical PBL curriculum that could not be adopted in EDME145. For instance, there were constraints on teaching time, expense or established educational constraints such as the unit's content requirements, and the type and number of assessments within the unit. For example, in the medical school they have one tutor per eight students. In EDME145, there was the single lecturer in 2010 and two lecturers in 2011. Also, PBL is often used in medicine in an all-or-nothing way. That means that the entire medical course adopts a PBL approach, or it is not done at all. By taking this position, scenarios are complex, robust and cover a wide range of areas within medical education (such as diseases, anatomy, medicines and medical services). EDME145 on the other hand, is restricted to just mathematics education. In that way, the use of PBL in EDME145 had some noticeable differences.

Similarities with well-established PBL curricula

- Use of scenarios as stimulus for learning
- Scenarios are done in small groups (approx. 4–8 students)
- Use of an Open and Close in separate tutorials
- Opens are broken into packets of information (Triggers) which require brainstorming and problem-solving
- Use of Learning Targets as educational goals are created by the students with the assistance of the tutor at the conclusion of the Open
- Use of supplementary learning activities and lectures

Dissimilarities with well-established PBL curricula

- Only one lecturer for whole class, instead of typically one tutor per eight students
- Only one unit (EDME145) using PBL, as opposed to the entire course. Other education units taken by the preservice teachers had their own pedagogical approaches and were significantly different to PBL.
- Single content area (mathematics education), instead of all content areas

It is acknowledged that this inability to create a PBL approach across all of the education units did create challenges. Despite this, the study made use of this new initiative as a way of understanding how preservice teachers with different attitudes and implicit theories of intelligence responded to a challenging, student-centred approach to learning.

Conclusion

The data collection process was developed by utilising a case-study methodology, research instruments and procedures consistent within a theoretical framework. The research questions investigated the preservice teachers' past learning experiences and their current views and beliefs of learning and teaching mathematics. Consequently, the structure of the research methodology was broad and integrated several instruments, including both quantitative and qualitative data, in order to provide a rich and contextual interpretation.

Chapter Four

Results

Introduction

The following chapter presents the results of the data collected throughout the semester-long investigation. Both quantitative and qualitative data were collected at the beginning and conclusion of the problem-based learning (PBL) unit, with the main focus on the rich, contextual, descriptive contributions from participants. Quantitative data were collected from the Attitude Toward Mathematics Inventory (ATMI) and Implicit Theories of Intelligence (ITI) surveys, which were utilised to provide an overview of the cohort and identify potential key informants. Qualitative data was gathered through semi-structured interviews, online contributions and questionnaires, such as the unit evaluation questionnaire. These data are presented in relation to the research questions, which investigated how the participants' attitudes towards mathematics and implicit theory of intelligence might impact on (1) their view of learning and teaching mathematics, (2) their experience of student-centred learning, in the form of PBL, and (3) changes to their mindsets and attitudes over the duration of the unit. A major goal of the unit was to assist the preservice teachers to have a positive attitude toward mathematics and a mastery approach to learning and teaching mathematics. The quantitative data is presented first, followed by the extensive qualitative data.

Quantitative results

Attitude Toward Mathematics Inventory (ATMI)

The purpose of the ATMI survey was to obtain a measure of the preservice teachers' attitudes toward mathematics. The survey designed the items into four factors – self-confidence, value, motivation and enjoyment. These data, along with the Implicit Theories of Intelligence (ITI) survey, were used to provide an overview of the cohort, and as the main information to identify key informants from each cluster for the qualitative component of the study.

The survey was administered in the first week of semester and again at the conclusion of the semester-long unit, to identify any changes in attitudes and theories of intelligence. The pre-study took place in July 2011 and the post-study was conducted towards the end of October 2011. There was only one minor revision to an item in the ATMI. Item 28 was originally worded as "I would like to avoid using mathematics in *college* [emphasis added]", but was modified to "I would like to avoid using mathematics at *university* [emphasis added]" to better suit an Australian sample. A six-point Likert scale was used (Strongly Agree, Agree, Somewhat Agree, Somewhat Disagree, Disagree and Strongly Disagree). Using an even-numbered scale, as opposed to an odd-numbered scale, insisted that participants leaned towards one side or the other for each item as there was no middle score. This can be used when participants are experienced with the content, which in this case was about their feelings toward mathematics after many years of schooling. Each item was given a score from zero to five, with the largest value reflecting the most positive attitude level.

Responses to the ATMI survey

The following Table 4.1 summarises the results from 176 pre-study respondents and 158 post-study respondents from the cohort of 458 EDME145 students (on- and off-campus). This equated to 38.8% and 34.4% of the entire cohort respectively. The highest possible score for the ATMI questionnaire was 200, which indicated a very positive attitude toward mathematics, while the lowest possible score was 0, indicating a very negative attitude toward mathematics. Note that the Agree column contains the total of Agree and Strongly Agree, while the Disagree column contains the total of Disagree and Strongly Disagree. The four factors have been included in the table and are abbreviated as SC (self-confidence), V (value), M (motivation) and E (enjoyment).

Table 4.1 – Pre-study and post-study ATMI results (n=176 and n=158 respectively)

	Pre-study (n=176)		**Post-study (n=158)**		
Item number (Tapia & Marsh, 2005)	**Agree**	**Disagree**	**Agree**	**Disagree**	**Factor**
Mathematics is a very worthwhile and necessary subject	94%	1%	96%	0%	V
I want to develop my mathematical skills	90%	1%	94%	0%	V
I get a great deal of satisfaction out of solving a mathematics problem	60%	4%	78%	3%	E
Mathematics helps develop the mind and teaches a person to think	80%	1%	88%	1%	V
Mathematics is important in everyday life	87%	1%	89%	1%	V
Mathematics is one of the most important subjects for people to study	69%	2%	77%	2%	V
High school math courses would be very helpful no matter what I decide to study	54%	5%	65%	3%	V
I can think of many ways that I use math outside of school	79%	1%	84%	1%	V

	Pre-study (n=176)		Post-study (n=158)		
* Mathematics is one of my most dreaded subjects	34%	31%	35%	23%	SC
* My mind goes blank and I am unable to think clearly when working with mathematics	37%	19%	40%	18%	SC
* Studying mathematics makes me feel nervous	35%	27%	38%	22%	SC
* Mathematics makes me feel uncomfortable	42%	21%	43%	16%	SC
* I am always under a terrible strain in a math class	44%	16%	44%	9%	SC
* When I hear the word mathematics, I have a feeling of dislike	47%	19%	47%	14%	SC
* It makes me nervous to even think about having to do a mathematics problem	48%	16%	47%	12%	SC
Mathematics does not scare me at all	29%	28%	28%	25%	SC
I have a lot of self-confidence when it comes to mathematics	21%	22%	21%	19%	SC
I am able to solve mathematics problems without too much difficulty	26%	15%	23%	14%	SC
I expect to do fairly well in any math class I take	27%	12%	23%	17%	SC
* I am always confused in my mathematics class	38%	9%	33%	8%	SC
* I feel a sense of insecurity when attempting mathematics	32%	15%	35%	12%	SC
I learn mathematics easily	20%	17%	20%	15%	SC
I am confident that I could learn advanced mathematics	19%	29%	19%	32%	M
I have usually enjoyed studying mathematics in school	40%	21%	30%	26%	E
* Mathematics is dull and boring	38%	9%	52%	4%	E
I like to solve new problems in mathematics	35%	10%	43%	5%	E
I would prefer to do an assignment in math than to	37%	28%	35%	25%	E

	Pre-study (n=176)		Post-study (n=158)		
write an essay					
* I would like to avoid using mathematics in college	42%	8%	42%	9%	M
I really like mathematics	29%	16%	31%	12%	E
I am happier in a math class than in any other class	9%	38%	6%	35%	E
Mathematics is a very interesting subject	34%	10%	48%	5%	E
I am willing to take more than the required amount of mathematics	18%	24%	15%	23%	M
I plan to take as much mathematics as I can during my education	20%	21%	17%	23%	M
The challenge of math appeals to me	33%	12%	26%	14%	M
I think studying advanced mathematics is useful	22%	13%	27%	17%	V
I believe studying math helps me with problem-solving in other areas	53%	5%	50%	3%	V
I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math	28%	13%	33%	13%	E
I am comfortable answering questions in math class	27%	17%	28%	14%	E
A strong math background could help me in my professional life	57%	1%	61%	5%	V
I believe I am good at solving math problems	26%	13%	23%	14%	SC

** Reversed items due to negative phrasing*

An analysis of the responses was undertaken to gain an overall picture of the cohort, and a deeper understanding of the similarities and points of difference within the cohort as a whole, thereby providing a context in which the clusters were formed. Items from the ATMI were split into the four factors designed by Tapia and Marsh (2000, 2002, 2004, 2005) and shown in Table 4.2.

Table 4.2 – Four factors in the ATMI by items

Factors in ATMI questionnaire	**Items**
Factor I: Value	1, 2, 4, 5, 6, 7, 8, 35, 36, 39
Factor II: Self-confidence	9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 40
Factor III: Enjoyment	3, 24, 25, 26, 27, 29, 30, 31, 37, 39
Factor IV: Motivation	23, 28, 32, 33, 34

While some items provided little differentiating effect, these items did signal solidarity among the cohort. Looking across the items there was generally a strong agreement for the *value* factor, which was the most highly "agreed" upon aspect. It indicated that the group, as a whole, did value mathematics and saw its learning as a worthwhile and pragmatic pursuit. This was despite other differences across other factors, such as self-confidence and enjoyment.

Another point of interest in the pre-study ATMI results was the responses that had a greater disagreement than agreement. Item 30 was the most notable of these with 38 per cent of the respondents (pre-study phase) disagreeing with the statement "I am happier in a math class than in any other class" compared to just nine per cent agreeing. This could be due to the phrasing of the statement and placing mathematics above all other classes. Items 23 and 32 also had noticeable division between the number of agreed and disagreed responses. These items related to undertaking advanced mathematics and doing more than the required amount of mathematics study respectively. Both items belonged to the "motivation" factor.

Implicit Theories of Intelligence (ITI) survey

The following Table 4.3 summarises the results from 176 pre-study respondents and 158 post-study respondents, from the cohort of EDME145 (on- and off-campus). The highest possible score for the ITI survey was 40, which indicated a very emergent view of intelligence, while the lowest possible score was 0, indicating a very fixed view of intelligence. Note that the Agree column contains the total of Agree and Strongly Agree, while the Disagree column contains the total of Disagree and Strongly Disagree.

Table 4.3 – Preservice teachers' responses to the Views of Intelligence questionnaire (pre-study and post-study)

	Pre-study (n=176)		**Post-study (n=158)**	
Item number	**% Agree**	**% Disagree**	**% Agree**	**% Disagree**
* You have a certain amount of intelligence, and you can't really do much to change it.	6%	51%	7%	55%
* Your intelligence is something about you that you can't change very much.	6%	54%	7%	62%
No matter who you are, you can significantly change your intelligence level.	58%	3%	58%	6%
* To be honest, you can't really change how intelligent you are.	2%	57%	2%	62%
You can always substantially change how intelligent you are.	48%	6%	52%	4%
* You can learn things, but you can't really change your basic intelligence	9%	42%	6%	42%
No matter how much intelligence you have, you can always change it quite a bit.	51%	3%	53%	2%
You can change even your basic	54%	4%	55%	2%

intelligence level considerably.				

** Reversed items due to negative phrasing*

Results from the ITI survey revealed that students tended to agree rather than disagree with the ideas of an emergent intelligence. For six out of the eight questions, a majority of students agreed more with the notion that intelligence is emergent than fixed.

Wilcoxon signed-rank test

Of the 158 participants who completed the post-study survey, 86 participants had also completed the pre-study survey. A Wilcoxon signed-rank test was conducted to gauge the impact on the participants' attitudes toward mathematics and implicit theory of intelligence at the beginning and end of the PBL mathematics education unit.

Comparing the pre-study and post-study scores for ATMI survey

This test compared the participants who completed both the pre-study and post-study ATMI survey. Using a Wilcoxon signed-rank test, a probability of less than 0.01 was obtained (2-tailed $p < 0.0039$) indicating that there was a statistically significant change in the cohort's attitude toward mathematics over the period of the PBL mathematics education unit.

Comparing the pre-study and post-study scores for ITI survey

A comparison of the participants who completed both the pre-study and post-study ITI survey was conducted using a Wilcoxon signed-rank test. A probability of less than 0.05 was obtained (2-tailed $p < 0.027$) indicating during the PBL mathematics education unit, there was a statistically significant change in the cohort's implicit theories of intelligence.

Quantitative conclusion

In reporting on the results of the quantitative aspect of this study, only tentative conclusions can be made. It is important to be mindful of biases such as the Hawthorne effect and end-of-semester excitement when completing the post-study surveys, along with confounding factors. With this in mind, the quantitative results suggested that the experiences of preservice teachers during the mathematics education PBL unit did have a positive impact on them to a significant level. The analysis implied that the preservice teachers' attitudes toward mathematics became more positive and their implicit theory of intelligence moved more toward an emergent view. The primary purpose of the quantitative aspect of this study was to identify potential key informants at the pre-study phase for case study research. The following section reports on the results from the qualitative portion of the study with the key informants.

Qualitative results

Introduction

The qualitative results of this study are compiled in three sections related to the research questions: the past experiences and current beliefs and attitudes of the preservice teachers and how these factors influenced their views and experience; their experience of learning in a student-centred environment; and lastly, the changes they experienced by the conclusion of the unit.

Qualitative data were gathered through pre- and post-study interviews with key informants, the Critical Moments questionnaires, informal forum posts on Moodle, unit evaluation questionnaire and the researcher's own reflections. The instruments provided a link between their experiences of learning mathematics and the current personal constructs of the preservice teachers' attitudes, implicit theories of intelligence and learning goals.

Clusters and key informants

Justification of clusters

Data from the responses to the pre-study ATMI and ITI questionnaires were scored using the values mentioned in the previous section. These scores from the two questionnaires provided each person with an ordered pair that enabled them to be placed on a scatter graph, which is presented in Figure 4.1. The vertical axis represents the scores from the ITI questionnaire, with a higher score indicating a growth view of intelligence, while a lower score implying a fixed view of intelligence. The horizontal axis represents the ATMI scores, with a higher score representing a positive attitude toward mathematics, and a lower score expressing a negative attitude toward mathematics.

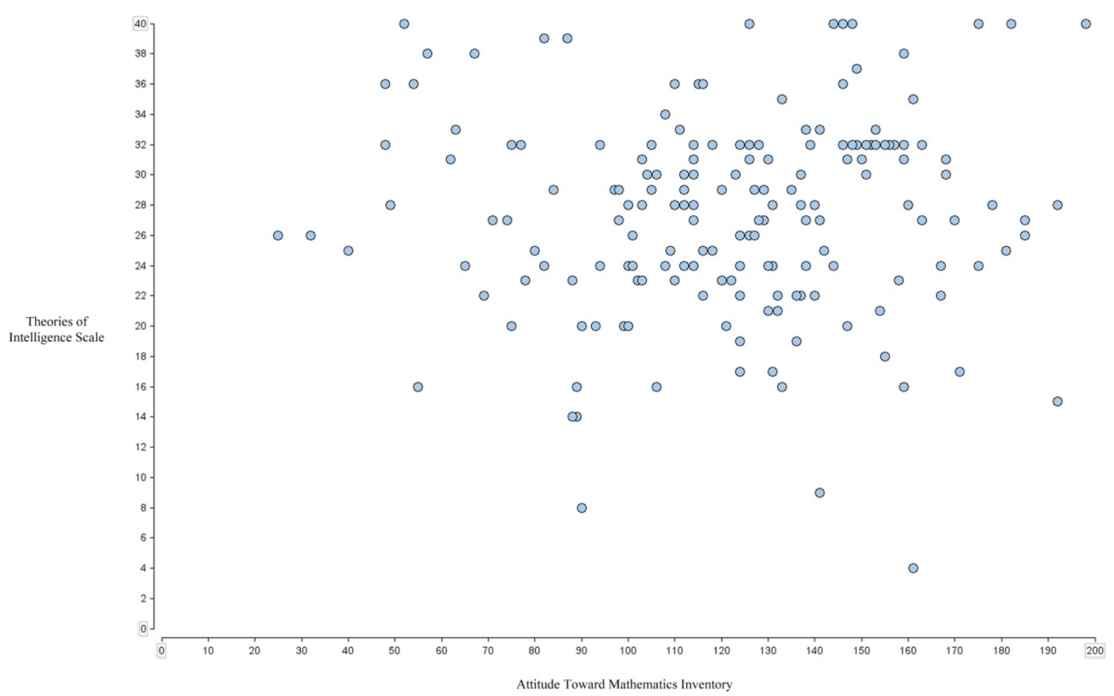


Figure 4.1– ATMI vs ITI pre-study scores (on- and off-campus, n = 176)

Using the median scores from the ATMI and ITI results, quadrants were formed using the medians to create approximately equal groups, shown in Figure 4.2. Scores that occurred on the medians were not included in any quadrants and withdrawn from further study. The quadrants represented *clusters of students* who shared similar characteristics for both attitude toward mathematics and implicit theory of intelligence. The clusters were named 1, 2, 3 and 4 and are summarised in Table 4.4 and shown in Figure 4.2.

Table 4.4 – Description and naming of clusters

Cluster	Characteristics	Cluster boundaries
1 (n = 41)	Negative attitude toward mathematics; fixed view of intelligence	ATMI – less than 124 ITI – less than 28
2 (n = 37)	Positive attitude toward mathematics; fixed view of intelligence	ATMI – more than 124 ITI – less than 28
3 (n = 36)	Negative attitude toward mathematics; emergent view of intelligence	ATMI – less than 124 ITI – more than 28
4 (n = 41)	Positive attitude toward mathematics; emergent of intelligence	ATMI – more than 124 ITI – more than 28

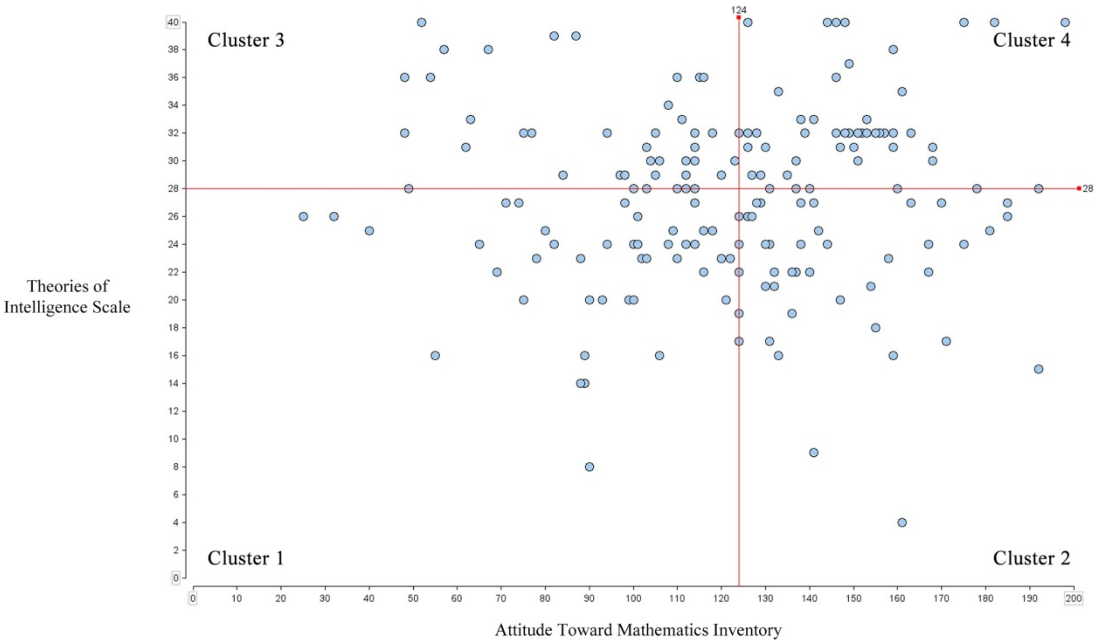


Figure 4.2 – ATMI vs ITI Pre-study scores with medians (on- and off-campus)

The clusters provided an opportunity to look for similarities and differences among the clusters in their view and experience of learning and teaching mathematics. The study was interested in investigating in particular, those participants who exhibited strong measures in both characteristics. These participants became key informants for the cluster.

Justification of key informants

Extra regions were created to identify participants who exhibited strong characteristics of both attitude toward mathematics and an implicit theory of intelligence. These guiding lines were positioned one standard deviation away from the mean for both scales and created four areas in the corners of the scattergraph. These extreme areas were used to identify and invite two potential key informants from each cluster, preferably one each from on-campus and off-campus, as well as male and female.

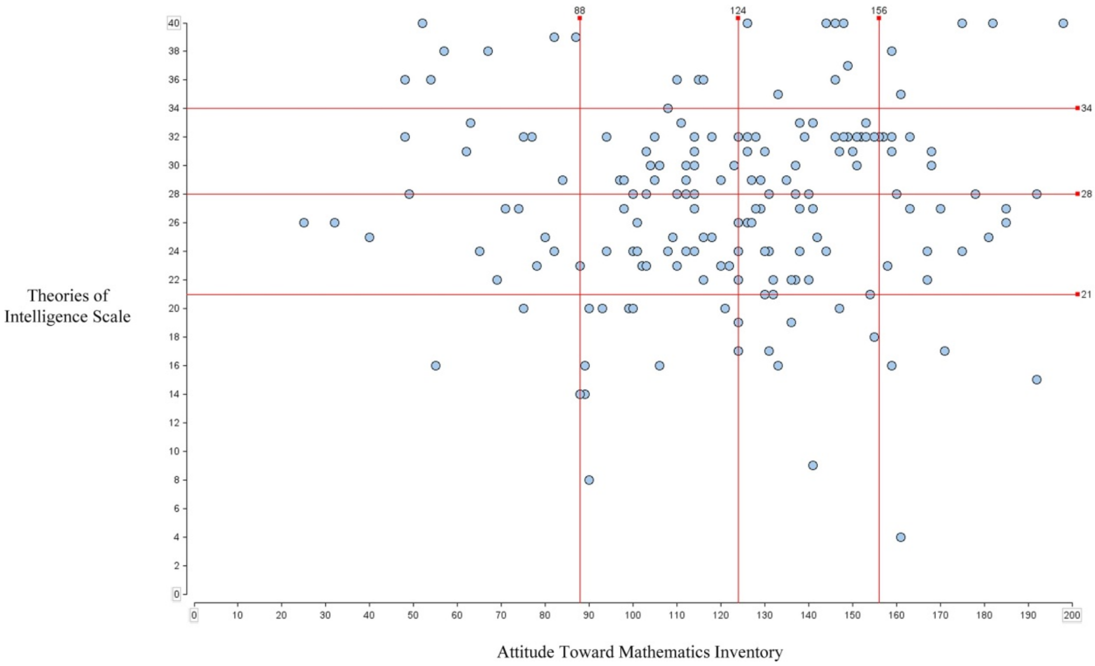


Figure 4.3 – Selective corners within the clusters (on- and off-campus)

Figure 4.4 shows the placements within each cluster of the eight key informants who volunteered to participate further.

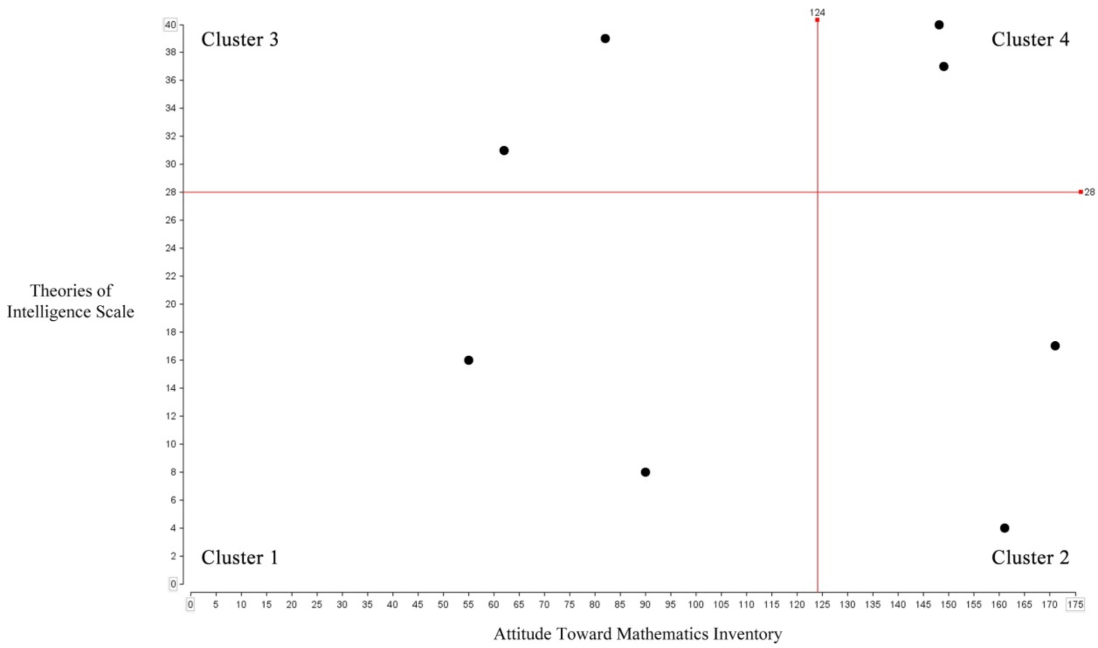


Figure 4.4 – Actual key informant locations (on- and off-campus)

The selection of eight key informants (two from each cluster) occurred in the first two weeks of the study. The purpose of the informants was for the researcher to achieve a deeper understanding of the participants' views of learning and teaching mathematics in relation to their attitude toward mathematics and implicit theories of intelligence, to relate their experiences of learning within a student-centred environment, and to discuss changes that may have occurred during the mathematics education unit.

The selection of informants was done purposively, with the selection criteria being their position within the cluster – namely, that they were placed well within the cluster, away from the median scores for the ATMI and ITI. All of the participants who fulfilled the selection criteria were invited to be further contributors to the study in the form of a key informant. In the end, there were participants who satisfied the selection criteria more fully than those who actually became the key informants, but either did not respond to the invitations or declined to participate further.

For ethical reasons it was necessary to protect the identities of respondents in the pre-study stage, as the researcher was also the lecturer. The researcher took extra steps during the processing of survey scores and inviting participants for interviews. The initial scoring of survey responses was done by asking a colleague to remove all identifying and personal information from the data. After all survey responses were processed, the researcher identified potential participants based on their survey scores. These results were then given back to the colleague who identified the participants and sent out invitations. Each participant was then informed by the colleague about the details of participation (such as confidentiality and the voluntary nature of participation). Once permission by the participant was given, the researcher was then able to undertake interviews. Pseudonyms have been used to ensure confidentiality and protect the participants' privacy.

All eight participants completed the questionnaires in the pre-study stage of the study. In the post-study phase, seven were able to complete the post-study questionnaires (four on-campus and three off-campus). Table 4.5 shows the details of the key informants from the clusters and information that could be gathered from their voluntary participation.

*Table 4.5 – Key informants survey results for pre- and post-study (off-campus and *on-campus)*

	Pre-study		Post-study		Shift	
Preservice teacher	ATMI (max=200)	ITI (max=40)	ATMI (max=200)	ITI (max=40)	ATMI (% change)	ITI (% change)
Gretel*	55	16	89	22	+34 (62%)	+6 (38%)
Leanne	90	8	112	23	+22 (24%)	+15 (188%)
Jamie*	171	17	-	-	-	-
Katherine	161	4	156	10	-5 (3%)	+6 (150%)
Alicia*	62	31	95	33	+33 (53%)	+2 (6%)
Sienna*	82	39	112	28	+30 (37%)	-11 (28%)
Susanna*	149	37	160	33	+11 (7%)	-4 (11%)
Shaun	148	40	166	32	+18 (12%)	-8 (20%)

** On-campus student*

The goal with selection of key informants was to choose two participants for each cluster – one on-campus student and one off-campus student. This was achieved for each cluster except Cluster 3, where no off-campus students were either able or willing to participate in the study. Consequently, an extra on-campus student joined the study in Cluster 3.

Research question 1: View of learning and teaching mathematics

The following section provides the results related to the preservice teachers' experiences, views and beliefs about learning and teaching mathematics. As they were first-year education students in their first mathematics education unit, they were only at the very beginning of their journey towards teaching mathematics and had far more experience as learners rather than teachers. Hence it was expected that their views of learning mathematics would be more deeply formed and articulate than their views of teaching. The main focus was asking them to reflect on their own previous learning experiences and their current beliefs about learning, and attitudes toward, mathematics. Multiple sources were analysed for both common and distinct themes, in an effort to better understand the key informants' experiences, current feelings and beliefs. The data used in this section were primarily obtained from the Critical Moments questionnaire and the pre-study interviews.

Cluster 1

Participants in Cluster 1 were respondents whose scores reflected a negative attitude toward mathematics and fixed view of intelligence. Based on their survey results, they found mathematics difficult to value and enjoy, and struggled to feel motivated and confident when undertaking mathematics. Coupled with this attitude was their belief that intelligence is a fixed trait of an individual, meaning that effort, perseverance and teaching cannot make a significant change in one's intellect.

Gretel

Background

Gretel completed most of her schooling in QLD but moved to NSW in early high school and graduated Year 12 in 2009. She completed lower-level senior mathematics and according to her recollection, achieved average marks. She said, "if I tried really, really hard I could get a B" (Gretel, pre-study interview). The following section provides corroborating evidence of Gretel's characteristics that confirm her placement in Cluster 1, as well as highlighting a number of interesting themes in Gretel's beliefs and experiences, that help deepen our understanding of Gretel's perspective.

ITI and learning goals

There were numerous pieces of evidence to support Gretel as a person with a fixed view of intelligence. Along with achieving one of the lowest scores in the pre-study ITI survey, a number of responses and behaviours from Gretel were consistent with indicators of performance learning goals, very often as a consequence of a fixed mindset.

People with performance learning goals tend to focus their success and failure on their performance, such as grades and correct answers, rather than on growth and learning. This was evident in a number of Gretel's responses. For instance, when she was asked when she feels smart, Gretel immediately answered with "when I get the answer right". This was followed by her giving the example of a time when she got a mathematics question correct when everyone else in the class did not. The teacher asked her to explain to the class how to answer the question. The focus on performance and correctness was more important than other effort and overcoming a deep challenge.

Challenge and failure are particularly confronting for people with performance learning goals, and failure is often avoided if possible. While undertaking a similar task done by Diener and Dweck (1978), Gretel demonstrated this quality when asked to complete a number of Sudoku-like puzzles, called KenKens. Gretel was presented with two beginner-level KenKen puzzles to learn the basic rules and achieve early success, followed by a significantly more challenging KenKen. Unexpectedly, Gretel struggled on the first, easiest KenKen, most likely due to a simple misunderstanding of the rules. After trying to solve the puzzle for a minute, she then slid the unfinished puzzle across the table saying, “I’m done”, which meant she was finished trying and was quitting that task.

When asked if she believed that there are some people who can learn and understand mathematics and some who cannot, she said “yes”. She described that there are people who can just do mathematics easily and that it either “clicks” or it does not and said, “you can try but … [did not finish sentence]” (Gretel, pre-study interview). In the post-study interview, she described herself as not being “a maths person” (Gretel, post-study interview). These responses were consistent with survey data that she held a fixed mindset.

Attitude toward mathematics

Interview and questionnaire data clearly confirmed that Gretel had a negative attitude toward mathematics at the pre-study phase. When asked what her attitude toward mathematics was, she replied that she did not like mathematics, that it made her feel frustrated, overwhelmed, emotional, and she believed she had never been very good at it. This was despite recalling fairly recent occasions in her senior years at school where she achieved some high grades.

Gretel identified the transition from QLD to NSW as a key moment in her mathematics learning, where she felt high levels of anxiety and failure. During this time, she believed that she was well behind in her content knowledge compared to the other students. She felt that other students knew much more than her about content she had never learnt before.

> … when I moved schools from a state school to a private school and also from NSW to Queensland I was very behind in my maths and even though I should have learnt it the year before, I didn't. So there was a lot to take on in that year. I felt very behind and there was just general stuff that everyone else knew that I just had no idea about sort of thing.
>
> (Gretel, pre-study interview)

This experience caused ongoing frustration and a loss in self-confidence toward mathematics. Her perception was that “everyone else knew” but she “had no idea”. Her language suggested a global situation in which she personally felt she did not belong.

View of learning and teaching mathematics

Gretel’s view of learning mathematics showed connections with her past experiences, and focused on two aspects: a preference for learning mathematics in small steps and for needing a caring and patient teacher.

Gretel was asked how she liked to learn mathematics, to which she responded that she preferred mathematics to be broken down considerably into small steps rather than engaging in more complex, challenging tasks. This was especially the case when the content was new and unfamiliar. This was confirmed in the post-interview when she mentioned her dislike of the extended nature of the PBL scenarios in lieu of smaller tasks. The reasons she gave for this were that she felt more successful and faster in her learning, and it avoided the feelings of confusion and being overwhelmed

For Gretel, her learning of mathematics placed a significant emphasis on the role of the teacher, for two purposes. First, she desired the teacher to provide patient assistance with learning content, and that when she struggled with learning content, she needed “a teacher that will have the patience to be able to help me with that” (pre-study interview). In the Critical Moments questionnaire, she explained how important a teacher was to her experience, that “to me, teachers were always an extremely important aspect of my learning. If I didn't click with my mathematics teacher then it was hard for me to want to learn about a subject I highly disliked” (Critical Moments questionnaire). In the same way that the teacher was one of the main sources of her positive moments in learning mathematics, so too was it the source of her most negative, and most recent, mathematics learning moment. In Year 12, Gretel described her mathematics teacher as a person whose behaviour appeared to show a significant lack of care and patience for her learning, as well as making Gretel feel stupid and different from the rest of the group.

> In Year 12 I had a negative experience with mathematics as I did not get along with my teacher … Whenever I would put my hand up and say that I did not understand, he would sigh and make me feel stupid. He made me feel like I was the only person who did not understand and that I was holding everybody back. He never had time for me, or cared that I felt lost and was confused.
>
> (Gretel, Critical Moments questionnaire)

Finally, Gretel saw a need for her teacher to directly influence her affect. In the pre-study interview, Gretel spoke of a teacher who was very dedicated to helping her and other students when they were struggling with their learning. There appeared to be a reliance on her teacher to provide her with motivation, encouragement and self-confidence. Gretel expressed this as a general view of characteristics that an effective teacher displayed, namely, someone who impacts on a student’s affect, such as self-confidence and motivation.

> … a dedicated teacher [will] stay behind with them at lunchtimes or after school or something like that to build up their self-confidence, because as soon as you don't think you can do it, you don't want to do it.
>
> (Gretel, pre-study interview)

Overall, Gretel demonstrated a fixed view of intelligence, performance goals and a negative attitude towards mathematics. She had both positive and negative experiences while learning mathematics, and these appeared to centre around the way the mathematics was presented and the teachers she had at the time.

Leanne

Background

Leanne was an off-campus student aged between 36 and 40. She graduated Year 12 in NSW in 1991 and attempted the lower level of mathematics in that year. Like Gretel, Leanne was placed in Cluster 1 based on her ATMI and ITI scores. She had the second lowest score for the ITI of the entire cohort, which indicated a strong belief in a fixed view of intelligence. She was more positive toward mathematics than Gretel, but still felt high levels of anxiety and low self-confidence toward mathematics, which was evident from her responses.

ITI and learning goals

Despite Leanne's low score in the ITI survey, responses that related to identifying her as having performance goals were inconsistent. The main discrepancies appeared between what she said while being interviewed and her experiences of the past. For example, Leanne completed the lower-level mathematics course in Year 12, which she described as fairly simple and easy for her to achieve high grades. But in retrospect she mentioned she would have preferred to try the higher, more challenging level of mathematics because she believed she would have benefited from it more; however, she was too enticed by the success at the lower level. Her knowledge of this decision and the easy successes had caused feelings of regret later in life. More about this is discussed in the next section.

Similar to Gretel, there were some indications of conflict between Leanne's learning goals. Some responses she gave in the interview were more closely aligned with those expected from a person with mastery-learning goals. This is also in the context of Leanne achieving one of the lowest ITI scores in the sample. In response to the question of whether she would prefer to learn things that are easy or challenging, she said she would prefer challenging. In her mind, she would prefer to have a challenge and get it wrong than have a simple question and get it right. In her Critical Moments questionnaire, she recalled feeling it was "wonderful that each day brought with it new challenges and more learning to achieve, but only when I wanted to" (Critical Moments questionnaire). Along with this idea of challenge, she also said she would prefer to attempt the harder KenKens because they are more of a challenge. Despite struggling with the far more difficult KenKen, she said she had no intention of quitting during the task and was "excited" to undertake it. So while she espoused almost a passion for challenging learning, she was confronted with challenging emotions of a different kind.

Attitude toward mathematics

Leanne had a relatively low score on the ATMI survey, indicating a negative attitude toward mathematics. This was confirmed through other data such as the pre-study interview and Critical Moments questionnaire. This attitude included low self-confidence and high level of stress-related emotions.

While undertaking the KenKen puzzles, Leanne mentioned to the researcher the high level of anxiety and fear she was experiencing during the tasks. She also commented on her thinking while doing the tasks, which involved mistakenly believing the mathematics tasks were more challenging than they actually turned out to be – a habit she says she often did. At each step throughout the KenKen task, she repeatedly asked if she was on the right track and seemed to need confirmation that her understanding was correct.

> I know that it is simple but … I feel quite emotional, not knowing if I'm going to get it right or not. I think it was a bit harder than it was, and I have trouble getting out of that.
>
> (Leanne, pre-study interview)

It appeared that her view of the value of mathematics had changed significantly since her time at school. In her Critical Moments questionnaire, Leanne describes that she did not apply herself and how she regretted the missed opportunity of learning mathematics more deeply. She mentions the mathematics content as being at times arbitrary, but identifies the main reason for her disengagement was herself, saying "I guess what I am trying to say is that the teacher, and mathematical content was great, it was the student that made it sometimes negative" (Critical Moments questionnaire). She had made her failure a very personal part of her experience.

View of learning and teaching mathematics

There were two themes through Leanne's view of learning mathematics. She clearly valued mathematics and wanted to be good at it. She expressed how she wished she had learnt at a higher level, risking immediate success for more significant learning. But at the same time, learning mathematics made her feel highly anxious, even fearful. At the conclusion of the study, Leanne's result for EDME145 was a fail as she did not achieve an overall pass mark of 50 per cent or higher.

Like Gretel, Leanne also valued a positive and passionate teacher. She said it made her feel "enthusiastic" and turned her into a "positive" student (Critical Moments questionnaire). With regard to her own teaching, Leanne said she would use challenging work in her class, as opposed to more simple work where students will experience lots of success like she experienced. She aspired to create individuals who grow up to be successful, look for challenge in their lives and feel complete. As a consequence of using more challenging work, she was asked how she would react when students got things wrong. The response was of an emergent intelligence type. She believed that students cannot really fail, if they persevere there will always be a solution, they just have to find it for each individual and each problem. She added that she might just need to try harder to help them find another way and think differently about it. Finally, when asked if everyone can get significantly better at mathematics, she said. "I believe you can get better at maths, you just have to want it" (Leanne, pre-study interview).

Cluster 2

Participants in Cluster 2 were those whose survey scores implied a positive attitude toward mathematics and a fixed view of intelligence. These traits anticipated responses to be relatively favourable toward mathematics in terms of value, motivation, enjoyment and self-confidence, while preferring easy successes, being averse to significant challenge and having a strong urge to always appear smart and avoid failure, especially in front of others.

Jamie

Background

Jamie was an 18–19-year-old on-campus student in his first year of study. He graduated Year 12 in 2010 in NSW, completing the lower-level mathematics. His pre-study interview data confirmed performance-oriented goals, which were a likely consequence of his fixed intelligence mindset. His attitude toward mathematics was fairly positive, indicating a high value, enjoyment and self-confidence toward mathematical endeavours. The story of his positive and negative experiences at school raised interesting themes of the role of peers, praise and motivation.

ITI and learning goals

Jamie appeared to have performance goals that often saw him orient his goal to always appear smart, and avoid challenge and opportunities where he could fail. In his early mathematical learning experiences, Jamie was placed in an advanced mathematics class, where he experienced a strong sense of satisfaction and thrill for this achievement. In his positive Critical Moments response, he reflected on the feeling of "superiority" and enjoyment he felt from the attention he received. When asked when he felt smart, Jamie replied that it is when he is "able to achieve something that someone else can't" (Jamie, pre-study interview). This is a response expected from a person with performance goals, as it is external evidence of a high intelligence. In a similar way, Jamie was asked to imagine how he felt when working on a really hard mathematics question. He said that he enjoys trying to figure things out that he should not be able to do. Coupled with this enjoyment, however, was a feeling he described as a "cost versus benefit". When taking on challenge, he said he hates "trying heaps and not achieving well".

Therefore, a challenging question would only be undertaken if he felt that there is a good chance of success before undertaking it.

Attitude toward mathematics

Jamie seemed to have a positive attitude toward mathematics in terms of enjoyment and self-confidence, even rating himself “very confident” in his ability in mathematics. Mathematics was enjoyable to Jamie for most of his schooling. A positive critical moment was in Year 4 when he had a “healthy rivalry” (Jamie, Critical Moments questionnaire) with his friend as they tried to out achieve each other in class.

In contrast, his most recent experience in senior years at school were more negative in a rather interesting way. Jamie explained the situation by starting with the teacher who had a teaching style that did not “work well” for him. It was hard for Jamie to articulate exactly what this meant but he identified the teacher’s inability to explain things in real-world terms and the repetitive and pointless worksheets. He felt his engagement and motivation deteriorate, and as a result, his marks began to fall. As he saw himself not achieving highly at the advanced level, he gave up trying to succeed in that class and moved down to the lowest level mathematics. There he achieved 98 out of 100 with very little effort. When asked if it felt good to get such high marks in the lower-level mathematics, Jamie’s reply was “Absolutely!” (Jamie, pre-study interview).

> This mathematical content that was taught was only given as formulas without an explanation of relevance. This created the illusion that the knowledge I was acquiring was borderline comical and irrelevant. Due to this attitude, my learning became more difficult as I felt I did not need the content. I became complacent and uncaring about the class. Due to this, my marks fell …
>
> (Jamie, Critical Moments)

During the times when Jamie was experiencing mathematics in a negative way, he described the embarrassment, and even shame, he felt for failing advanced mathematics and succeeding so easily at the lower-level mathematics. Jamie was keenly aware of the lack of challenge General Mathematics offered to him but, at the same time, was thrilled by the high level success. Jamie appeared to feel embarrassed for failing at advanced mathematics, as well as advanced English, in both his Critical Moments questionnaire and in the pre-study interview. To cope with the shame and embarrassment he felt, he adopted a number of strategies. These included not admitting being enrolled in “General Mathematics”, but instead he would say he was in “Mathematics”, which was the title of the more advanced mathematics course. His lying was to avoid negative judgement of others.

> … I became embarrassed of not achieving at a high level. To cover my embarrassment I adopted the persona that I didn’t care. This created a fast downward spiral where I end up dropping to General Mathematics.
>
> (Jamie, Critical Moments)

While Jamie’s experience of his friends in primary school saw a “healthy rivalry”, his experience in senior school with his friends became a source of anxiety and a noticeable factor towards his embarrassment. Jamie described his friends as very intelligent and that he felt inferior to them by not performing at their level.

View of learning and teaching mathematics

Jamie's view of learning mathematics offered both positives and negatives. He enjoyed the external elements of learning mathematics successfully, such as the attention, which fed his motivation to succeed. However, when success was absent, he appeared to feel very low motivation and little interest in mathematics. Jamie mentioned in the pre-study interview that he believed it was important to have challenging work in class, as he thought that this was where all the growth occurs. But at the same time he also believed there was a balance required between that and easier material, that gives students motivation and provides evidence to students that they can do it. Jamie felt that it was crucial that students did not start with failure, as he thought that students will be susceptible to giving up and "there is no way maths can be fun and enjoyable" (Jamie, pre-study interview). Motivation was crucial for him to persevere. There was recognition that failure is a part of learning, but for Jamie, that was easier said than done.

Katherine

Background

Katherine was a 36–40-year-old off-campus student who completed Year 12 advanced mathematics in 1991 in NSW. Katherine's responses to the ATMI survey and her responses during the interview indicated a very high level of self-confidence toward mathematics coupled with a very strong view of fixed intelligence. In fact, Katherine achieved the lowest ITI result in the entire sample, scoring only four out of 40. Her responses during the Critical Moments questionnaire and pre-study interview were consistent with those expected from a person who had a fixed view of intelligence and performance goals.

ITI and learning goals

Katherine's score in the ITI survey was the lowest score of the cohort, indicating she strongly agreed with the notion that an individual's intelligence is fixed and nothing can be done to change it. Many of her responses in the questionnaire and pre-study interview aligned with her fixed view of intelligence. She defined intelligence as the "level of *inherent* [emphasis added] ability or aptitude" (Katherine, ITI survey). In the post-study interview, she added that intelligence is not about how much you understand, but is "your ability to reason and deduct and think critically, and I think that's fairly fixed" (Katherine, post-study interview). Katherine appeared to feel a strong confidence in her intelligence, mentioning that she saw herself as intelligent, and sure she could complete any work at university. She believed that an intelligent person should not have to work hard, implying that if a person was intelligent, it should be easy. Struggle is only evidence that you are not good enough and do not have what it takes to succeed. When asked if everyone can learn mathematics, she mentioned that you are "limited by a *natural* ability" (Katherine, pre-study interview). When offered a choice between being challenged or receiving a good grade, Katherine chose the good grade. Her view on how much intelligence is a result of effort and how much was from ability, she gave effort five per cent and ability 95 per cent. These values were the second lowest in the sample, only ahead of Jamie who gave zero per cent for effort and 100 per cent for ability. To place this in perspective, the average for the people categorised with fixed mindsets was 40 per cent effort and 60 per cent ability.

Like other people who had a fixed view of intelligence, Katherine provided responses to questions that were consistent with performance goals. For example, she said she felt most smart when getting the correct answer. One particularly interesting response was to the question of whether she prefered to learn things that were easy or things that were challenging. She immediately replied with "more challenging" (Katherine, pre-study interview), but then paused and said:

> Actually no, … there's probably a different angle here. 'Easier' I suppose is relative, so when you say problems being easier or harder, I generally say I like them to be harder as in harder for the general population, which means they're not necessarily harder for me. So I like to be tackling things that are more complex but for me not necessarily be that hard. So maybe I should revise my answer and say that not too hard.
>
> (Katherine pre-study interview)

The response demonstrated her ideal situation within a learning environment, which was namely, that the work be challenging for everyone else but relatively simple to her. Katherine did reflect on a situation where mathematics learning was challenging because of how she thought her peers would perceive her if she did not understand. Like Jamie, the presence of friends in the class influenced and inhibited help-seeking behaviours. The advanced class she was in also had a number of her own friends, who according to Katherine were "geniuses". Because of this, she was frightened to ask for help because of "intense fear of my friends' negative opinion" (Katherine, Critical Moments questionnaire).

> My negative experiences with mathematics occurred in my final year of school (Year 12). At this stage I was doing advanced mathematics (3 unit), and tackling difficult concepts. I was in the class with two of my closest friends, who were both mathematical geniuses (I'm not kidding, they both scored TER's of over 99 and went on to study medicine at university). My perspective as a learner … This in fact was of more importance to me than getting the help I needed in class. So when I was stuck on understanding a concept or the process to arrive at a

> particular result, rather than ask for help from the teacher I would sit and worry about whether it was a silly question to ask. I was terrified of looking silly or not smart in front of my friends.
>
> (Katherine, Critical Moments questionnaire)

Noticeably absent in her reflections was any significant role of the teacher, for either her positive and negative moments. She only mentioned the teacher twice in passing. The first was to state that she did not recall any particular influence the teacher had on her, saying "that the teacher was not an important part of the learning experience for me" (Katherine, Critical Moments questionnaire). The other mention was to state that she had great respect for her maths teacher at the time, but wished she had been told by the teacher that it was acceptable to ask questions in class and that the teacher had reassured her that she was "intelligent". Katherine mentioned that "I do now wish that my teacher had taken me aside and let me know it was okay to ask questions, giving me reassurance that I was in fact intelligent and no question would be too silly" (Katherine, Critical Moments questionnaire). For Katherine, learning mathematics was enjoyable when she was successful at it and when it came easily.

Like Jamie, Katherine also described a habit of applying an informal risk assessment in applying effort to a difficult task. She mentioned, "I do a bit of an assessment and I always toss up the relevant cost versus benefit analysis" (Katherine, pre-study interview). This described her tendency to decide on whether a task was worth putting in the effort if there was a significant enough chance of success. Similar to Gretel in Cluster 1, Katherine mentioned she liked to receive immediate feedback to know if she is on the right track and correct any errors she may have made.

Attitude toward mathematics

Katherine was consistent in her responses about her positive attitude toward mathematics. In fact, it was almost a reverence. She seemed to value and enjoy mathematics, and asserted a very high level of self-confidence with the subject. When asked if mathematics was a food, what would it be and why, Katherine described mathematics as a "masterpiece of fine dining. All precision, delicacy, surprising flavours, lovely relationships between the elements of the dish" (Katherine, Critical Moments questionnaire). She described her relationship by saying "it's just part of everyday life, I really enjoy maths, I enjoy helping my children with maths. Yeah I don't sort of have any of these issues about maths." (Katherine, pre-study interview).

Her reflection in the Critical Moments questionnaire of the positive experiences did not seem to involve either her teachers or the content. When asked to consider positive critical moments in relation to learning mathematics, she only mentioned the use of Cuisenaire rods (wooden bars of different lengths and painted different colours) she used in early primary school.

Cluster 3

Cluster 3 participants were grouped by a common negative attitude toward mathematics and an emergent view of intelligence. Based on their survey responses, the characteristics of people in this cluster included not enjoying mathematics and feeling low motivation and self-confidence toward mathematics. Coupled with these characteristics is the belief that intelligence is not fixed, but rather something that can be built and improved upon through effort, learning and time.

Alicia

Background

Alicia was an on-campus student aged 18–19 who completed lower-level mathematics in NSW in 2009. Alicia's responses to the interview and questionnaire responses were largely consistent with her ATMI and ITI scores and matched expectations with the literature. She did provide evidence that matches that of a person with mastery-learning goals, but this was tempered by her relatively negative attitude toward mathematics. Alicia did appear to like mathematics and see its value, but was frightened of its difficulty and previous experiences that were frustrating and embarrassing.

ITI and learning goals

Alicia's language indicated an emergent view of intelligence, which concurred with her high ITI survey score. This was demonstrated while reflecting on the KenKen activity, where Alicia described her frustration in struggling with the harder task, while acknowledging that it was something she could learn more about and get better at over time. The key term in the following quote was her use of the word "yet", which suggested a process and growth mindset.

> I kind of felt frustrated. I felt like I should be able to do this because it's my … it's probably more aimed at my age and stage but I'm probably not there *yet* [emphasis added]. So it's kind of hard. It's very hard when you're not there.
>
> (Alicia interview)

Unlike some of the previous key informants, who when asked if they considered giving up the difficult KenKen task said "no", Alicia also said "no" but provided a rationale. She stated that it was important to keep going when you met challenge, because otherwise you would never know what you are capable of and if you do fail, there is always help available to overcome it. On two different occasions in the pre-study interview, Alicia mentioned these ideas of persevering when meeting challenge and discovering where your development is currently: first, when talking about the challenging KenKens, and secondly when imaging doing a difficult mathematical task.

> … if you stop then you never know if you're going to achieve it or not, so you might as well just keep going and if you get the answers wrong, then someone tells you how to do it.
>
> (Alicia, pre-study interview)

> … why give up when you don't know? So you might as well just do it and if you get it correct, then you've achieved something. But if you're going – if you do make mistakes, there's always someone there who's going to be like, 'okay, this is what you did wrong and this is what you need to do'. So you might as well keep going.
>
> (Alicia, pre-study interview)

This emergent mindset and acceptance of failure was in the context of Alicia struggling with mathematics for most of her schooling. Alicia was diagnosed with a receptive language comprehension difficulty when she was younger and described her comprehension as "never going to be strong". She believed this may have factored into her ability to learn mathematics more deeply. Nevertheless, Alicia recalled achieving a mark of approximately 80 per cent in her Year 12 mathematics. Instead of implying it was simple, Alicia was very direct in how difficult she found mathematics and the large amount of effort and help that was needed to obtain that grade. Alicia very much valued the teacher's feedback and general assistance. As well as this, she also received tutoring. She felt more successful when the mathematics became level-based (general, middle and advanced) as she felt it was more appropriate to her abilities. Even with the help, Alicia saw that she still had to work very hard to achieve her mark of 80. When asked if she felt like she had to work hard for her success in mathematics, Alicia replied:

> Yes, I did. I really had to. I had to go to tutoring and get extra help after school and thought I had to concentrate more on my maths than any other ones [subjects].
>
> (Alicia, pre-study interview)

When asked when she felt smart, Alicia initially said it was when she could answer a question that no one else could, which would be a response expected from a person with a fixed view of intelligence. However, she then clarified by saying it is when she can explain something to someone else really well. She feels smart "if you really understand it".

Reflecting on a significant positive moment in her mathematics learning experience, Alicia regaled about the time when she developed her skills and understanding enough to work independently of the teacher and tutors. It was this achievement that she chose as her most positive moment, more than obtaining the 80 per cent mark.

> My perspective of being the learner completely changed when I actually understood the content and could complete homework tasks by myself without the need of scaffolding from the teacher or an external tutor. This was the most positive moment of my maths learning experience.
>
> (Alicia, Critical Moments)

When asked if she would give challenging work to her students, unlike the key informants with performance learning goals, Alicia did not respond with an immediate "yes". Rather she gave a more nuanced answer. She said that it really depended on the student as to the amount of challenge to provide them. Her goal was to avoid placing unnecessary anxiety and concern on students by providing work that was not appropriate to the student. Through some sort of assessment, Alicia would cater to the different levels of student ability in her class. In other words, her response identified the wide variety of abilities of students that teachers need to cater for in their classroom. Probing further into this, the researcher asked if she would then provide easier work that the students will get correct. Alicia said “yes, to start off with”. Her reason for this is to avoid breaking the student's self-confidence with experiencing a failure too early in the learning. She thought that providing work that they would get correct would build their self-confidence, creating resilience for when the more challenging work was presented.

> You’re building up their confidence. If you give them something that they’re going to get wrong the first time, then they’re going to think, ‘oh, I got the first question wrong, I’m going to get everything wrong’.
>
> (Alicia, pre-study interview)

She was asked how she would deal with students in her class failing at tasks she provided to them, to which she gave a response that focused on the flexible use of teaching methods. She said that “if they kept getting it wrong, I would have to reflect on how I’m teaching and change my ways and … ask them to come in at recess and ask them how they learn, how they would like to learn maths” (Alicia, pre-study interview). When considering the level of challenge she preferred when learning mathematics, Alicia’s responses mirrored her own teaching position, where she preferred easier things until she grasped the concept, then to move on to something more challenging. When asked why she prefers to learn in this way, she replied:

> I think it's because you're exposed to something new and you don't know what the right or wrong answer is yet so once you do one and you get it correct then you're like, okay, I can do another one just to make sure I have really understood it. But then jumping a few steps ahead it's just too much like it sort of frightens you [to get it wrong].
> (Alicia, pre-study interview)

Alicia's mastery goals were interrelated with her attitude toward mathematics, which was classified as negative.

Attitude toward mathematics

Alicia's score on the ATMI survey was low which indicated a negative attitude toward mathematics. Her pre-study interview responses appeared to suggest that she was not hostile toward mathematics, or defeated by it, but rather, frustrated and embarrassed by a number of occasions in her previous learning experiences. These feelings were in connection with her ability and challenges, rather than outside factors like teachers. In fact, her recollection of her relationships with teachers was very positive. The issue was more personal and permanent. The following quotes came from her reflections in her Critical Moments questionnaire.

> I never really had any negative moments with teachers or tutors as they were so supportive and they were able to help me progress to the next stage or step. This is an excellent point here as it shows that I had positive learning experiences due to my teachers and tutors.
> (Alicia, Critical Moments)

> My perspective of myself with maths was low self-esteem and low academic levels of mathematics. I was always frustrated with myself because I could not understand

> mathematical concepts and I was embarrassed to do maths due to the fact I could not do it.
>
> (Alicia, Critical Moments questionnaire)

When presented with the challenging KenKen puzzle, she said that she did not feel scared but concerned she would not be able to finish. She described her feelings as frustrated and embarrassed, because she thought she should be able to complete the puzzle. She then turned this into a positive aspect by mentioning that these feelings she felt would help her become a better teacher. Having gone through these feelings herself, the experiences would allow her to empathise with her students.

> If I go into a classroom and one of my kids is embarrassed not finishing their work I would know – I will be empathetic because I know how that feels, so I can probably handle it better than a teacher who would be able to finish that work.
>
> (Alicia, pre-study interview)

Overall, Alicia's evidence in her Critical Moments questionnaire and pre-study interview was consistent with her survey scores, which indicated an emergent view of intelligence and a negative attitude toward mathematics. Despite the latter quality, she viewed learning as a journey where it is possible to improve significantly.

Sienna

Background

Sienna was an on-campus student aged 20–25, who completed the lower-level Year 12 mathematics in 2008. Like her cluster partner Alicia, Sienna was grouped in Cluster 3 due to her relatively negative attitude toward mathematics and emergent view of intelligence.

ITI and learning goals

Sienna's survey score indicated a very strong emergent view of intelligence, implying that she believed a person's intelligence could grow significantly with effort, learning and time. Despite this, there were many responses given during the pre-study interview that were not expected from a person with this belief, but rather from a person with a fixed view of intelligence and performance goals.

It appeared that Sienna had a number of experiences of significance during her schooling, which greatly impacted on her response to challenge and her understanding of the meaning of failure. In Sienna's pre-study interview and Critical Moments questionnaire, her most recent experiences of mathematics occurred at a large, private school. Sienna mentioned that in Year 3, she moved from a very small, rural school to a large, private school. During this decade of schooling, a number of her teachers appeared to her to have strong goals that focused on performance, rather than learning. Both at the private school and at home, Sienna felt expectations were to succeed. She felt both her teachers and family believed she had to get "it" right.

> My family and school background making everything about 'you have to get it right' and you have to try for 100 per cent, school and home.
>
> (Sienna, pre-study interview)

This placed a lot of pressure on Sienna who began to feel frightened to try in case she got things wrong. Sienna also believed that her teachers would stop helping if you did not reach a certain standard of performance, believing her teachers thought it not to be worth their effort trying to teach her. Failure was not acceptable at the school and teachers either scolded her for getting it wrong, or made the work painfully easy by providing all the answers so you could not fail.

> The general attitude of the many teachers I had for mathematics was that if you were not able to obtain 100%, then you were not worth teaching.
>
> (Sienna, Critical Moments questionnaire)

> It was just very different to being in a big private school in your own class with a teacher who was – I found them – most of my teachers were very judgemental and very 'you can't do it, well I'm not going to bother'. Which made me just give up on it, can't do it.
>
> (Sienna, pre-study interview)

> In Year 11 and 12, I had a teacher who also made you work from the textbook but on top of this, would give you the answers to class tests before the test day.
>
> (Sienna, Critical Moments questionnaire)

In contrast, Sienna viewed herself as trying to achieve, but was not able to meet the standard set by the teachers. Her inability to achieve highly enough made her think that the teachers believed she "wasn't listening, wasn't paying attention, wasn't trying because I wasn't doing well. But I felt that I was trying" (Sienna, pre-study interview).

During the pre-study interview, she was asked when she felt most smart. Her reply was when she was able to make sense of something and understand why you are doing it, which usually happens when something is practical. This very rarely occurred during her private schooling, so in that sense, she had rarely experienced herself as smart in mathematics lessons. Sienna described herself as "a practical, hands-on learner" and the way she was taught mathematics was theory and in an overly independent manner.

Sienna's emergent view of intelligence was clearly articulated during the pre-study interview when asked if she believed that there were people who could do mathematics and those who cannot. Her view was that there are people for whom mathematics simply "clicks", making them more able than others. But at the same time, for those people who struggle, Sienna believed if they worked hard they could work things out just as well. Just because some people have the ability to do some things, does not mean that other people cannot; it is just that it is not as easy.

Besides Sienna's ITI score, there was little other evidence to confirm a connection between her strong belief in an emergent intelligence and a person with mastery goals. In fact, her responses were consistently those expected from a person with performance goals. This was particularly evident when talking about challenge and failure.

Sienna was asked if she preferred things that are easy to learn or hard to learn. Her response was "easy", because she liked to be able to conquer it and know that she has got it right. At the same time, she accepted that not everything could be made easy. She went on to explain that she does not like challenge in general, mainly due to failing in front of others and their consequential perception of her.

> I don't like anything hard full-stop. I don't care if everyone else's finding it hard, I just don't like the idea. I think it's the idea of not being able to do it and failing and everyone thinking I'm dumb, that sort of idea.
> (Sienna, pre-study interview)

Like Alicia, who is in the same cluster, Sienna believed that she would only provide challenging work to the students who she saw as needing it. For the other students, she said she preferred to give them things that they can conquer, making them "feel good, instead of challenging them all the time" (Sienna, pre-study interview). Sienna had a strong sense that challenge and its inherent risk of failure was in direct conflict with a sense of “feeling good”. In order to manage this in the classroom, she intended providing work in slow steps, building up to harder work so the students felt successful.

Attitude toward mathematics

Sienna’s attitude toward mathematics was clearly evident and consistent in the pre-study interview and Critical Moments questionnaire. She appeared to enjoy mathematics in her early schooling from Kindergarten to Year 2, but increasingly disliked it from then onwards. During those first years at school, while Sienna attended the small, rural school, she had the same teacher. She described this teacher as “very patient and used mathematics in very practical ways” (Sienna, Critical Moments questionnaire) who provided many mathematical games and activities instead of worksheets and repetition. She added a number of aspects that she also enjoyed and found helpful, making them positive experiences. These included many hands-on, practical experiences and group work, where students would help each other. Assistance came from students in higher grades as a consequence of the smallness of the classes and the necessity for composite classrooms (children from different grades in a single class). In Year 2, she recalled a practical activity that involved creating two-dimensional shapes using straws and pipe-cleaners, then having to convert them into three-dimensional solids (e.g. a square to a cube). As a learner, she remembered feeling that mathematics was exciting and interesting because the teacher provided these experiences.

Afterwards, she moved to a larger, private school for the rest of her schooling and recalls “not liking anything after that” (Sienna, pre-study interview). The time in this school, which was a vast majority of her schooling, stood in her mind in stark contrast to her previous experiences. While her early mathematics learning featured a teacher whom she felt was patient and engaging, her later teachers were elitist and authoritarian, who used didactic, teacher-centred approaches. She recalled a time in Year 6 where her teacher sat the class on the floor and asked students to recite the times tables from one to twelve, then "scolded" them if they got one wrong or did not say them quickly enough. Another teacher she had from Year 7 to Year 10 simply worked from the textbook, chapter by chapter, which she especially did not like. In Year 11 and 12, her teacher provided the answers to the exams beforehand, so that no one would fail the lower-level mathematics course.

There was significant evidence that confirmed Sienna's negative attitude toward mathematics along with her ATMI survey score. When asked how she felt toward mathematics in general, she replied in language that was permanent and pervasive, such as using words like "never" and "whole".

> I don't particularly like maths. I've never really been able to conquer it, never fully understood much to do with maths and I don't like the whole 'it's easy to fail because you can easily get it wrong'. Well, in my mind I find it that way.
>
> (Sienna, pre-study interview)

Like all the previous participants, Sienna undertook the KenKen activity involving two simple puzzles followed immediately by a very challenging puzzle. She described some level of anxiety and frustration in attempting the larger puzzle, but persevered during the amount of time permitted. Her main concern, which she identified later in the pre-study interview, was related to getting incorrect solutions to questions she perceived as simple. It was not that she felt pressure being put on her by the researcher, but rather simply by the presence of the other person being there and watching. For Sienna, her previous traumatic experiences in mathematical learning environments seemed to have moved her more towards performance goals.

Cluster 4

Cluster 4 were participants whose ATMI and ITI scores indicated a positive attitude toward mathematics and an emergent view of intelligence. People within this cluster believed that anyone could significantly change their intelligence with effort and time, and they valued and enjoyed mathematics, and were motivated to do mathematics and feel self-confident toward mathematics.

Susanna

Background

Susanna was aged 18–19 and completed Year 12 General Mathematics (lower level) in NSW in 2010. Susanna's responses were entirely consistent and demonstrated the importance the role a teacher played in her positive mathematics learning experiences.

ITI and learning goals

Susanna achieved a high score in the ITI survey, especially in comparison to other students in the on-campus cohort. It indicated her strong belief that a person's intelligence has an emergent property, which she reiterated on a number of occasions within the pre-study interview. Along with this emergent belief of intelligence was evidence of mastery goals in the form of valuing challenge, showing resilience to failure, and learning and improvement being a journey.

Susanna enjoyed mathematics from Year 8 onwards, for which she gives credit to her teacher who took her for most of her mathematics from then onwards. She described the characteristics of her teacher and the culture of the classroom in a very positive light. The teacher himself appeared to have strong mastery-learning goals, which Susanna enjoyed. He appeared to value effort, resilience and perseverance, and recognised the importance of time when learning. Susanna felt that he would start slowly rather than rushing through the work like other teachers she had. The teacher would ensure that students were up to date with their work – always checking progress in each lesson. For example, at the start of a lesson, he would ask if there "was anyone who wasn't up to date, anyone who doesn't understand" (Susanna, pre-study interview). When he marked the roll, he would ask who had done their homework. When probed as to what he did when students had not completed their work, Susanna said that he would put a dot next to the name. Rather than handing out punishments, he would insist on them attending a lunchtime study session with him if there were too many dots. Susanna mentioned that her teacher acknowledged how busy his students were, but used these lunchtime sessions as an opportunity to put in the effort to catch up and receive extra help from the teacher – a tutoring session. The lunchtime sessions were so positive and helpful that "he ended up having more than half the class at lunchtime" (Susanna, pre-study interview). Susanna said it was the first time in her learning of mathematics that if she asked for help, she knew she would receive it.

Many of Susanna's responses exhibited mastery-oriented goals, such as valuing challenge and prioritising learning over grades and looking smart. She was asked when she felt smart at mathematics, and she immediately replied, "definitely *not* [emphasis added by Susanna] when I get the answers straightaway!" (Susanna, pre-study interview). Instead, she felt smart when the work was challenging and effort was required to solve the problem. Her belief about mathematics is "not just about learning and studying to get 80% or more in a test, it is about learning the mathematical skills that will help a student succeed in the future" (Susanna, Critical Moments questionnaire). Easy work was considered boring to Susanna, and instead she preferred work that is above her level of ability. She mentioned another reason that she enjoyed mathematics after Year 8 was the challenge. Despite the fact that there was no doubt challenge was present for her in mathematics before Year 8, she seemed to view it differently afterwards because now she was getting the help she needed. She described her time before as never really trying because she could not keep up with the work, and she felt she simply needed more help and time.

Attitude toward mathematics

While Susanna clearly had a positive attitude toward mathematics, this was not always the case. Mathematics was not her favourite subject at school, especially in primary school. She preferred English as she enjoyed creative writing and felt particularly successful at it. In fact, before having her Year 8 teacher, she described the experience of learning mathematics as "hating it" (Susanna, pre-study mathematics) and was afraid of it.

One of the major sources of her dislike during her primary school was the rampant use of worksheets, which she disliked passionately, which overly focused on practice and repetition. Her recollection during this time was that "mathematics learning was about printed sheets of paper" (Susanna, Critical Moments questionnaire) full of calculations and times tables. She would often not attempt them when given for homework, and would instead take them out of her bag when she got home and throw them in the fire. Susanna appeared to view the use of worksheets as an ineffective way of learning and objected to the idea that completing a worksheet indicates learning – "it doesn't work that way" (Susanna, pre-study interview). She made this point in both her Critical Moments questionnaire and the pre-study interview.

Susanna gave an interesting answer to the question, if mathematics was a food, what would it be and why? She viewed mathematics like spaghetti and meatballs. Within her answer, she described the messiness of learning mathematics, the importance of the teacher and itself as a subject, and the different tastes people have for it.

> It is very slippery and can often be difficult to actually get the spaghetti into your mouth. Mathematics can be a slippery thing, hard to learn and difficult to grasp without the right guidance. The second is the meatballs, the variety of flavours you can make or buy could represent the many different types of mathematics that must be learnt throughout schooling. There are many people who really like some flavours and others who are simply disgusted by them. This is similar in mathematics, there are some who enjoy a particular element of the subject and may find it easier to understand than those who dislike those elements. Also, meat is one of the five main food groups which can be a representation of how important

> mathematics can be as one of the staples in our education system.

Overall, Susanna's positive attitude was closely connected to the positivity and mastery orientation of a teacher she had for most of her schooling. Susanna seemed to always be interested in learning, rather than just scoring well on exams. Interestingly, Susanna did not always like mathematics and was not high achieving, but still saw its value and was motivated to undertake it.

Shaun

Background

Shaun was an off-campus student, aged between 36 and 40, who completed the Year 12 middle-level mathematics in NSW in 1991. He considered himself an average student, despite being highest ranking student in his primary school. His ITI and ATMI survey results placed him in Cluster 4, as a person with a positive attitude toward mathematics and an emergent view of intelligence. Shaun's responses to beliefs about intelligence and learning goals were entirely consistent with expectations based on his ITI and ATMI scores.

ITI and learning goals

Shaun rated himself as highly confident in his own intelligence, saying he felt very sure he was be able to learn successfully at university and considered himself intelligent. This view of himself had only been in recent times and was in stark contrast to his earlier life. For most of his life, he did not consider himself smart, in fact calling himself "dumb" (Shaun, pre-study interview). When he was younger, he felt he was not able to achieve, not just in mathematics, but in general. This was one of the reasons why he had not enrolled into university earlier in his life. This was compounded with other situations in his life, such as a challenging relationship with his father – who tended to have a negative outlook and was very difficult to please – and getting divorced. These brought him to a point of reflection and crisis, where he consequently learned to adopt an “I can do it” attitude and so undertook study. At the time of the pre-study interview, he had completed seven units of university study, and attained five distinctions and two high distinctions.

Shaun demonstrated mastery goals during the KenKen activity, as well as provided answers that alluded to seeking challenge and viewing failure as a part of progressing. During the KenKen task, Shaun said that he enjoyed the activity and that he always enjoyed playing with numbers, but felt nervous when asked to complete the larger KenKen due to the time constraint permitted by the interview. When asked if this made him consider giving up, his reply was immediate and adamant, “never, no I don’t give up, no, no, no, no, no, not even a thought” (Shaun, pre-study interview).

Shaun appeared to seek out challenge for the chance to learn. He said that he preferred the more challenging KenKen puzzle and seemed authentic in his response, through the immediacy and conviction with how he said it. In the ITI questionnaire, he listed that he would prefer to undertake problems he would learn a lot from, rather than problems he is likely to get correct. As well, he strongly disagreed to the idea of undertaking a task simply to look smart, or avoiding a task because he would not do well or achieve the best grades. He believed that a more intelligent person was someone who had to work hard at something, rather than someone who did not have to work hard. He believed that intelligence was half effort and half ability. This is in contrast to Jamie and Katherine in Cluster 2 who almost entirely saw intelligence as ability.

Shaun was asked if he would use challenging work in his teaching, and his response was “one thousand per cent!” (Shaun, pre-study interview). His main reason for this was witnessing his own child through their early schooling years. Shaun mentioned that his son was gifted and talented and required challenging work. This led him to form the view that children are “not going to learn, they’re not going to develop, they’re not going to progress” (Shaun, pre-study interview) without challenge. Shaun went on to say that he intended to work with every child to provide challenging work and develop them further. When asked how he would respond to a student who was failing as a consequence of taking on challenging work, despite his best efforts, he thought he would do his best to create an environment where they could learn from the mistake. He replied that he would use his strengths of patience and empathy to meet their needs through scaffolding. He also felt he would pay strong attention to the child, learn as much as he can about them by taking a “listening approach” (Shaun, pre-study interview). This was a more articulated response than many other key informants provided.

Attitude toward mathematics

Shaun said that he had always enjoyed mathematics, playing with numbers, and never felt afraid of it. However, he quickly added that he has never been exceptionally talented at it. Before the pre-study interview, he thought to peruse his high school report cards and was surprised to find that his performance in mathematics progressively declined throughout high school, culminating in failing mathematics in Year 12 by achieving 40 out of 100 as a final mark.

In the Critical Moments questionnaire, he reflected on his most positive experiences in mathematics and felt deeply affected by his Year 8 mathematics teacher. He described her as someone who was warm and approachable, but not accepting of misbehaviour. He described the lessons as quite teacher-directed, with the flow of information mainly going from the teacher to the student, and student participation happening occasionally. But he admired her assertiveness and engaging presentation of the content. As a result, he felt much learning took place.

In contrast, his negative experience was in Year 9 with a young, male teacher who seemed to struggle significantly with classroom management. Shaun remembered the teacher literally screaming at children to behave and Shaun feeling constantly stressed in the classroom. From this experience, Shaun saw the value of a calm, engaging, organised and positive environment in which to learn mathematics.

Shaun mentioned on his own accord how interested he was in the constructivist theory of learning, and understanding of learning as an active process where people build knowledge based on their previous experiences. He said he liked the idea of scaffolding children in their learning as believes it is more meaningful, rather than presenting a procedure and asking the students to use it.

Research question 2: Response to student-centred learning

The following section is presented in two parts. First, data collected during the teaching of the PBL unit reports on the experiences of the students and the researcher as teacher. The main sources of data for this section are the PBL experience questionnaire, anonymous unit evaluations, and forum posts in Moodle. The purpose is to provide an overall context of the semester-long PBL unit, which acts as a lens through which to view the second part of this section, namely the responses of the key informants to their experience of student-centred learning in the form of PBL. Data were gathered from post-study interviews with key informants and their personal responses to the PBL experience questionnaire.

PBL experience

At the conclusion of the teaching period, data was collected that suggested the unit was generally received quite positively. Two separate unit evaluation questionnaires were administered by the university to the on-campus students (n=26 out of 113 – 23%) and off-campus students (n=137 out of 399 – 34.3%), each returning a score 4.2 out of 5 as an overall rating. However, it was not without significant issues related to the implementation of PBL. These were mostly experienced with the off-campus cohort and are described in detail in the following section. The three-circle framework of Lappan and Theule-Lubienski (1992) is used to structure the reporting using the three domains of knowledge: pedagogy, content and student.

Pedagogy

Teaching mathematics education using a PBL approach is a form of student-centred learning, which involves the teacher becoming a facilitator and flexibly responding to the needs of students throughout the learning process. Consequently, PBL insists on the use of small groups, which was challenging as it involved constant monitoring, and was compounded by the sheer size of the cohorts. The final numbers were n=113 on-campus and n=399 off-campus students. Another lecturer was available and assisted in all aspects of the teaching and administration of both the on-campus and off-campus units. These parts were team-taught by both lecturers, and it included helping design the unit, being present at all lectures and tutorials, contributing online and answering student queries. From a teaching perspective, it was critical to have another lecturer to help reduce the workload, but it was still challenging. To provide a comparison, it is common for medicine to have one tutor for every eight students, whereas this unit had two lecturers for the entire on- and off-campus cohorts. Even with the assistance of an extra lecturer, the workload was still significant enough to impact on the quality of the unit, especially in the area of prompt feedback and support. This was particularly pronounced for off-campus students, where there were over 660 students at the beginning of the unit, and 90 small online groups. It became difficult to provide focused feedback to groups and to view student contributions in their wikis, as well as provide sufficient support to students who were finding navigating and learning through the new online environment challenging.

The comments made in the unit evaluation from off-campus students confirmed the researcher's own concerns about the lack of timely feedback. The following quotes are a sample of many comments made in the off-campus unit evaluation.

> Feedback on work submitted to the wiki's on the weekly activities/scenarios. I wouldn't expect individual feedback, but more timely feedback than giving it all at the end of the unit, and just before the exam. It's like flying blind when you don't know if the work you are doing is even halfway correct.
>
> (Off-campus unit evaluation)

> Feedback on group work was sparse. I have a friend who did the unit on-campus and felt that the support the internal students received was great.
>
> (Off-campus unit evaluation)

> NO feedback on weekly activities on wiki – just discussions in groups of 6 (in my group 2) about activities – no idea if on the right track or not. Mid semester opened wikis but found many groups had not contributed. Only in week 13 were there responses posted by lecturers re best answers to PBL situations/activities.
>
> (Off-campus unit evaluation)

> With the large number of external students, Marty and Brenda were unable to provide feedback to each of the ‘groups’ which left the possibility of going off-track uncorrected.
>
> (Off-campus unit evaluation)

> I received constructive feedback on my work, because if I wrote a direct question on the forum of course it was answered but my actual work on the wikis which I really needed the feedback on I received nothing and I had group that offered no help as well so I gave up doing the activities which is where I would’ve learnt the outcomes better. But with no support or feedback it was useless.
>
> (Off-campus unit evaluation)

Further feedback from the off-campus students described their need for greater guidance and explanation about PBL. When asked “What aspects of the unit are most in need of improvement?”, many responses provided from both the on-campus and off-campus unit evaluations related to the need for assistance and scaffolding around the learning requirements. These included how to work in groups, study expectations and PBL-specific characteristics like learning targets.

To support the PBL activities, video recordings of the on-campus lectures were provided to students studying off-campus. The content of the lectures contained information that would assist in their working through the PBL scenarios. It was intended to be supplementary to other sources of information, such as readings, but resulted in being one of the most positively received aspects of the unit, shown in the off-campus unit evaluations. This was partly due to the use of video, rather than text. It appeared to create a connection between the lecturers and the students.

> I enjoyed the video lectures. They are much more interesting to listen to and watch, rather than just audio. It makes a difference being able to see what the lecturer is explaining and referring to when they say ‘look at this’.
> (Off-campus unit evaluation)

> The video lectures provided very clear instruction, information and motivation.
> (Off-campus unit evaluation)

> The videos of the lectures were informative and engaging as an external student.
> (Off-campus unit evaluation)

Overall, teaching of mathematics education adopting a PBL approach was very challenging and required enormous resources to provide the support to students and lecturers, which still was not enough. It was made particularly difficult with the very large cohort size, combined with the newness of the approach for both the students and teaching staff.

Content

The researcher and teaching colleague created the PBL unit EDME145 using as a guide what was observed in medical PBL curriculums, along with advice from medical PBL tutors and relevant literature. They were unable to find a unit in mathematics education that had used a PBL approach and so it was necessary to create the unit from the very beginning. This mainly involved creating the scenarios that were to be used as the stimulus to learning. While some small scenarios and video vignettes already existed in mathematics education, they were judged by the teaching staff as being insufficient for a PBL scenario, since they did not adequately provide enough complexity and breadth.

The content of the unit was clearly laid out because of the previously established unit outcomes. It was then a task to create scenarios that would help students meet those outcomes. This included creating rich scenarios, lectures and supplementary activities. Lectures were able to be easily adapted to the new unit as the lecturers had already a collection that had been created over previous years. Activities were also able to be brought into the unit from past occasions. It was the scenarios, which were the main feature to drive the learning in a PBL approach, that were the newest and most challenging to create.

The process of conceiving of scenarios was difficult for a number of reasons. First, there was the inexperience of the researcher and colleague in creating PBL scenarios. Secondly, there was a noticeable constraint in the content, as the scenarios had to cover certain mathematical content areas. Lastly, the lack of resources, such as video clips and work samples, made it challenging to create a major scenario. Each of these will now be described further.

First, there was the inexperience of the researcher and colleague in creating rich, contextual PBL scenarios. Even though great efforts were made to learn about scenarios through the literature, watching medical PBL sessions and gathering information about PBL scenarios, it was still challenging to translate it to a mathematics education context because it was new.

It became apparent during the process of creating scenarios that there was a significant constraint in the breadth that was possible. Originally, PBL was designed to teach medicine holistically, which results in scenarios integrating many separate content areas of medicine as a whole. PBL medical courses use scenarios to investigate many broad topics relevant to being a clinician, such as "key social, cultural, legal, ethical, and clinical and community aspects" (Monash University, 2011, para. 8). As an example, a single scenario could integrate content and concepts from anatomy, diseases, medical services, clinical practice, patient-doctor relationships and pharmacology. This holistic approach allows for a broad range of topics to be visited over and over again within scenarios throughout the entire course of the degree. It also allows for sufficient complexity and breadth in content so that each PBL group member can have a different learning target. In this sense, PBL was designed for the teaching of medicine as a whole, not for use in a single unit, such as anatomy. Translating PBL to this study, would have meant that scenarios would have been built around general educational situations with the aim to learn about teaching, not to teach just mathematics education.

Attempting to adopt a PBL approach in a mathematics education unit, rather than education as a whole, narrowed the topics that were able to be drawn upon. While it would be possible to design complex educational scenarios that investigated relevant teaching knowledges, such as subject content, pedagogical issues, student-teacher relationships and educational services, many of these fell outside the scope of the mathematics education unit. This restriction contributed to less complex and integrated scenarios. It also meant that the learning targets students were expected to arrive at were less global and more specific. Consequently, it was very difficult for the students to arrive at them on their own, without significant guidance from the tutor. This proved challenging due to the high student to teacher ratio.

Finally, there was the lack of content resources for the scenarios. For the creation of these PBL problems, the structure and approach mirrored those in medicine. Medical PBL scenarios are designed as a single-patient case, and contain authentic supplementary materials such as X-rays, test results, doctors' letters, and are based on actual real-life cases. While going through the scenario, PBL students use these resources, providing authenticity, richness and reduction in the abstraction of the scenarios. The mathematics education PBL scenarios also sought to mirror this structure by creating single student "cases" that used authentic materials such as video clips, work samples and teacher/school notes. It proved very challenging to find sufficient resources to create adequately complex and fully realised scenarios. While teaching resources existed on the internet, there were not a significant amount of materials that lent themselves to the creation of single-student cases. For example, while there were work samples and video vignettes available on the internet, they were of different students in different grades with different teachers investigating different mathematical content. Consequently, it was necessary to combine work samples and video clips from entirely different places to “pretend” to be a single case, which consequently made the scenarios lack cohesiveness and a clear, intentional narrative.

The EDME145 unit was offered to both on- and off-campus students and as a result technology played a significant role in the communication of students, especially the off-campus cohort. The use of technology was a noticeable challenge during the unit due to its newness to students and staff, and the relative immaturity of the software. There were a number of technologies used in the unit that were unfamiliar to many students, such as wikis, which required time and guidance to use. These technologies included the university’s new online learning platform, Moodle, which contained features such as wikis, forums, surveys, videos, audio files, quizzes, PDFs, spreadsheets and links to external websites. Wikis played an integral role in the PBL unit as a space for students to work on the same document. It turned out to be very low in features, such as being able to work synchronously, and low in usability because of confusing interfaces and design.

When this study was undertaken it coincided with the university’s transition from testing two online learning platforms, Blackboard and Sakai, to a single online learning platform, Moodle. It was the first time the teaching staff had ever seen or used Moodle and so was a completely new environment for the students and teaching staff. In the end, it seemed that there were too many new and unfamiliar technologies in the unit, with varying degrees of quality and useability.

Student

This section looks at the aspects of the unit related to the students' affective response to the experience of the unit. The PBL unit was undertaken in a first-year mathematics education unit, and for many of the students this was not only their first mathematics education unit but also their first semester at university. Consequently, PBL was a significant undertaking. There were a number of assumptions made by the teaching staff that turned out to be problematic, mainly related to skillsets, such as working in groups and working with technology. Despite these setbacks, what was overwhelmingly apparent was the relationships between students and teachers was of vital significance and most likely played a crucial role to the unit still achieving a high satisfaction rating.

EDME145 experienced a significant and unusual amount of attrition in 2011 when the study took place. At its peak the unit had just over 665 students, but in the end finished with only 399 enrolments equating to a 40 per cent attrition rate. This is in comparison to other years where the same unit has had around 15–20% attrition. Besides what has already been mentioned so far in this PBL section, there were also students' impressions. The two main themes that appeared in the unit evaluations were the large workload and the reliance on group work.

While best efforts were made by the researcher and colleague to create the most productive and meaningful PBL curriculum possible, an unintended consequence of trying to provide a complete and rich educational experience was the excessive workload students felt. They were expected to work in groups of eight students on a PBL scenario over a 2-week period, after which it starts again. Along with these were lectures and a small number of mathematical activities that would support them to work through the scenarios. This large workload was especially felt by many off-campus students who considered the volume of work too high, and that the time and effort required to cover the work was excessive. This was compounded by the new technologies mentioned earlier, as well as trying to study how to work within a PBL learning environment. Students felt they were working too much on the unit rather than on learning about mathematics education.

> The workload for this unit was huge, it was very hard to keep up to date and the continual group work was impossible if there were no willing participants in your group wishing to help.
> (Anonymous student, off-campus unit evaluation)

> There was so much to cover in each week.
> (Anonymous student, off-campus unit evaluation)

> There is masses to (sic) much content in this unit.
> (Anonymous student, off-campus unit evaluation)

> There was too much content to get through. I found it very easy to get lost and confused.
> (Anonymous student, off-campus unit evaluation)

Engagement was one of the most significant challenges faced in the unit. A PBL approach is intimately connected with group work, considered a core tenet. Each member is responsible to the rest of the group for their contribution, especially in the role of reporting on their Learning Targets. In this way, a lack of engagement creates a noticeable deficit to the group's effectiveness, knowledge and student affect.

For the on-campus cohort, many students either chose or were unable to complete their work outside of class time, and while this did produce tension between group members, it could be managed to an extent, during tutorials. It was possible to share information and ideas among the group as a whole, thereby somewhat overcoming the lack of a particular group member's input. This lack of engagement seemed to be defused mostly, since no negative feedback relating to the use of groups was given in the unit evaluations, but did impact on the PBL experience. Group members not doing their work was mentioned by some of the key informants in the post-interviews but was negligible compared to the off-campus experience.

For the off-campus cohort, the lack of engagement from group members was extensive and a significant source of stress and anxiety to the group members who did participate. The term "lack of engagement" was seen as not contributing to the online discussions, undertaking group work and otherwise appearing absent to the group. This aspect of the PBL experience featured highly in the unit evaluations for "aspects most in need of improving". Many students shared how this lack of engagement by group members impacted on their experience of the unit and their learning.

> Online group work. Not sure about that one. It seems like a good idea, but if your group isn't interested, then it doesn't work, and you miss out.
>
> (Anonymous student, off-campus unit evaluation)

> It was not fair that some people did not contribute to the group work when this was part of the learning process. Those of us who started and carried the group (e.g. 2 people), we just decided to use our time on other subjects rather than doing detailed work on the activities for posting. We did our own work and didn't post. Why should others get the benefit of our time at our expense?
>
> (Anonymous student, off-campus unit evaluation)

> I found this [group work] to be useless as I had an inactive group. The group work needs to be either compulsory and graded or allow people to form their own groups if they intend to participate.
>
> (Anonymous student, off-campus unit evaluation)

> The wikigroups did not help me in my learning because many of the students did not participate in them, and hence I felt I was not being supported in my learning.
>
> (Anonymous student, off-campus unit evaluation)

Another source of tension for the off-campus students was the asynchronous nature of their study patterns, which was in strong contrast to the on-campus experience where they had synchronous, face-to-face tutorials. This again impacted on the requirements of group work in a PBL approach, where each person contributes and the group relies on each member contributing in a timely manner. The following quotes come from a single Moodle forum thread and serves as a typical example of the comments that were made in Moodle during first half of the semester.

> I'm having no luck. It's Sunday night and I haven't had any luck with input from my group. Helen was having some input but hasn't showed any input for over 1 week. I'm finding it too difficult to do it on my own. Need other input. I'm currently assigned to group 8, but I'm it! Help please…
>
> (Student 1, Moodle forum post, http://moodle.une.edu.au/mod/forum/discuss.php?d=24354)

> [In response to the above post:] Hi, I'm in the same situation. Not much fun. I've just about given up!
>
> (Student 2, Moodle forum post, http://moodle.une.edu.au/mod/forum/discuss.php?d=24354)

> [In response to the above post:] I also feel that this is not an ideal situation, my group’s work gets started each week but then doesn't seem to get finished. I really feel as though I am not learning much and am starting to freak

> out about the assignment because I feel I am in way over
> my head.
>
> (Student 3, Moodle forum post, http://moodle.une.edu.au/mod/forum/discuss.php?d=24354)

Going through this teaching experience revealed the large skillset required by students to learn effectively in a PBL environment. It required students to be skilled at working within a group, managing group dynamics, handling their own study patterns and being self-motivated and self-determining when working towards their individual Learning Targets. The beginning of the on-campus unit was spent helping students learn the skills and knowledge related to working in groups. It included supporting them through the process of setting expectations, assigning roles to group members and explaining the purpose and responsibility of each of those roles. It was also necessary to have a discussion with the students about group management, including communication and deadlines. This added significant time and effort that was not normally necessary when teaching in a non-PBL way, but was crucial due to the heavy reliance on effective group work. The result was a bloated, content-heavy unit, which was challenging for time-poor students.

Withdrawal of group work and PBL

By halfway through the semester, the stress levels for the students, particularly the off-campus students, got to such a high level that it was necessary to consider the removal of group work and the further use of PBL. Other options were considered, such as combining smaller groups into larger groups, and providing greater guidance and scaffolding in the form of video instructions on the use of wikis, and exemplar examples of work, but these proved ineffective at overcoming the earlier experiences, lack of trust in the process and the resulting disengagement and stress. The group approach was so ineffective, such a distraction from the learning and source of frustration and anxiety, that the researcher and colleague finally, halfway through the unit, decided that they would discontinue the use of PBL. The following forum post made by an off-campus student is an example of the stress and feeling of ineffectiveness many students felt at the time.

> Sorry but again I am feeling overwhelmed, I am spending more time trying to find out what I need to do and when and how to do it than I am actually learning! I have not participated in the wiki because I simply do not know what I'm meant to be doing when and what resources I am meant to use for what activity … I can see that it is written down, but there is sooooo much info there that I need help to disseminate it and work through it all. I feel really guilty when I hear people talking about no one else appearing on their wiki's but I can understand why some people haven't appeared … it is a very confusing format when you are off campus and reliant on no information other than what you can find. I don't know how to solve this, I just know that I need more structure and guidance. This is the only subject that I have taken that has stressed me this much … I don't say this as an accusation, but more that I want you to understand that I'm not lazy or a sub standard student usually.
>
> (Student 4, Moodle forum post, http://moodle.une.edu.au/mod/forum/discuss.php?d=17872)

Amazingly, despite the many challenges and adverse experiences of the students, there were still some positives that were revealed at the end of the unit. These included some on-campus students enjoying group work, appreciating the scenarios and the authentic supplementary materials and finally, having benefited from the wide range of skills needed for PBL. But in the end, the most common positive aspect of the unit reflected in the unit evaluations was the positive relationship between the students and lecturers. Despite all of the challenges and stress experienced by many students, a significant number still found the unit very beneficial with the most valuable part of their experience influenced by the role of teacher. This was seen in comments mentioning use of video lectures, teachers' enthusiasm, clear explanations, creating interest for students and being approachable. The following quotes are samples of comments provided in the unit evaluation questionnaire and provide an illustration of the experience.

> Marty and Brenda are so passionate and it really makes them GREAT teachers. Even during the lectures, it didn't feel like we were being 'lectured' it felt like we were being taught. I have learnt so much about mathematics not only for my future students, but also for myself. Thank you so much.
>
> (Off-campus student, unit evaluation questionnaire)

> This unit provided a view of mathematics in terms of the teaching of it. There was a lot of information provided for each topic and the method of delivering the topics made it easy to understand.
>
> (Off-campus student, unit evaluation questionnaire)

> The video lectures were very informing and interesting. This is the first unit I have completed that has provided video lectures.
>
> (Off-campus student, unit evaluation questionnaire)

> The variety of topics covered and the dynamic way we were taught was a highlight for me. I loved that Marty and Brenda could laugh at themselves and include extra pieces that made me laugh helped me to feel more comfortable studying this topic. The content was very helpful in both teaching me what I missed at school and the way I will teach it to my future students. Brilliant unit! I also loved that I could see the lectures and that I had the slides for later revision!
>
> (Off-campus student, unit evaluation questionnaire)

> The teachers! They are some of the best teachers i've ever had (and this is my third degree). They were very encouraging, engaging, patient, and they made not only this course fun, but showed us how maths can be really interesting and fun for all.
>
> (Off-campus student, unit evaluation questionnaire)

> The way the lecturers worked together, and communicated with passion and clarity.
>
> (Off-campus student, unit evaluation questionnaire)

> The lectures in this unit were amazing and really interactive. Marty and Brenda provided really interesting and practical ideas and spoke in terms that were easy to understand and not too confusing. I really enjoyed the lectures and information I received in this unit.
>
> (Off-campus student, unit evaluation questionnaire)

This section has provided the context for the following results. The next part presents the key informants' responses about their experiences during the PBL unit and whether they align with student-centred pedagogies.

Key informants' responses to student-centred learning

This section looks specifically at the key informants' experiences of PBL as a student-centred approach to learning. Initial impressions were gathered in pre-study interviews where they had undertaken PBL for two weeks, as well as other data gathered in the post-interviews and PBL Experience questionnaire at the end of the semester. The qualities that were being investigated were those outlined in the framework proposed by Simon (1994), which utilised a social constructivist paradigm and listed the qualities of a student-centred, social constructivist experience. As a consequence of the turbulent PBL experience, and removal halfway through the semester, these results must be taken tentatively.

Cluster 1 – Fixed view of intelligence/negative attitude to mathematics

Gretel

There were some aspects of student-centred learning that Gretel identified as being meaningful to her learning. These related to the chance to problem-solve a specific context before moving to abstraction, having a level of control to develop concepts and the validity of ideas herself, and the opportunity to communicate with other students. These manifested themselves mostly in two experiences. The first was an activity that made use of base-ten manipulatives and the second was the use of scenarios and video vignettes within PBL.

Gretel thought that EDME145 was a very different unit to any other units she had studied due to the use of PBL. It was the only unit she studied that semester that used group work extensively and real-life scenarios. The use of videos and working through specific student examples made her feel she had to consider many aspects of the learning, such as how a child was doing mathematics and why they made the choices they did. Interestingly, when considering the PBL scenarios, Gretel did not like the extended nature of the PBL scenarios for two reasons. First, there was the sense of not getting as much done or experiencing the feeling of satisfaction on finishing due to the time it took to work through the task, and the second reason related to having to do work outside of class time.

In the post-study interview, Gretel mentioned she enjoyed learning within a group as it offered an opportunity to talk with others, but with qualifications. When groups were assigned by the teaching staff to undertake the PBL scenarios, she noted that there were difficulties with group members not meeting their responsibilities, such as one girl who was away often, while at the same time, other members simply did not contribute as much. In the second half of the semester, they were allowed to create their own groups which seemed to her to work more effectively.

Another aspect Gretel seemed to prefer was the autonomy of independent study and the role of the teacher being a facilitator rather than lecturer. There were times where she was anxious and frustrated by the work, but felt that the autonomy and responsibility for her own learning created an environment where it was "easier to stay calm" (Gretel, post-interview).

Leanne

Leanne completed the PBL Experience questionnaire but was unable to make herself available for a post-interview. She felt she had a very positive response to the unit and valued the discussion between students.

> I love it. I think it is excellent. To be so interactive and that online and to talk to everybody and just to air everything, you get different perspectives on problems is fantastic, I really like it.
>
> (Leanne, pre-study interview)

Like Gretel, Leanne also valued the practical examples of PBL, which involved students working through specific contexts that were then used to generate abstract ideas of teaching mathematics. As this was only in the first two weeks of the semester, it is unknown how she felt over the course of the unit.

Cluster 2 – Fixed view of intelligence/positive attitude to mathematics

Jamie

Jamie also completed the PBL Experience questionnaire, but was very brief in his responses, and was also unable to make himself available for a post-study interview. Overall, Jamie thought the unit provided him with various strategies to implement into his classroom teaching. Specifically, he identified the use of concrete materials before moving onto abstraction as having significance to him.

Katherine

Katherine was not able to complete the PBL Experience questionnaire but was able to give an insightful and frank post-study interview. This was her first semester of study, and EDME145 was one of two units she was taking at the time. Her overall experience was not positive to PBL and many of these qualities aligned with a student-centred approach. In fact, there were a number of aspects where she mentioned she would have preferred to have had a more teacher-centred learning environment.

Katherine was able to recall many activities that were in the unit, including all of the PBL scenarios and activities within the first half of the unit. Of these, the two activities she felt were the most useful, practical and helpful for learning about teaching were the two PBL scenarios – early counting and four operations – but said they were the activities she "learnt the least from" (Katherine, post-study interview). While she liked the idea of the scenarios as an activity and the significant use of videos, she found herself feeling most confronted by the PBL approach and "extremely frustrated" (Katherine, post-study interview). It seemed that the lack of direction was the source of the frustration, mentioning that she did not know what resources to use and not having all the information upfront. She said she found the whole “discovery-learning thing” (Katherine, post-study interview) very frustrating. Katherine said that she felt like she did not have time to go and find out what she needed to know, and would have preferred to be told what to know and learn through application. She wanted to “know where to find stuff and what to expect” (Katherine, post-study interview). She expanded on this to offer being given Learning Targets upfront, rather than the more open, autonomous approach where they were assisted by the lecturer to develop their own. She disliked this aspect so much that she actually skipped it.

> I really don’t feel that with the scenarios, that I had enough information that I needed upfront. So when you had it set out that you had to specify learning objectives, I completely skipped that step. I would rather have learning objective set and say these [are] what you are going to know as a teacher to be able to perform these things. So the learning objectives are the things you have to understand like understand what the syllabus is, CMIT, and all that stuff. I would rather that these be set and say, ‘these are the things you need to know. Go away and research them’, rather than go through that whole process of trying to find out.
>
> (Katherine, post-study interview)

When asked if, despite her concerns with the scenarios, she was able to get from it what she felt like she needed, she answered, “not really” (Katherine, post-study interview). On further investigation, it was difficult to determine what it was that she felt that she missed or required. She said she still would not be comfortable assessing where a child is at in their development. Her concern is that she would miss something important and not do a thorough enough job.

She felt strongly that her goal was to learn the work of the unit rather than simply get through the activities. She viewed the mathematics as “pretty straightforward" (Katherine, post-study interview), so wanted to learn about pedagogy, and "needed that information" (Katherine, post-study interview). When asked about her thoughts on receiving 69 out of 100 for her assignment, she said she felt quite disappointed. The assignment involved writing a report based on a video of a child being assessed in early numeracy. She thought she did better than that but "must have been quite off-track" (Katherine, post-study interview), however she said she did enjoy the assignment, which the PBL scenarios were designed to support.

Cluster 3 – Emergent view of intelligence/negative attitude to mathematics

Alicia

Alicia was not able to complete the PBL Experience questionnaire but managed to be interviewed at the post-study phase. Her responses evidenced a strong affiliation with many student-centred learning qualities, such as working on specific problems to develop abstract ideas, having concepts discussed by students in their own language rather than the teacher's, and the opportunity to communicate with other students.

Alicia gave very positive comments about the use of PBL. Before enrolling in the unit, she felt very anxious and wondered if the unit was going to be like mathematics at school, which was not what she wanted. Instead, she wished it to be an education unit where the focus was not only mathematics content knowledge, but also pedagogy. Consequently, she enjoyed the broad nature of the scenarios and how they covered a number of areas beyond the mathematics content, such as assessment and services available to support teachers.

> I really liked doing that problem-based learning, because it actually covers everything. Like, that is what you'll be doing as a teacher, is analyse everything and it was really good to do that on the first day.
>
> (Alicia, post-study interview)

Within the unit, PBL scenarios and many of the supplementary activities were not able to be solved in a short time, and instead, often required an extended amount of time to solve. This appealed to Alicia as she preferred the exploration and development of new ideas as it required more effort and offered a serious opportunity to "build up a lot of strategies and knowledge from just one question" (Alicia, post-study interview).

Alicia did find the group work challenging at times. She preferred the teacher-assigned grouping instead of the self-assigned groups. Some of the reasons included her knowing that she would not work as effectively with her friends as she would with others, and that working with acquaintances adds to the realism of the scenarios, where at school, you will most likely be working with people who you do not know as friends. Alicia was asked if facing a scenario on the first day of the unit was also challenging. Her response was that it was not because she and her group were able to bring their own experiences to the scenario, "I like how we can relate ourselves to the maths scenarios" (Alicia, post-study interview).

Alicia appreciated the autonomy of having control of her learning. She felt she had to take responsibility for finding the information herself and then know when to ask others for help. She believed this was important as she wanted the students that she will teach to follow her example.

> I don’t want to rely on you guys all the time, because then when I go out into the big, wide world, […] I need to do this, and then if I do those practices, it’ll pass on to my students. So if I’m dependent, then they’ll [her students] become dependent on me. So I thought it was really good that you created that so I learned to be like that when I have my own class. So I don’t give the answer straight away, they’ll be able to wait and figure it out.
>
> (Alicia, post-study interview)

At the end of semester, Alicia said she felt more confident toward mathematics learning by the end of the trimester, in part due to her assignment result (70%), but also the focus on working through scenarios from the perspective of a mathematics teacher. She felt the experience of the unit helped her learn strategies that she would be able to use to relate to her students. For her, it was most important to learn how to teach, not just to learn the mathematics content. She strongly felt “more hands-on is the way to go. Give them as much practical time as possible” (Alicia, post-study interview). Alicia noticed the difference in pedagogy of the unit compared to school, recalling that at school:

> … you sat down, you listened to the teacher, she gave you examples and then you did the textbook. But here, it is like, you do the activity, see how you think of strategies that you can implement in your classroom.
>
> (Alicia, post-study interview)

Alicia found she learned better when working through specific situations where concepts were developed by her and others, and expressed in their own language rather than the teacher’s. The lectures were challenging for her as she felt she struggled to sit still and listen to the lecturer, but in the tutorials she had an opportunity to apply her knowledge in a practical way through the activities. She felt her retention was much better from the scenarios because you could relate to them easily. Compared to other units she had done, Alicia felt the PBL approach was more effective for her as it was a simulation of teaching as it is used in student scenarios and real-life situations.

Sienna

Sienna mentioned a number of aspects that aligned with a student-centred approach, and which she valued from her experience during the unit. These included the freedom to develop ideas and concepts herself and with others, rather than the teacher or textbook, as well as first working on specific problems in context rather than abstract ideas. This also included the importance of the experience of learning from the student's point of view, in understanding learning as a process that involves mistakes and challenge.

She claimed that the most valuable activities she experienced were the PBL scenarios because they were immediately connected to being a teacher. It was important to her to learn and understand what was covered in the scenarios and the assignment, as she felt that the content was closely aligned with what she will be undertaking when she begins teaching. The other supplementary mathematical content tasks, which were not scenario-based and were more focused on mathematics content, were less compelling and she just wanted to move past those activities. She thought it was because they were not as immediately relevant to learning to be a teacher as the scenarios were.

Another aspect Sienna mentioned was the openness of working on things herself rather than being told exactly what needed to be learnt. This process of determining Learning Targets is seen in PBL as a crucial skill to develop, and was guided by the lecturer. She said it allowed her to make connections on her own and determine for herself the parts that are important, and that working things out yourself, "you realised why you need to do it" (Sienna, post-interview). Initially, Sienna felt it was difficult to get used to a less teacher-led approach, but in the end she found that she preferred the increased level of self-determination, where she controlled some of the pace and direction of the learning. She felt active in her own learning and preferred this over a more passive learning process and being "spoon-fed" (Sienna, post-study interview) information. Sienna recognised that this mathematics education unit was quite different to the other education units, that seemed to her to be more teacher-centred. She described that "most of them have been very 'sit down, we're doing this, listen, write, retain that information, spew it back out in an assignment'" (Sienna, post-study interview). In contrast, Sienna valued the opportunity to make connections herself and with the assistance of others in her group and class.

Sienna said that despite valuing the qualities previously mentioned, it did take time to get used to as she was so familiar with learning in a teacher-centred environment. Consequently, Sienna described experiencing a feeling of concern about failing because she, along with the rest of the students, were expected to take more control for their learning. This caused some anxiety because she felt like she could not hide in the same way she felt you could in a teacher-centred environment, where you can "sit there and not do anything if you want" (Sienna, post-study interview), which makes it "easier" (Sienna, post-study interview). Over time, she began to relax, once she realised that the lecturers were accepting of mistakes as a part of the learning.

> [The work] was challenging, but not overwhelming. At first, it was 'scary-challenging' … failing, not doing well, being asked questions and not knowing the answers, but, um, as the unit went on it sort of didn't matter if you got it wrong cause I kinda learnt you guys weren't going to jump up and down and go, 'you're wrong!'
>
> (Sienna, post-study interview)

Sienna also enjoyed the sharing that occurred as a part of the group work in the scenarios where there is a combining of different ideas, but similar to others before, she acknowledged it did cause tensions when group members were failing to meet their responsibilities to the group. Even with these difficulties and challenges, Sienna said she still preferred group work over learning passively in a teacher-centred classroom.

Cluster 4 – Emergent view of intelligence/positive attitude to mathematics

Susanna

Susanna's involvement throughout the unit provided her with valued experiences that often aligned with those from a student-centred perspective. She recognised a lot of differences between the unit and other units she was studying. These included the learning through active involvement and application of new ideas versus simply listening and reading, and the increased control within the learning process. Like Sienna, these features of a student-centred approach initially concerned her, but with time and experience, she came to see the benefits to her learning and the quality of retention.

Susanna completed the PBL Experience questionnaire in which she mentioned that she valued the challenge and autonomy of the PBL approach. She also enjoyed the lack of "spoon feeding" (Susanna, PBL Experience questionnaire), upfront, direct instruction by lecturers, and the practical nature of the scenarios. This allowed her to work at her own pace and recognise how far she had come in her learning on her own efforts. Overall, Susanna had a very positive experience to the student-centred approach of EDME145, but she did have reservations about the use of PBL.

Comparing the PBL unit to other units she had and was studying at university, Susanna said there were many differences, with most of them being favourable. First, the amount of work that was expected to be done. It was the only unit that had work required to be completed in-between classes. In the beginning of the semester, Susanna found it overwhelming and resisted beginning the work because she felt there was so much. It was not the difficulty but rather the volume of work. She eventually started because she knew she had to begin working to succeed in the unit, and felt an obligation to the group to do her part. Susanna eventually found that work was useful and felt like she was learning from her efforts. She came to see the amount of work as reasonable because there is not a great deal of class time, so more work outside those hours is fair to expect.

Susanna said she learnt well in the unit, as it involved very interactive tasks, rather than through the process of being "spoon-fed" information, which she described as "utter crap" (Susanna, post-study interview). She gave the example where in another unit she was studying, the tutor said to the class that we were running out of time so I am just going to give you all the answers, at which she felt very annoyed. She preferred to be offered a challenge and work for her learning rather than just simply be given the answers, saying "it is so much better than being spoon-fed!" (Susanna, post-study interview). Another aspect that appeared to meet Susanna's needs came from something mentioned in the pre-study interview and again in the post-study interview. While at school, she said she benefited from having a teacher that did not rush who provided time to get to know and understand the work. In this unit, the focus was on finding a solution to extended problems which by their nature took time to solve.

Susanna's hesitation with the use of PBL related to being overwhelmed at the beginning of the new approach, along with a feeling of not being ready to get the most from it. Susanna said that the real-world simulation of the scenarios was useful "because you get to see how you have to deal with students", but "I do think it would help a little if we had more information [about PBL learning] before we did that sort of stuff" (Susanna, post-study interview). She suggested going through an example as a class might have helped. Interestingly, the reason she identified this need was because that was how she was always taught. Namely, students are presented with examples and then follow these examples to solve other exercises. Susanna summed this by saying "that is just how I've learnt all through schooling" (Susanna, post-study interview).

Shaun

Shaun described his experience of a student-centred approach as "a very rewarding method of learning" (Shaun, PBL Experience questionnaire). At the beginning of the unit he felt the same as some of the other key informants, having feelings of uncertainty and hesitancy towards a PBL way of learning. He recognised the focus on the higher level of student autonomy and the greater responsibility on his own efforts to learn and become your own "teacher". Overall, he found the most valuable aspects of the unit to be his gradual discovery of concepts through exploration, and the scaffolding provided by the lecturers, which helped him be guided through the tasks.

Shaun was able to easily recall activities that were done in the unit, with the first ones being the PBL scenarios and collections of videos, called the Video Vault, showcasing students' strategies while undertaking number problems. The use of the videos in both the scenarios and Video Vault made a significant difference to his learning as he was able to make the connection between the theories he had read about in the readings and listened to in the lectures, and what he was witnessing in the videos.

> Your approach … your balance of theoretical but making it practical, and linking it to personal stories that then relate back to theoretical was a great … I found it worked.
> (Shaun, post-study interview)

He also mentioned the benefits of alternative methods to solving problems with fractions (e.g. fraction walls) and multiplication (e.g. array method) alongside the more traditional methods, such as the multiplication algorithm. He said that the advice that he would give to future mathematics teacher education students would be to be open to new strategies and ways of learning. The way you have learnt in the past may not have been the best way.

One of the most significant impacts on him, related to the learning and teaching of mathematics, was the concrete-pictorial-abstract (CPA) representations used in mathematics. He mentioned this unsolicitedly in both the PBL Experience questionnaire and the post-study interview. For him, the significance came from the connection he saw in its potential to scaffold student learning. For him, it was the "stand out" (Shaun, post-study interview) aspect of the unit because of its effectiveness in his own learning in the unit and the stark absence of it in his own learning at school. He made the comments in the context of his learning in the 1980s at school, where he felt it largely relied on teacher-centred instruction, with rote learning without understanding.

Shaun felt he learned best when he is able to have a relationship with his teachers. He identified the use of video clips and personal stories by the researcher/lecturer as a key aspect in helping him relate to the unit's material but also create a connection with the lecturer. Other units had more mundane content and less personal connection with students, and were difficult to engage in and be motivated to learn.

While Shaun could see the potential with group work in the PBL approach, he quickly identified some major issues that come with it, particularly for off-campus study. Although Shaun was very active and open in trying to get his group working, such as posting on Moodle forums and contributing in his group's wiki, he recognised that many other groups did not have "leaders" and were doomed to be unsuccessful. He felt sorry for the people who did contribute but were not supported by other group members who did not engage. Overall, he did not find group work useful or worthwhile.

Research question 3: Change in attitude and mindset

The following section relates to the third and final research question, which briefly investigated the changes, if any, key informants experienced over the duration of the unit. The main sources of data were the post-study ATMI and ITI surveys, the PBL Experience questionnaire and the post-study interviews.

Cluster 1

Gretel

Gretel expressed that she felt as though changes had occurred to her during the unit, and this was corroborated by various sources of data. It appeared that these changes were genuine, showing modest improvements in both attitude toward mathematics and her implicit theory of intelligence.

She expressed in the post-study interview that she felt that her attitude had become more positive, which was confirmed in her post-study ATMI score which went from 55 to 89 (out of 200). The factor that accounted for the most change was self-confidence, where she increased by more than a point on average for each of those items in the ATMI survey. She achieved a score of 70 out of 100 for this assignment, and was quite surprised and excited by the mark, saying that it made her feel slightly more confident. She qualified the feeling though, saying it was a “bit of a fluke” because she said she was “not a maths person” (Gretel, post-study interview). Gretel said that at the beginning of the unit, she “didn’t have the most positive outlook on maths. Still don’t really, but it has improved” (Gretel, post-study interview).

During the pre-study interview, Gretel described how nervous she felt at the beginning of the unit, having to study a subject she had never really enjoyed. After a few weeks, she was surprised by how much she was enjoying it at that point and mentioned that it became her favourite tutorial. Despite these changes, there was still a definitive negative attitude apparent. She still did not appear to be enthusiastic when considering doing another mathematics education unit later in her course. Her brief responses in the PBL Experience questionnaire said she felt "more confident now about teaching mathematics, however I still do not enjoy it" (Gretel, PBL Experience questionnaire).

In terms of change in her implicit theory of intelligence and learning goals, Gretel stated that she did find learning about learning goals during the unit beneficial, describing it as "positive" (Gretel, post-study interview) and had changed her perspective on learning mathematics. Her post-study ITI survey score confirmed this slight change with a score of 22, compared to 16 at the pre-study phase. She felt that she had made some progress in her perspective on learning.

> I don't have to get everything right all the time and that students need to take there (sic) time when learning maths.
> (Gretel, PBL Experience questionnaire)

She also said that achieving relatively well in the assignment made her think that improving at mathematics was possible. But at the same time, there was still evidence of her strong performance learning goals within the unit. Her main goal was simply to pass the unit and move on.

> With teaching, I feel like you have to know what you're doing because you're going out into the workforce. It is important to learn, but at the same time, to be honest, you are like … 'ok, I just need to get through this'.
>
> (Gretel, post-study interview)

Overall, Gretel showed some change in both her attitude toward mathematics and implicit theory of intelligence. These seemed delicate in nature but were able to be corroborated across various sources of data.

Leanne

Leanne was able to provide brief responses to the PBL Experience questionnaire but was not available for a post-study interview. She felt that she did experience some change over the semester, mainly in relation to her attitude in the form of her feelings of fear and anxiety toward mathematics.

> I'm not as scared as I was in the beginning when faced with mathematics. I can do it [but] will just take me longer sometimes to get there.
>
> (Leanne, PBL Experience questionnaire)

While she did express change in her belief about her potential to learn mathematics, there was not sufficient data to make conclusions.

Cluster 2

Jamie

In the PBL Experience questionnaire, Jamie stated that he believed that his feelings and beliefs toward mathematics did not change over the course of the unit, but acknowledged a realisation he had about performance goals in mathematics and to be aware of these when teaching students.

Katherine

Katherine did not generally exhibit any changes in terms of attitude toward mathematics, which was already relatively positive, or her implicit theory of intelligence, which was particularly fixed. She was not able to complete the PBL Experience questionnaire but could participate in a post-study interview.

Katherine mentioned that she still felt very positive toward mathematics, appreciating the logical nature of the subject. With regard to her emotions, she said she never felt anxious or concerned with the mathematics, due to her high level of achievement at school and the fact that this was primary school level. Her post-ATMI score was 156, which was fairly stable compared to her pre-ATMI score of 161 (out of 200). She did, however, mention she still felt "worried" about not knowing enough about teaching, despite completing the unit. She placed the cause of this on the use of PBL and her experiences in the first term. She much preferred to be directed on what to learn and felt that PBL was too unstructured for her. Consequently, it did not make her feel as though she had made much progress in learning how to teach mathematics and instead, still felt anxious and concerned she was not ready for the classroom. Katherine felt that the qualities of a good mathematics teacher were to make the work relevant to the students, be able to make it fun, make it easy to understand and make it enjoyable. Kids learn through play and enjoyment. She suggested giving students who are achieving more to do, including challenging work, but slightly hesitated when she said it.

With regard to changes in her belief about intelligence being fixed or emergent, Katherine continued her strong belief that intelligence is fixed, saying she believed it at the beginning of the unit and still believed at the end. Her post-ITI survey score was 10, which was over two times as much as her pre-IT score of

4 (out of 40), but still very much in the fixed-mindset range. She did seem to make a distinction between a person's intelligence and their knowledge and skills, with the latter not being fixed. She defined intelligence as the ability to reason, deduct and think critically, and it is this part of a person that is "fairly fixed" and limited. In other words, a person can learn lots of things, but it does not change their higher-order thinking skills. In the interview, she mentioned that "a person can greatly increase their understanding and knowledge and skills, I do not think that is related to intelligence" (Katherine, post-study interview). In other words, Katherine believed that people can learn, but not become more intelligent. She defined intelligence as "level of inherent ability or aptitude" (Katherine, ITI survey) and "ability to reason and deduct and think critically" (Katherine, post-study interview). The researcher sought clarification during the interview about this distinction and asked if there was a limit on a person's ability to think critically, to which Katherine responded, "absolutely! Yep, definitely!" (Katherine, post-study interview), which was consistent with her strongly held belief in a fixed view of intelligence.

Cluster 3

Alicia

Alicia did feel she made some progress toward a more positive attitude toward mathematics, which was also identified in her post-ATMI survey score of 95, compared to 62 at the beginning of the unit. Like Gretel, the significant area of change among the four factors in the ATMI survey was her self-confidence. Her relatively emergent view of intelligence appeared consistent. She did not complete the PBL Experience questionnaire but was able to participate in a post-study interview.

During the interview, Alicia was asked what her attitude toward mathematics was and she immediately stated that she felt that her attitude toward mathematics had changed over the time of the unit. She said she felt at the beginning that she “hated” (Alicia, post-study interview) mathematics, having had many bad experiences, but after the unit and undertaking the scenarios, she felt more confident as a teacher of mathematics. She thought her experiences would be useful in her teaching when she meets students who feel like she did. She felt the real-life simulation of the scenarios and assignment had a positive connection to her learning. She did not feel as scared of future mathematics education units and her confidence in her own abilities to learn to teach.

Alicia said she experienced a higher level of confidence as a teacher due to the learning about “how” to teach, as opposed to “what” to teach. She wished to learn more about pedagogy rather than just mathematics content. This includes a range of strategies to teach children and engage them in their learning.

> I think I've changed my attitude from when I first started. […] I was hating on maths. I really hated it, bad experiences, but now after doing this unit, I'm more confident in myself as a teacher. I know now that there will be students like me when I go into my classroom and I'll be able to help them, which is really good. I have different strategies, like, helping other students, and not just the content, but how to teach it, is most important to me. You gotta make it like, not like 'fun', but interesting and relate [it] to the students, instead of out of a textbook. […] More hands-on in maths, I say.
>
> (Alicia, post-study interview)

It is important to note that there were moments in the unit when Alicia did feel insecure and anxious about the learning, and this centred around certain times when the learning was difficult. She spoke of an example when learning a new strategy to do multiplication, called the array method, and how she struggled to understand it immediately. She said that it "threw" her and she reverted to the "insecure little kid who couldn't do it" (Alicia, post-study interview) and distracted herself and disengaged from the work. She mentioned that while she did achieve relatively well in her assignment, which was evidence to her that her engagement was working, this was tentative. She mentioned that if she did not do well, she would have thought "why put all that effort in if I only got this [low] mark" (Alicia, post-study interview). However, she went on to say that she would not think of herself as "dumb", but just that her strategies were wrong.

Sienna

Compared to the beginning of the unit, Sienna's main progress seemed to be in relation to her learning goals, which then impacted her attitude. She recognised in herself that she had moved more towards a mastery approach to learning rather than focusing on performance, but felt that she had made further progress toward those goals throughout the semester. Her post-ITI survey score of 28 was noticeably lower than her pre-study score of 39. It is important to recall that she did display performance goals in the pre-study interview, but she seemed to be aware to this in herself.

> I realised that I was halfway to becoming a mastery learner when I started this course. Now I believe I'm nearly there. Mastery learning has really helped my confidence and I hope I can move the students I teach on to becoming mastery learners.
>
> (Sienna, PBL Experience questionnaire)

She did say that she felt that her belief toward learning mathematics had changed over the unit, but was unchanged in the way she felt about mathematics. Her attitude toward mathematics at the beginning of the unit was 82 but went up to 112 by the conclusion of the unit, which was mid-range for the survey. Like the other key informants who exhibited significant changes in their ATMI scores, the factor relating to the most change was self-confidence. The work on learning goals and mindsets appeared to influence her on the learning of mathematics. Rather than mentioning any specific content areas, Sienna described the change in relation to the belief that she did not feel in the unit the need to get everything right all the time, and that students need time to learn. Again, she focused on the process of learning as being helpful to her when asked, "What aspects of the unit do you feel have been helpful to you?"

> The general attitude of it's ok to fail as long as you have learned something. This attitude is helping become a teacher who also follows this attitude. This attitude will benefit me and my students.
>
> (Sienna, PBL Experience questionnaire)

In the post-study interview, Sienna felt that the discussion of learning goals made a significant impact on her, calling it a “big thing” (Sienna, post-study interview) that was memorable from the unit. Despite achieving a high score of 39 out of 40 in the pre-study ITI survey, she had always believed that getting things wrong was a “bad thing, you’ve got to get it right” (Sienna, post-study interview). This new insight made her feel less scared and consequently she was able to learn without feeling anxious, which is in stark contrast to the beginning of the unit.

She explained that a significant contributor to her anxious feelings about getting things wrong stemmed from her experiences at school. In all her classes, the culture seemed to value students who could do the work, were very smart and kept up with the pace of learning. If you were not able to achieve this, Sienna felt you were ignored or yelled at for getting things wrong. She believed herself to be in the latter group. When she asked a question of the teacher, it would often be turned on her that another student in the class already knew the answer and she did not. She thought of all her mathematics teachers in the past and she considered all of them ineffective, mainly because she felt they would not listen to her.

The consequence of these experiences was to avoid failure and mistakes as much as possible. In the post-study interview, she mentioned how she had made progress with accepting mistakes and actually started to realise the valuable part they play in learning, as well as the need to try, rather than give in to the thought that it is too hard.

> It's ok to get it wrong and … you can learn from mistakes, whereas I hadn't realised that before. I've heard people say it before but I've gone, 'yeah, yeah, whatever'. So that's a big change.
>
> (Sienna, post-study interview)

Sienna still thought that she would look forward to mathematics, but when considering doing another mathematics educations unit, she said she felt "fine … I'm not feeling as worried or nervous or anxious about it" (Sienna, post-study interview), but at the same time, did not seem overly enthusiastic. Overall, Sienna had made a general movement in a positive direction.

Cluster 4

Susanna

Susanna mentioned in the PBL Experience questionnaire that she felt she had changed in terms of feelings and belief about mathematics, which was also observed in her post-ATMI survey of 160 compared to 149 at the beginning of the unit. The post-study interview revealed that she had started to enjoy mathematics more than she had previously. In fact, she described "hating" mathematics at certain times at school but never feeling bad at mathematics, the main reason being that she never saw mathematics as a creative subject, unlike her preferred subject of English. She explained that the increase in her positive attitude was due to experiencing mathematics in different ways such as hands-on materials, and embedding it in other subject areas like art, rather than just worksheets and questions.

It appeared that the impactful moments for her were not the PBL scenarios but mathematical activities not directly related to teaching. In the post-study interview, Susanna was asked which activities she could recall and she instantly mentioned doing an activity that involved making a metric clock (only using numbers such as 1, 10, 100, etc.). It was a task that was done in the second term of the unit during the place value module. She said she found it fascinating and loved the problem-solving nature of the task. Interestingly, Susanna was not concerned at all that it was not a "real-life" task or even a teaching task, like the scenarios were. Another task she recalled was a puzzle called the Number Crunch Machine, which required identifying a number pattern and using problem-solving skills to find an efficient solution.

She did not immediately answer with the PBL scenarios and, in fact, the topic had to be raised by the interviewer. Her explanation was that these two mathematics-oriented tasks were quite difficult, which she particularly enjoyed. Many of the other tasks were more simple and did not "take too much to get your head around" (Susanna, post-study interview). She clarified that the other tasks were not easy, but these two tasks were particularly challenging, and that interested her. The impression was that she did not particularly enjoy the PBL scenarios and only began "doing the [PBL] activities because you have to" (Susanna, post-study interview). She confidently said that her reluctance was not because she was "phased by how difficult it was", but just that there was so much to do and it "was going to take me more than 20 minutes" (Susanna, post-study interview). She described herself at the time as just being a "lazy"(Susanna, post-study interview) student.

She continued to give mastery-oriented responses during the post-study interview, despite showing a small decline in her post-ITI survey score, going from 37 to 33. For example, she connected her achievement directly to her effort, rather than her innate talent, when asked about her thoughts on receiving a pass grade of 30 out of 50 for her assignment. Her response was that she was very deserving of that mark because she had not put a great deal of effort into it and just started it too late.

She also linked her positive outlook toward mathematics with her view of learning as a process, which can see you get smarter with time and effort.

> You just work through the issues you're having with maths, and you can do it on your own. You don't have to just sit and suffer in silence. You just have to give students time to allow them to understand it, rather than giving them the information and sending them home. I know I've said before, 'time is a big thing', and I really do think it is.
> (Susanna, post-study interview)

Susanna felt that the unit validated her belief that mathematics takes time to learn and requires practice and experience, along with opportunities for independent learning. When considering what she learnt from the unit in regard to teaching mathematics, Susanna realised that you cannot rush students, that learning is not simply giving students information and that it is important to cover things multiple times in order to learn.

> Mathematics can be difficult for some, but all success comes from practice, mathematics is no different. This is why it is so important in schooling for maths to be taught and learnt in efficient and successful ways.
> (Susanna, PBL Experience questionnaire)

Susanna was asked about what she thought mathematics is about and while her reply listed some things related to the importance of mathematics, it moved into a discussion about it being more than just numbers and symbols, and the importance of effort, perseverance and practice in order to be successful.

Shaun

Shaun was able to complete the PBL Experience questionnaire along with a post-study interview. As a person with a relatively positive attitude toward mathematics and emergent view of mathematics, the results at the end of the unit saw a continuation of these traits. His ATMI score saw an increase from 148 to 166, while his ITI dropped somewhat from 40 to 32. Nevertheless, his responses in the post-study phase showed a continued and consistent theme of mastery orientation. Like Susanna in Cluster 4, he maintained a preference for challenge in his study, where effort, perseverance and practice were required. Like Susanna, he felt unsure of the approach at the beginning of the unit, but was willing to give it a try and persevere. He was relatively prominent in the forums on Moodle and active in his attempt to lead his PBL group. While the group work was ultimately unsuccessful, he did not seem upset or frustrated by the failure. He said "you have run with the show" (Shaun, post-study interview). Overall, Shaun appeared to maintain his attitude and mindset throughout the unit.

Summary

This chapter has presented the quantitative and qualitative results of the research study. It has used the clusters to present the most relevant data related to the research questions that will be discussed in the next chapter. The limitations, implications and recommendations for further study are also included in the following chapter.

Chapter Five

Discussion

Introduction

This study focused on investigating how preservice teachers' attitudes toward mathematics and implicit theories of intelligence impacted their view of learning and teaching mathematics. The research occurred within a semester-long unit, in which groups of preservice teachers engaged in scenarios of school students learning mathematics. The groups of preservice teachers were required to attend lectures and tutorials, and complete supplementary mathematics activities. The goal of the unit was to move students to a more positive attitude toward mathematics, and shift focus from performance goals towards mastery-oriented goals while learning mathematics education. This objective was coupled with the use of a student-centred approach in the form of problem-based learning (PBL). The study sought to determine how the students with varying attitudes and mindsets responded to student-centred learning.

Theoretical perspectives were developed in Chapter Two and used to analyse the key informants' attitudes toward mathematics and their implicit theories of intelligence. A framework was developed for the qualities of student-centred learning. It provided a pathway for analysing and integrating the position key informants had on their experience of PBL, and possible implications the experience might have on their future teaching approaches. All of these theoretical perspectives were based on a constructivist ideology, which provided a lens to view the research results. The three-pronged approach of investigating attitudes, mindsets and student-centred learning in this research study provided a layered perspective of the phenomena over the period of the semester.

This chapter begins with a discussion of the results of the study in relation to the three research questions that guided the investigation. Afterwards, the implications of the findings will be outlined in relation to teacher education in mathematics, along with the limitations and future research possibilities for mathematics teacher education. The final section will review the central aspects of the study that are summarised to conclude the thesis.

Views of teaching and learning mathematics

The first research question sought to investigate preservice primary teachers' views of learning and teaching mathematics within the context of their current attitude toward mathematics and their implicit view of intelligence. Clusters of students were formed with the use the Attitude Toward Mathematics Inventory (ATMI) and the Implicit Theories of Intelligence survey (ITI). Certain participants were identified primarily by their position within the cluster and they became the key informants for the particular clusters to which they belonged. Semi-structured interviews were employed to gauge these views in more depth, and in the context of their past experiences obtained in the Critical Moments questionnaire. The significance of the results will be discussed within the structure of the clusters, which were combinations of positive and negative attitudes, and fixed and emergent views of intelligence.

Cluster 1 – Negative attitude toward mathematics and fixed view of intelligence

When examined through the lens of affect, Gretel and Leanne viewed mathematics as an ominous undertaking, where prior successes had not helped them become resilient and motivated mathematics students. Their previous experiences of failure and confusion were connected to their current feelings, and so future struggles had the potential to confirm their current beliefs about their ability to learn mathematics. Both described themselves as having low self-confidence and feeling high levels of anxiety when confronted with challenging mathematical learning situations. This was despite both key informants espousing in the pre-study interviews a preference for challenge. While it may be true that they saw the worth of challenge in terms of learning, their affective responses had a powerful effect on their behaviour. This was evidenced by Gretel during the KenKen activity when she gave up on the more simple, introductory puzzle, saying “I’m done” (Gretel, pre-study interview) and sliding the paper away from herself. For Leanne, her response to challenge was to avoid it by attempting the lowest level senior mathematics course. The easy success of high grades while in Year 12 was far more tempting than the alternative struggle and potential for failure offered by the higher level mathematics courses.

Although both key informants had at times achieved fairly high levels of success at school in mathematics, these accomplishments did not impact positively on their confidence or motivation to do mathematics. Gretel believed she struggled greatly to earn the high grades she obtained, but these struggles produced mixed feelings of satisfaction on the one hand, and frustration and anxiety on the other because she had to struggle for them. They saw learning mathematics as a performance, rather than a journey of progression. Gretel appeared to cope with this stress by preferring to learn mathematics in very small steps, which reduced the challenge and her anxiety, and instilled a sense of progress. Leanne, on the other hand, opted for the easy level of mathematics, which she regretted many years later when interviewed for this study. Reflecting on this, it seemed that even successes viewed within a performance mindset did not qualify as meaningful success. Gretel described how disappointed she felt after achieving an A-grade in Year 12, but failing to have this acknowledged by her teacher.

> I worked hard throughout Year 12, but I didn't achieve the marks I wanted usually ending up for a C. Finally all of my work paid of[f] in my final exam and I was rewarded with an A. My teacher could not have cared less, and was not in the slightest happy for me. This really upset me because I thought he would give me some credit for getting an A and at least pretend to be happy for me because he knew I was generally a C/B grade student.
>
> (Gretel, Critical Moments questionnaire)

Both Gretel and Leanne acknowledged the importance the teacher had in their learning of mathematics, both positively and negatively. They seemed to express the impact in affective terms rather than technical teaching pedagogy. Leanne mentioned that an effective, good teacher makes her feel “enthusiastic” and a “positive” student, while Gretel said she needed a teacher with “patience”. Both Gretel and Leanne expressed, in an indirect way, the desire to be taught mathematics in a mastery way. Gretel described a type of teacher she preferred to learn from as being “dedicated” (Gretel, pre-study interview) and providing ample opportunities to learn. She wished to be taught by a teacher who will persevere for their students. Gretel seemed to empower the teacher to significantly dictate her attitude toward mathematics. She looked to the teacher to “build up” her “self-confidence”, in the same way that Leanne needed it to be an “enthusiastic” student. It is possible to see the potential for learned helpless responses to challenging situations when the locus of control seems to be handed over to the teacher, as displayed in Gretel’s KenKen reaction and Leanne’s choice of an easy mathematics course.

Participants from this cluster have considerable challenges to overcome in order to become positive learners of mathematics and to take on a view that everyone is capable of significant learning in their classroom. The many experiences they had during their previous learning of mathematics had led to them believing it is better to avoid challenge and failure, and the accompanying feelings of high levels of stress, embarrassment, low self-confidence, and at times, even fear. They had learnt from their prior experiences that mathematics was hard to grasp, requires significant effort and is full of risk and emotion. Boaler (2016) suggests that “the fixed mindsets that many people hold about mathematics often combine with other negative beliefs about mathematics, to devastating effects” (Boaler, 2016, Introduction, paragraph 3, location 345 of 5967). It is crucial that people with these experiences and mindsets, when in their future classrooms, are at risk of sending negative messages, both implicitly and explicitly, to their students about learning and mathematics (Boaler, 2016).

Cluster 2 – Positive attitude toward mathematics and fixed view of intelligence

The key informants in Cluster 2 seemed confident and motivated to learn mathematics, on one condition, that they were successful at it. Both Jamie and Katherine had moments of high success in mathematics while at school and were recognised for it. They had very able peers who they felt obligated to match in performance, and felt concerned that they would be found lacking in comparison. The coping strategies the key informants used during these stressful times involved not admitting to struggling, and avoiding help-seeking opportunities. In this respect, mathematics learning produced anxiety based around judgement and under-performance.

The key informants in this cluster were both very able students of mathematics. They seemed very confident and proud of their success, even seeing it as a part of who they were. It seemed to make them feel smart, especially when they compared themselves to others. Jamie described just how much he enjoyed the feeling of "superiority" by being in the advanced class at primary school, while Katherine said she felt most smart when others were struggling to do the work but she was finding it easy. They both never spoke in terms of how much they were learning, only measuring their learning by being more successful than others. This was especially in relation to their close friends. Katherine and Jamie felt the pressure to never appear to be struggling, which they saw as a result of having very bright friends who performed well. Unfortunately for Jamie and Katherine, they both experienced this situation in Year 12. Jamie chose to drop to the lowest level mathematics course and Katherine simply avoided asking questions in class and struggled in silence instead. This created a phenomenon where they would explicitly weigh up the chance of success versus the amount of effort to achieve success. This "competition" to match or outperform their peers may have been created in their own minds, created among peers as with Jamie in primary school, or promoted by the teacher as a class culture. Whatever the source, both Jamie and Katherine revealed how it affected their behaviour and inhibited their learning. Katherine refused to seek help from the teacher in front of her friends, and Jamie stopped trying when his grades began to fall. Competition has been found to promote performance-oriented goals rather than mastery. Dweck, Walton and Cohen (2014) described the impact of competition on learning behaviours and its link to mindsets.

> Research also suggests that students are often more motivated and successful when classroom activities involve cooperative rather than competitive or individualistic goals. Cooperative goals can foster greater motivation through a number of avenues. For example, students working together on a task may feel a greater sense of responsibility to try their best because they do not want to let down their group members. In contrast, students working in competitive environments may engage in more self-handicapping, withholding effort so that they can attribute failures to a lack of effort rather than to a lack of ability … Research suggests that competitive environments are associated not only with lower achievement but also with students liking each other less.
>
> (Dweck et al., 2014, p. 8)

Like the key informants in Cluster 1, Katherine and Jamie demonstrated learned helpless responses, where they found themselves in situations of believing they had no influence in overcoming the situation, and it was out of their hands. These were coping strategies used in the face of not appearing smart. As students, they valued getting the answers correct without struggle, but these are not behaviours that would be useful for teachers to value in their classroom. If left unchallenged, their experiences might lead them to portray challenges as something to be avoided and mistakes to be undervalued.

For this cluster, their view of learning mathematics was that there were some people who could do mathematics and some who could not, and for the most part they were the fortunate ones who could. The fact that they had experienced high levels of success meant that they generally felt confident in their abilities, were motivated to learn and enjoyed achieving well, which culminated in them having a positive attitude toward mathematics. However, the fixed mindset led to their focus on appearing smart at all costs. This was evidenced in Jamie being too embarrassed to ever admit to anyone that he was doing the lowest level mathematics course and Katherine feeling high stress levels worrying that her friends would think of her as unintelligent if she appeared not to know how to do the work. Overall, the participants in this cluster demonstrated that a positive attitude does not promote resilience when faced with challenge and failure, and confirmed with the literature that their implicit theory of intelligence determined the behaviour when risk of failure was present.

Cluster 3 – Negative attitude toward mathematics and emergent view of intelligence

Analysis of the results revealed that the key informants of Cluster 3 viewed learning mathematics warily and participated with reluctance, despite clearly having an emergent mindset. The interplay between attitude and beliefs was witnessed with this cluster. While Alicia and Sienna consistently stated their belief that people could become smarter, which the researcher believed was sincere, it did not always lead them to mastery goals. It seemed that their previous negative experiences had tempered their desire to embrace challenge in mathematics learning. In the case of Sienna, this was most likely a consequence of strong and consistent fixed-mindset messages from home and school. For Alicia, mathematics was simply a constant struggle to understand and master.

> My perspective of myself with maths was low self-esteem and low academic levels of mathematics. I was always frustrated with myself because I could not understand mathematical concepts and I was embarrassed to do maths due to the fact I could not do it.
>
> (Alicia, Critical Moments questionnaire)

Alicia and Sienna both had firm beliefs in a person's ability to get smarter through effort, learning and time. Besides their relatively high ITI survey scores, they consistently provided responses that concurred with this notion of an emergent mindset. Alicia described the reason why a person should continue to try to work through challenges, even though they might fail. She described that there is a chance you may accomplish something, and if you do fail, you will learn something when you get help. Sienna clearly articulated her belief that everyone is capable of significant learning. It was unclear from her responses how she came to have this belief.

Looking into the previous experiences of the key informants, the clearest connection between past episodes and their current view of learning mathematics was observed in the story of Sienna. Despite having an emergent view of intelligence, supported by her ITI score and direct interview responses, she had very strong performance-oriented goals to learning. Looking on the events she identified as critical moments in her learning journey, the theme of greatest significance was the transition from her experiences at a small, rural primary school to a large, private school. While there was a noticeable change geographically, it was the culture shift of the learning environment that was stark for Sienna. The move signified a change in focus from learning to performance, and considerable pressure not to fail for fear of reprimand. The new culture was performance-oriented and for someone like Sienna, with an emergent view of intelligence, it appeared the dissonance of what was valued led to significant frustration and stress for her. The researcher noticed this emotion during the pre-study interview when she described her learning history. The impact of this had seemed to lead Sienna to adopt performance goals herself. Dweck (2000, 2008) has shown that it is possible to change people's goals to either performance or mastery simply by changing the focus on being correct or learning respectively. Sienna appears to demonstrate that prolonged exposure to performance goals can have a significant impact, in spite of a person's implicit theory of intelligence.

The struggle and emotions Alicia and Sienna experienced appeared to lead them to being reluctant to provide challenging work to all their future students in mathematics. Alicia and Sienna believed they would provide challenge to their students, but were very cautious of its risk of causing stress and perhaps even trauma. Alicia suggested she would start off with "easy" work, while Sienna said she would only challenge the students who could do the work, but for students who struggled she would give them easy work to "feel good, instead of challenging them all the time" (Sienna, pre-study interview), which is a response expected from a person with a fixed mindset. Sienna mentioned in her own learning that "I don't like anything hard full-stop. I don't care if everyone else's finding it hard, I just don't like the idea" (Sienna, pre-study interview).

It appeared that they were quite concerned with creating harmful experiences when learning mathematics by creating too much stress and struggle. While every teacher is concerned with excessive challenge, these key informants seemed to feel and express this concern quite keenly. Dweck (2008) has reported previously on teachers with fixed mindsets offering "comfort-oriented" feedback to students in order to console students. In contrast, teachers with emergent views of intelligence tended to provide feedback that was more oriented towards finding a solution. It may be possible that a negative attitude as a consequence of many emotional learning experiences, moves a teacher more towards comforting students with simpler tasks rather than challenging them, in fear of creating situations similar to the one the teacher went through. It is important to be mindful that these key informants were young and newly out of high school, and consequently close to these experiences.

The key informants both showed signs of empathy for their future students. For example, Alicia described how her understanding of the feelings of struggle and confusion would lead to her being a better teacher. This is likely to be true, but there is a risk that her attitude toward mathematics could supersede her mastery orientation. Perhaps at some stage what you believe about something becomes irrelevant if the feelings of doing that thing become overwhelmingly strong. Similar to the previous two clusters, this cluster's key informants had certain qualities that may prove to be barriers to them providing rich learning experiences to all their students. It is not through a lack of care or dedication, but through implicit and explicit messages and behaviours to students that can impact on learning.

Cluster 4 – Positive attitude toward mathematics and emergent view of intelligence

The key informants in Cluster 4 viewed learning mathematics as consistent with expectations found in the literature. They were generally positive toward mathematics and were not deterred by the challenges and struggles. Susanna and Shaun gave consistent responses regarding their belief of an emergent intelligence and aim towards mastery-oriented goals. Interestingly, the two informants did not feel particularly strong at mathematics and shared moments of struggle over their schooling. Shaun actually failed Year 12 mathematics and Susanna found the subject difficult for much of school, saying she "hated it" (Susanna, pre-study interview). Different from the other clusters, these two preservice teachers had moments where they were able to see themselves overcome difficulties and succeed.

Susanna's mastery approach to learning mathematics appeared to be significantly influenced by her high school mathematics teacher. During the pre-study interview, she described how her teacher impressed on her many of the qualities prized in a mastery-oriented environment. This included seeing learning as a progress, valuing effort and persistence, and believing that every student is capable of significant learning. She told with affection how the teacher would check that all students were understanding the work, completing homework and asking for help if they got stuck. The teacher did not punish students for incomplete homework, but insisted on providing opportunities for individuals to catch up during lunchtimes because getting better at mathematics was valued. Susanna had this teacher for approximately four years of her secondary schooling and was therefore present for many experiences that had appeared to help her create, or confirm within her, a belief in an emergent mindset and mastery goals.

Shaun's beliefs about learning mathematics seemed to be formed after his schooling had finished. While he never thought he ever had a negative attitude toward mathematics, he was surprised by his results at school. Before the pre-study interview had formally begun, he was going through his previous school report cards and was surprised to discover that his mathematics grades were in a steady decline throughout high school, culminating in achieving less than 50 per cent in the Year 12 course. As a mature-age student and father, Shaun said that life experiences, including a difficult relationship with his father and getting divorced, had forced him to reflect on these events. An important breakthrough for him was the realisation that tremendous personal growth can occur from struggle, and that failing offers an opportunity to learn something important. Having been through those experiences, he came to see that failure is not a thing to feel frightened to go through.

The responses from Cluster 4 never involved comparing their learning to other people or focus on grades, but was about themselves (or others) and their personal development. Susanna showed she valued learning over grades by offering that learning mathematics at school "is not just about learning and studying to get 80% or more in a test, it is about learning the mathematical skills that will help a student succeed in the future" (Susanna, Critical Moments questionnaire).

Summary and implications

The qualitative evidence suggested that the interaction between preservice teachers' attitudes toward mathematics and their implicit theory of intelligence contributed, in a complex and mutually dependent way, to the development of their overall current view of learning and teaching mathematics. Neither attitude nor mindset were completely dominant in determining participants responses to challenge and failure, or with dealing with the emotions felt within a learning experience. These emotions cannot be understated, as "mathematics is the one [subject] that triggers the strongest negative emotions, which may become established and even end up in an attitude of refusal towards the subject, or may block thinking processes" (Di Martino & Zan, 2011). The various combinations of positive and negative attitudes, and beliefs in fixed and emergent intelligence, came together to provide an overall view that culminated in both effective and less effective behaviours and thoughts.

By paying particular attention to the previous experiences of these key informants it was possible to identify, in some cases, experiences that were impactful to their current views. These were sometimes single moments in time, such as Gretel failing to be recognised by her teacher for a successful examination mark, or were more often repeated occurrences over time. For instance, Susanna witnessing over many years a teacher who modelled and valued mastery-oriented goals in his classroom, demonstrating the value of a teacher's mindset within the classroom (Boaler, 2016).

The instances that were of particular interest for this study were the reflections from key informants involving challenge and failure in mathematics learning. The reason for this was that it is well accepted that challenging tasks, compared to easy tasks, offer greater opportunity for learning (Dweck, 2000). Framed within social constructivist theory, simple and trivial tasks are potentially outside an individual's zone of proximal development, as it is likely dealing with what is already known and, therefore, of little use for learning (Wass & Golding, 2014). Growth only occurs when tackling work that an individual cannot do without assistance, which always occurs near the edge of challenge and failure. The study was interested in investigating what key informants thought and how they behaved when they were in these moments of opportunity to learn, not when they were within their learning "comfort-zone" (Dweck et al.,2014). The study included the positive and negative critical moments from the key informants' past, as a way to identify these responses.

Consequently, each cluster revealed an important aspect in the way attitude and beliefs about intelligence played a role in their view of learning mathematics. The results were starkly contrasting views. In some cases, such as in Cluster 1, learning mathematics was viewed with immense trepidation, while participants in Cluster 4 viewed learning mathematics as an opportunity for growth and were undeterred by the challenge. These two results might not be surprising as the key informants' implicit theories of intelligence and attitudes towards mathematics seem aligned, to an extent. For instance, Cluster 1 had a negative attitude toward mathematics and a fixed mindset, which meant that when challenge and risk of failure occurred, these two qualities made it difficult to always persevere to succeed, with the one quality not improving the other. Having a fixed mindset and negative attitude may make failure more likely, which reinforces the belief in a fixed intelligence. On the other hand, Cluster 4 key informants had a growth mindset and a positive attitude toward mathematics, which created a resilience to setbacks and positive attitude towards mathematics. Somewhat unexpectedly, were the findings from Clusters 2 and 3. These two clusters appeared to evidence the interaction between attitude and belief in intelligence, showing that both attitude and mindset play a critical role to being a positive and resilient student. For Cluster 2, their positive attitude toward mathematics, such as enjoyment and self-confidence, did not provide the support needed to always persevere when extensive difficulty appeared while learning. This example concurred with much of the literature (Dweck, 2000). In the case of Cluster 3, the key informants' attitudes appeared to suppress some of the "seeking and enjoying [of] challenge and remaining undaunted in the face of it" (Dweck, Walton & Cohen, 2014, p. 22) expected from people with an emergent view of intelligence. While they did have a growth mindset and believed everyone could learn, their urge to provide challenge to all students was tempered, with both key informants saying they would initially provide easy work for less able students. For Sienna personally, the distaste for anything challenging was clear and definite. It seemed that for this cluster, the numerous negative experiences they had faced while learning mathematics took precedence, to an extent, over what they believed about learning and the role of challenge. Cluster 3 key informants were noticeably influenced by their attitude, which is known to contribute to behaviour (Di Martino & Zan, 2015), whereas Jamie's positive attitude (Cluster 2) did not provide sufficient support to continue attempting the higher level mathematics course in Year 12. These results from Clusters 2 and 3 add to the literature around the complexity in identifying attitude as a consistent, clear, causal relationship with achievement (Di Martino & Zan, 2015; White, Way, Perry & Southwell, 2006; Hannula, 2002) and they demonstrate the importance of both attitudes and beliefs.

Overall, Cluster 4 appeared to separate from the other three clusters when reflecting on their resilience to failure and desire for challenge. Despite admitting that they were not the best mathematics students, they were not deterred by the difficulties and did not seem to view failure as anything other than not having the skills and knowledge yet. The other three clusters were each impacted by the possibility of challenge and failure to some degree. An implication of this finding is the level of support provided for the three clusters in terms of their learning, coping with the challenge of university and teacher education. The participants in the three clusters all reported occasions while learning mathematics where they had either avoided challenge, felt high levels of anxiety or behaved in a way that was self-handicapping to their learning. It suggests the need for mathematics education lecturers to both explicitly teach and implicitly model the qualities of an emergent mindset and a positive attitude. Otherwise the risk of a continuing pattern will most likely occur for the students in their classes.

As the key informants were only in the initial stages of their learning about teaching, a lot of their views were based on their personal experiences. As could be expected the responses were not articulated with deep knowledge of learning theory, and many responses were general in nature. Based on the reflections they did provide it was clear that, while all key informants saw the value of challenge and failure, they varied in the degree to which they would implement it as part of their teaching. The most obvious of these was Cluster 3, where Alicia and Sienna mentioned they would not provide challenge to all their students. Sienna even went further and said that we should not be "challenging them [students] all the time" (Sienna, pre-study interview). Boaler (2016) describes the importance of the messages teachers transmit about mathematics and learning, which Sienna shows to have been impacted by. It is clear that educators have an opportunity in teacher education to help students reframe their view and understanding of the roles of challenge and failure in learning, in an effort to move all teachers towards being positive and resilient teachers of mathematics. Further insights about the potential impacts their attitudes and mindsets might have on teaching are discussed in the next research question.

Response to student-centred learning

The second research question investigated the different clusters' responses to student-centred learning utilising a problem-based learning (PBL) approach. The findings are tentative due to difficulties experienced with PBL during the semester, and the fact that some key informants were not available for the post-study instruments.

Cluster 1 – Negative attitude toward mathematics and fixed view of intelligence

Gretel was the only key informant available in this cluster for a post-study interview. The interview allowed her a chance to reflect on the PBL unit and the aspects that she found valuable. Gretel appeared to be receptive to a number of student-centred qualities utilised within the activities of the unit. She was interested in the CPA framework of Bruner (1966), which incorporates specific contexts and concrete materials first in the learning journey, before moving on to abstraction and the generalisation of ideas. Gretel provided examples from the unit of the base-ten materials for introducing skills and concepts in number, and the incorporation of actual student scenarios and work samples within the PBL scenarios and assignments, utilised as a way for preservice teachers to learn about assessment and planning in mathematics. Gretel described that she had never seen children do mathematics before and consequently felt "alert" (Gretel, post-study interview) and engaged by those moments.

Gretel did seem to believe it was important for her to learn in small increments, rather than longer projects. She espoused this both in a general way in the pre-study interview and again specifically in the post-study interview, when reflecting on the use of scenarios and Learning Targets. While she did appreciate the extra autonomy of a PBL approach, there was a possible tension between freedom and her desire for small-size tasks, which rely heavily on close support from the teacher. Simon (1994) described that within a social constructivist approach the meanings of ideas are negotiated among students, and responsibility for determining the validity of ideas resides with the classroom community and is expressed in the language of the students. As this does take time, it may be that Gretel's need for small tasks and regular guidance by teachers may not align with these student-centred qualities.

Cluster 2 – Positive attitude toward mathematics and fixed view of intelligence

Katherine was the only key informant available for a post-study interview, during which she revealed a number of aspects of student-centred learning that she did not seem receptive to in her own learning. Katherine made it quite clear that she did not like the approach taken in the unit and this focused mainly around the locus of control moving from the teacher towards the student. Katherine described that she was "very frustrated" (Katherine, post-study interview) with not knowing exactly what to do, what to learn and what resources to use – in other words, the lack of direction and structure provided by the teacher. She went on to say that she did not "have time to go and try and figure out what I need to know. I need someone to let me know" (Katherine, post-study interview). She described her experience within the first two weeks of the unit.

> I have been very frustrated by it because to me challenge is fantastic and one of the most important parts of learning. However, I'd say almost equally important to me is structure. And so I'm struggling, I'm really struggling with the structure side of it, and I need challenge within a very structured environment.
>
> (Katherine, pre-study interview)

It is acknowledged by the researcher that the issues raised by Katherine about the unit, which were reported in the previous chapter, were fair and warranted. PBL was a drastically different approach to learning for the preservice teachers and the implementation did have significant flaws. But the focus of interest was the way Katherine framed these in the context of her needs as a learner. It displayed some of her possible beliefs she had about knowledge, learning and how teaching should be done.

The most significant of these is her belief about where knowledge is located and how it is learned. Katherine seemed to believe that knowledge is simply something that can be listed and remembered. The teacher was the expert and holder of knowledge and their role was primarily to be the information giver. Hence, the most direct path for her to get this knowledge was simply to be told what to learn.

Both Jamie and Katherine also did not seem to place important significance on the relationship with the teacher. Starkly absent from their recollections of past critical moments learning mathematics was the role of the teacher in their learning, despite being explicitly asked to include it in their reflections in the Critical Moments questionnaire. Katherine did not mention the teacher at all. In the case of Jamie, he only mentioned a teacher once in his recollections, and remembered one teacher in his senior years because of the negative effect the teacher had on his motivation, which led to him falling in achievement and subsequently dropping to the lowest mathematics level for Year 12.

Katherine appeared to desire a learning environment where she was told what she needed to learn and would be happy to learn it independently. There was no need for discovery, investigation or much value on the process. Katherine was satisfied, at least at this point in time, to give up any power to direct her own learning and consequently placed responsibility in the hands of the teacher. In contrast, student-centred learning has been described as:

> …ways of thinking and learning that emphasize student responsibility and activity in learning rather than what the teachers are doing. Essentially SCL has student responsibility and activity at its heart, in contrast to a strong emphasis on teacher control and coverage of academic content in much conventional, didactic teaching.
> (Cannon and Newble, 2000, p. 16)

There are some explanations that may explain Katherine's need for such a didactic structure to learning, but further research would be required. One possibility is that a person with fixed mindset may prefer the responsibility for learning to lie outside themselves, with the teacher for example, as a way to offset their responsibility for potential struggles. This may explain her need for "immediate feedback" (Katherine, pre-study interview), similar to how Gretel in Cluster 1 wanted to learn in small, broken-down steps. Another reason may be simply that some mature-age students who are studying independently at a distance may be so time-poor that it shifts their goals to a more performance-orientation. Yet another reason might be that she has previously been very successful within a teacher-centred learning environment and, combined with a fixed mindset, is not receptive to another way of learning. Whatever the reason may be, it was clear that she wanted a much higher level of direction by the teacher, in order to ensure her success in learning.

Cluster 3 – Negative attitude toward mathematics and emergent view of intelligence

The key informants in Cluster 3 appeared to be receptive to a number of aspects of student-centred learning. It was not a simple transition for Alicia and Sienna, as they both felt anxious at the beginning of the unit, not only because it involved mathematics but because it took a different approach that they had not experienced before, either at school or university. Nevertheless, they were able to accept it, and in the end found they preferred the overall approach, with its increased student responsibility for learning and the process of PBL.

Both Sienna and Alicia connected with the scenarios the most, describing them as immediately relevant to their future work as teachers. The broad nature of the problems was attractive, especially to Alicia who noticed that one problem provided a wide variety of concepts and required learning a number of strategies to solve. They saw that working in groups was challenging at times, but they both found value in the process of learning through the scenarios, not just being "spoon-fed" (Sienna, post-study interview) the information. Unlike Katherine in Cluster 2, Alicia and Sienna recognised the benefit of the process of working through the scenarios with some level of autonomy and control. Alicia saw the need in herself to move towards accepting more responsibility for her own learning and, by doing so, model the quality for her future students. This higher level of independence created some uncertainty and challenge, but it seemed they were both able to cope with it, despite their previous acknowledgment of heightened anxiety. Sienna believed that the difference was the culture of the unit, where it was expected to make mistakes and that they were simply a part of the learning process. She was receptive to a learning environment that promoted *having a go* and *taking risks*. It is curious to consider whether their emergent view of intelligence helped them cope with the challenges and anxieties they felt, allowing them to remain engaged and open to a different approach to teaching and learning.

Cluster 4 – Positive attitude toward mathematics and emergent view of intelligence

Similar to some of the previous key informants, Susanna and Shaun approached this unit with some apprehension, due to its different approach. Shaun still engaged in the unit immediately but found a lack of response from his PBL group inhibited the group experience. Susanna said that the scenarios appeared to involve so much work that she did not engage with them initially. In fact, she found the amount of work required was a deterrent, but once she did engage she was able to see the benefits in her learning.

The aspects of the unit Susanna valued were the higher level of responsibility required within a student-centred approach, and the extended nature of the problems. However, she added that she would have benefited from more information. When she said this, the researcher was interested to see if this was the same critique that Katherine from Cluster 2 offered. Katherine believed that there was a lack of direction as to the specific content that should be learnt and the resources she should have used, but for Susanna in Cluster 4, it was a need for a greater understanding of PBL. In other words, it was an understanding of the process rather than any specific direction in content which she desired. Susanna was not asking to be told what to study, but how to approach it. She did not want to been told specifically what she was to learn. In fact, Susanna was deeply frustrated by being “spoon-fed” (Susanna, post-study interview) in other units, just like Sienna was in Cluster 3. Susanna described spoon feeding as “utter crap” (Susanna, post-study interview). Susanna was receptive to the new approach of PBL, despite the feelings of hesitation due to the workload. She valued the higher level of self-determination and extended nature of problems, where time was provided to work through the tasks.

Shaun was also very receptive to a student-centred approach. He found learning and experiencing student-centred approaches strikingly different from his time at school. He revealed previous learning experiences with teacher-centred, didactic instruction, that relied heavily on rote learning without understanding. The most significant aspects for Shaun were similar to those for Susanna, which were the higher level of openness within activities to explore, and the support for students through scaffolding. This was not articulated with a high level of sophistication, but revolved around helping students understand the work rather than just memorisation. For example, Shaun and Susanna enjoyed how the use of student video clips helped with their own understanding of teaching numeracy, along with other strategies such as the use of the Fraction Wall. Shaun felt that his previous teacher-centred experiences were not the best way to learn.

Both Shaun and Susanna mentioned how important a relationship with the teacher was to their learning. Unlike Jamie and Katherine in Cluster 2, who did not mention the impact of teachers in any significant way, both Shaun and Susanna explicitly mentioned the benefit they have had from their teachers. Lea, Stephenson and Troy's (2003) framework for student-centred learning acknowledges the importance of the student-teacher relationship.

Summary and implications

The results suggest that most key informants found a wide range of willingness to support a student-centred approach. The scope of this receptivity ranged from enthusiasm, primarily witnessed from participants with an emergent view of intelligence, to a reluctance and even dislike of the approach, as seen with Katherine. The participants who were most readily willing to adopt the qualities of a student-centred approach were those who had more mastery-oriented mindsets.

Currently, there appears to be a limited amount of research on teachers' implicit theories of intelligence (Jones, Bryant, Snyder, & Malone, 2012; Sun, 2014; Madni et al., 2015), let alone connecting teachers' mindsets and general pedagogical approaches. Some studies have looked at specific behaviours of teachers in the context of their mindsets and these findings have provided some indications that there may be a correspondence between an emergent view of intelligence and a preference for student-centred learning. The converse may also be true. Schmidt, Shumow and Kackar-Cam (2015) found that higher student outcomes were achieved when a teacher placed greater emphasis on mastery goals, conceptual development and use of learning strategies. In another study, Leroy, Bressoux, Sarrazin and Trouilloud (2007) found that implicit theories of intelligence contributed to establishing an autonomy-supportive climate for students in their classroom and that teachers with a fixed mindset caused a drop in the teachers' reported support for autonomy. Jones (2007) suggested that a student-centred approach "helps students to develop a 'can-do' attitude" (p. 1), which aligns with many of the qualities of mastery-oriented goals often valued by people with emergent mindsets, and works against the learned helplessness response that can occur for people with fixed mindsets.

The findings surrounding this research question have an alignment with those of a student-centred approach. This study offers another small piece of evidence towards this observation, by providing case studies which revealed that students with an emergent mindset tended to value more fully the qualities of a student-centred approach than those with a fixed mindset. In fact, in the case of Katherine, it seemed to be a rejection of some of these qualities and a preference for a more teacher-centred approach. There may or may not exist a connection between mindset and preferred teaching theories, but in this particular study, with these particular participants, there was a pattern that appeared to exist.

Student-centred learning is often framed in terms of focus from the instruction of the teacher to the activeness of the student (Jones, 2007). An element of this shift is a higher level of autonomy for students to be able to have some influence over their own learning (Jones, 2007). It is important that this autonomy means students are self-instructing, as "autonomous learners are dependent upon teachers to create and maintain learning environments that support the development of learner autonomy" (Rollings-Carter, 2000). In this study, each of the key informants with an emergent view of intelligence identified autonomy as a valuable aspect of their learning experience, some even going so far as rejecting the benefits of being spoonfed information. In contrast, Katherine, who held a fixed mindset at the time, sought to be directed about what to learn, how to learn and what resources to use. Perhaps a reason for this is the comfort teacher-direction provides from potential anxiety about the risk of not succeeding. By looking to the teacher to be significantly in charge of the learning experience, there is a level of security that a student will be shown everything they need in order to succeed. On the other hand, it might also be that they have had many previous successes in more teacher-centred classrooms and she was resistant to a more student-centred approach. However, Gretel in Cluster 1 mentioned that she preferred to learn in small steps, which could also be seen as a coping strategy whereby she could regularly check in with the teacher to make sure she was getting the work correct. As well, key informants with emergent views of intelligence did explicitly prefer the openness and extended nature of the work in the unit. Nevertheless, this study did not seek to identify the depth of why Katherine held these strong beliefs about the learning environment she felt she needed. Based on these findings, further research into the connections between student-centred learning and mindsets is recommended as a potential area for study.

Changes in attitude and mindset

The last research question focused on the changes that took place for the key informants with respect to their attitudes towards mathematics and implicit theory of intelligence and learning goals. For the eight key informants, six post-study interviews were completed, six PBL Experience questionnaires and seven post-study survey responses. The three sources of data provide an opportunity to gain understanding of how key informants' attitudes and mindsets changed throughout the duration of the unit.

Cluster 1 – Negative attitude toward mathematics and fixed view of intelligence

Gretel was the only key informant who was available in this cluster to participate in a post-study interview, where important data was collected relating to this research question. Consequently, the discussion of this section will mainly relate to Gretel's development.

This cluster represented participants who achieved low scores in both the ATMI and ITI surveys. The goal of the unit was to assist these students to move towards a more positive attitude towards mathematics and an emergent view of intelligence. It seemed that this goal was achieved to some extent for Gretel and Leanne. Both saw significant positive changes in their post-study ATMI and ITI survey scores. The key informants recognised their strong negative attitudes towards mathematics at the beginning of the unit, mainly in the area of self-confidence, but also in terms of motivation and enjoyment. For Gretel, the unit did appear to provide some positive experiences that helped her improve her attitude toward mathematics. She seemed to enjoy the unit, claiming it was her favourite unit to attend, even though Gretel began the unit feeling highly anxious. She also felt she had made progress towards a more emergent mindset, mentioning she had learned mastery-oriented goals, "I don't have to get everything right all the time … when learning maths" (Gretel, PBL Experience questionnaire).

Nevertheless, she still seemed to demonstrate a fixed mindset whenever successes occurred. This was identified in the pre-study interview where she achieved successes but was overshadowed by other negative struggles. When she achieved an above average result for her assignment, receiving 70 out of 100, she argued it away as a "bit of a fluke" because she was "not a maths person" (Gretel, post-study interview). It may be that her fixed mindset inhibited progress towards a more emergent view of intelligence. Gretel and Leanne both began with a fixed mindset, which was evidenced by their low ITI scores and pre-study interview responses. At the conclusion of the unit, both Gretel and Leanne's survey scores were higher than at the pre-study phase. Leanne's jump in score for her implicit theory of intelligence was quite significant, nearly doubling in value. However, it is difficult to make a conclusion on the positive impact with any confidence without further investigation. For Gretel, analysis of the survey and interview data seemed to suggest the main area of change for her was attitudinal rather than mindset. Her emotional response to being in the class went from high anxiety to enjoyment. Overall, Gretel still appeared to have a negative attitude towards mathematics and a fixed mindset, but some progress seemed to have been made in a positive direction.

Cluster 2 – Positive attitude toward mathematics and fixed view of intelligence

A similar circumstance occurred with Cluster 2 where Katherine was the only key informant who was available in this cluster to participate in a post-study interview. As such, this discussion will mainly relate to Katherine's journey.

Katherine's post-study survey results suggested she maintained a stable attitude toward mathematics and made a shift toward a more emergent view of intelligence, however she was still very much within the fixed-mindset range. In the post-study interview, Katherine reaffirmed her need for far greater direction in her learning than the PBL approach offered. It seems that identifying Learning Targets was not something she was receptive to and she did not find any value in that process. Consequently, her feelings towards the unit were not especially positive and, as such, there were little data to suggest a serious change in attitude. Katherine still held to her previously strongly stated belief that people are limited to the extent to which they can alter their intelligence, openly admitting "I still believe that" (Katherine, post-interview).

Cluster 3 – Negative attitude toward mathematics and emergent view of intelligence

Cluster 3 saw a generally positive development in attitude over the duration of the unit, and a continued high growth mindset for Alicia but a decline for Sienna, according to the post-study ATMI and ITI survey scores. The qualitative data gathered from the post-study interviews and PBL Experience questionnaire did not provide sufficient evidence to understand this decrease of Sienna's ITI score. The focus ended up being on her seeking to achieve mastery goals rather than performance goals.

The drop in Sienna's ITI survey score was significant in magnitude, amounting to nearly a third lower compared to her previous score. This brought her from having a strongly emergent mindset to slightly emergent mindset. When this score was compared with other data collected from the interview and PBL Experience questionnaire, it seemed that her experiences within the unit and learning about mindsets were meaningful. At the beginning of the unit, Sienna displayed very strong performance goals, openly admitting to disliking challenging work and the potential of getting things wrong in front of other people and having them thinking she was dumb. In contrast to this, she said what she valued most about the unit was that she had come to realise that it is normal to get answers wrong and that it is a part of learning. This was articulated in both the PBL Experience questionnaire and her post-study interview. Sienna admitted that she had heard this type of phrase many times before, almost as a cliche, but did not believe it because her previous experiences had never made her think it was true. In this sense, the mathematics education unit and simultaneously learning about mindsets explicitly, encouraged her to be more receptive to mastery learning, perhaps due to her emergent mindset. This was a significant development for Sienna.

Although both key informants asserted that they had made progress in attitude and mastery goals, they still had moments when they felt strong emotions and reverted to performance goals. Alicia found this when she was struggling with learning about multiplication and Sienna spoke of a general feeling throughout the unit. This is to be expected in such a short amount of time, but it raises an interesting aspect about people's performance goals.

Cluster 4 – Positive attitude toward mathematics and emergent view of intelligence

Shaun and Susanna made minor positive shifts in their attitude, but saw a drop in their emergent view of intelligence, according to their ATMI and ITI survey scores. It is unclear why the scores dropped as there was nothing within the interview and PBL Experience data that revealed a possible reason for the decline. On the whole, Susanna and Shaun maintained their emergent mindset and mastery-oriented goals.

Susanna and Shaun's main area of growth was attitudinal and appeared to be, at least in part, a result of the student-centred experience, but not the PBL approach directly. Susanna valued and felt positive toward the use of extended problems, hands-on materials and time to work through possible solutions. Susanna and Shaun mentioned that they enjoyed the challenging aspects of the work. For Susanna, these incorporated the more mathematical tasks rather than the teacher education scenarios. In Shaun's case, he found the PBL approach and the linking of theory and practice together provided him with challenge.

Despite the difficulties of the implementation of the unit, which Shaun and Susanna both recognised and raised during their post-study interviews, they still thought the approach was worthwhile.

Summary and implications

The key informants generally seemed impacted during the student-centred mathematics education unit, with a general movement in a positive direction in their attitudes towards mathematics and implicit theories of intelligence. For the latter, some of the ITI survey score shifts were quite significant, as in the case of Leanne and Katherine, but there were some key informants whose scores actually dropped in value. The post-study interview data did not precisely confirm or explain these changes through the responses given. This would have been a worthwhile follow-up question during the interviews. It is possible that because their values were still comfortably in the range of emergent mindsets that their interview responses did not appear inconsistent from their pre-study interviews. Some responses, from Gretel for example, and higher ITI scores, from Katherine, may have signalled a progression towards an emergent mindset, but their other responses were more aligned towards performance goals.

Key informants generally made improvements to their attitudes more than their implicit views of intelligence. When looking at the shift in attitudes more closely in terms of the four factors within the ATMI survey, it appeared the factors of *value* and *motivation* remained stable, while there was a slight increase in *enjoyment*. But the significant gain was in *self-confidence*. Gretel, Alicia and Sienna all moved up more than a rating across the 15 self-confidence items. Druckman and Bjork (1994) describe self-confidence as a person's perception of ability and "a judgment about capabilities for accomplishment of some goal" (p. 173). Both Alicia and Sienna were in Cluster 3 which were participants with a negative attitude towards mathematics and emergent view of intelligence. They believed that people can significantly improve their intelligence with effort, time and learning from failure. Despite this belief, they had struggled with mathematics from much of their learning. Bandura (1986) points out that people who believe that outcomes that are internally controlled by a person, as opposed to people who believe events are beyond their control, behave more self-deterministically. However, if a person who believes they have some significant control of an event's outcomes but is failing despite their efforts to improve would experience low self-confidence. It might be that the increase in their self-confidence over the duration of the unit was an increasing in their learning and a consistency between their beliefs about themselves and the outcomes of their efforts to learn.

It seemed that the changes that became apparent, both in survey scores and interview data, suggested that attitudes were more influenced over the time of the unit than their beliefs of intelligence. Perhaps this is to be expected based on the understanding of attitudes being less stable and more emotional than beliefs, which are stable, less emotional and more cognitive than attitudes (Hannula, 2002; Di Martino & Zan, 2015). This is also consistent with much of the other research in preservice teacher education that suggests:

- students enter teacher education programs with pre-existing beliefs based on their experience of school
- these beliefs are robust and resistant to change
- these beliefs act as filters to new knowledge, accepting what is compatible with current beliefs.

(White et al., 2006)

This study's findings are consistent with other literature, which confirms that preservice teachers' central beliefs are robust (White et al., 2006). It suggests that even more efforts should be given to how to develop experiences that can assist preservice teachers to progress towards more emergent views of intelligence. The literature from Dweck (2015) and others (see for example, Boaler, 2016) has shown that teachers with fixed mindsets make different pedagogical choices, and value different behaviours from their students. Consequently, these can have negative impacts on their students, who, if they become teachers, are likely to continue the cycle because of their experiences.

> Their experiences in primary and secondary schools give them ideas about what school subject matter is like, how students are supposed to act in school, and how teachers are supposed to act in school. Thus, when they begin to teach, they adopt the practices of their former teachers. (Kennedy, 1999, p. 55)

This explains, in part, the difficulties of impacting the beliefs of preservice teachers, but also raises the importance of the learning experiences they have during their mathematics education units. This program has demonstrated that change is possible within a student-centred and supportive environment. Further research, including a longitudinal study along the same lines of this study, would provide a more complete picture of the types of supports required to change different clusters. No communication occurred between participants from different clusters as part of this study. From a social-constructivist perspective, which values mutual interaction, perhaps the combining of clusters with similar and different perspectives in discussion and reflection may act as a catalyst for change among the participants. Further research in this area is justified.

In recent years, as the work of Dweck and others has become more popular, Dweck has observed a tendency for people to espouse emergent mindset beliefs and mastery goals, even though their behaviours do not match.

> In many quarters, a growth mindset had become the right thing to have, the right way to think. It was as though educators were faced with a choice: Are you an enlightened person who fosters students' wellbeing? Or are you an unenlightened person, with a fixed mindset,

> who undermines them? So, of course, many claimed the growth-mindset identity. But the path to a growth mindset is a journey, not a proclamation.
>
> (Dweck, 2015)

It is unclear, in the context of Dweck's comment, if the development in Gretel's mindset was a genuine positive progression towards an emergent theory of intelligence or whether it was more of a "false growth mindset" (Dweck, 2015). It seems further data, including observations, and a more longitudinal perspective are required to be more conclusive about the findings.

Another aspect from Dweck (2015) has attempted to bring greater understanding to the nuance of her framework of implicit theories of intelligence:

> Let's legitimize the fixed mindset. Let's acknowledge that (1) we're all a mixture of fixed and growth mindsets, (2) we will probably always be, and (3) if we want to move closer to a growth mindset in our thoughts and practices, we need to stay in touch with our fixed-mindset thoughts and deeds.
>
> (Dweck, 2015)

Dweck also added recently that we all have triggers that can bring on a shift toward performance goals (Education Week, 2016), which is an important nuance to the theory. These can include challenge, setbacks, criticism, and even being aware of someone more skilled than ourselves. This does make it slightly more difficult to determine a person's positive progress towards a mastery or simply a trigger. Further research would benefit from taking this nuance into consideration, recognising that it is less about whether you are of a fixed or emergent mindset because there is significant social desirability to be of a growth mindset (Schmidt, Shumow, & Kackar-Cam, 2015), and more on the journey to have mastery goals, and identifying the parts that distract us from those goals.

Limitations of the research

Case-study methodology has been the central component for gathering information in this investigation. Multiple research instruments, both qualitative and quantitative, have been employed to enhance the validity of the findings and conclusions. The purpose of the study was to investigate the impact attitudes towards mathematics and implicit theories of intelligence have on the way preservice teachers view the learning and teaching of mathematics. An underlying belief that has inspired this study is the impact of the affective domain on learning mathematics education for students undertaking teacher education courses. This belief has been a source of motivation to gain a deeper understanding of the impact teachers' attitudes and beliefs have on teacher education and mathematics education in particular.

It is acknowledged that this research had limitations that impacted on or influenced the interpretation of the findings. The following issues have been identified as limiting factors within the study:

- The size of the sample used within this research study may not have been representational in its composition. The goal was to incorporate a broad set of qualities in the purposive selection process, but the nature of qualitative studies with key informants insisted that a limited number of participants could be used. Generalisation is not the primary goal of qualitative research and case-study methodology, but rather a rich understanding of the specific (O'Leary, 2004). This study is restricted to certain participants, at a certain time, in a certain place.
- The Hawthorne effect refers to the modification of behaviour by participants in a study, simply due to their awareness of being observed (Adair, 2004). To lessen the possible impact of the phenomenon, the

methodology included the use of a triangulation process. This involved validating findings and conclusions by analysing data from multiple sources, confirming the participants' views of learning and teaching mathematics in relation to their attitude towards mathematics and their implicit theory of intelligence.

- The study relied on self-reported data to an appreciable amount. This is a consequence of researching the affective domain in attitudes and beliefs, as it is often required to obtain information by directly asking the participants (McLeod, 2009). The bias that may appear is often a result of people providing answers in the questionnaire that are socially desirable. To minimise the impact of this effect, a number of strategies were employed. These included the use of triangulation mentioned earlier, observation while undertaking mathematical tasks, along with interviewing techniques such as avoiding leading and closed-ended questions (Kvale, 1996).
- Qualitative research is by its very nature interpretive and, as such, involves the subjectivity of the researcher, which ultimately shapes the research (Hartas, 2010). The following instruments are acknowledged as having a subjective aspect and element of bias: key informant interviews, Critical Moments questionnaire and PBL Experience questionnaire. The use of triangulation was employed to minimise the subjective of interpretations.
- Finally, it is acknowledged that due to the researcher being an early career academic and researcher, there will invariably be parts of this thesis that could be achieved more effectively with hindsight.

However, the study did have significant findings that may be enhanced in future studies with these insights.

Conclusion

It is crucial that in order to improve the quality of mathematics teaching a focus is required on ensuring that preservice teachers have appropriate background knowledge, skills and dispositions. Currently there has been an emphasis at the national and state level on standards, teacher quality and assuring teachers are classroom ready on graduation from teacher education courses (Teacher Education Ministerial Advisory Group, 2014). A critical aspect acknowledged by the Australian Institute for Teaching and School Leadership (AITSL) is the role the affective domain plays in the development of preservice teachers. As part of initial teacher education, preservice teachers need to not only:

> …identify what their values and beliefs are about a particular matter but how they came to have those values and beliefs, that is, what influenced them over time. This is a critical component of effective initial teacher education. We know that if PSTs don't reflect on their own values, beliefs and assumptions, then their teacher education program will have little impact.
>
> (Le Cornu, 2015, p. 7)

A cycle currently exists where many preservice teachers who have previously had poor mathematics learning experiences, reenter the school system still retaining feelings of inadequacy and despair (Tobias, 2002). This is related in a significant way to the preservice teachers' attitudes and mindsets. Teacher education offers a chance to break this perpetual cycle of negative experiences, by acknowledging the impact preservice teachers' attitudes and beliefs have on their learning and modelling a deep commitment to student-centred approaches in mathematics education. Teacher educators need to simultaneously focus efforts on providing supportive, student-centred environments along with opportunities for preservice teachers to question and critique their previous mathematics learning experiences as a way to bring about disruption to this cycle and a wide pedagogical change to our education system.

The research questions which guided this investigation were chosen in an attempt to understand more completely the impact attitudes and mindsets have on preservice teachers' view of learning and teaching mathematics. Within the context of this study, it was apparent that there was a crucial link between the thoughts, feelings and beliefs of preservice teacher and the quality of their actions in the classroom, both as a learner and as a teacher. The findings exposed a link between preservice teachers' attitudes and beliefs and the influence these had on their view of learning and teaching mathematics, including their receptiveness to student-centred learning. The study revealed the wide range of attitudes and mindsets preservice teachers have on entering teacher education courses. Many preservice teachers have negative attitudes toward mathematics and a fixed mindset, both of which have come from their experiences in mathematics classrooms, some even deeply distressing. The implications of this for teacher education are a powerful reminder of the importance of high quality teacher education for dislodging negative dispositions. It reveals that focus in mathematics teacher education units cannot only be on mathematics content skills and pedagogy, but also needs to address the preservice teachers' affect towards mathematics and student-centred learning.

The study has demonstrated that positive changes to preservice teachers' dispositions are possible, however this approach was not completely effective for all preservice teachers. It also demonstrated that student-centred learning approaches were a meaningful path for learning and was more readily endorsed by students with an emergent mindset.

The introductory reference to this thesis from physicist, Richard Feynman, was a response given by a person who had a positive attitude towards his subject and believed that anyone is capable of significant intellectual growth. The ideal we seek is for all teachers of mathematics to begin their teaching experiences with a positive attitude, a growth mindset and a view that teaching and learning requires focus on the learner, as someone who incorporates new knowledge based on their previous experiences.

REFERENCES

Abelson, R. P. (1979). Differences between belief and knowledge systems. *Cognitive Science*, *3*(4), 355–366.

Adair, J. G. (2004). Hawthorne effect. In M. S. Lewis-Beck, A. Bryman, & T. Futing Liao (Eds.), *The SAGE encyclopedia of social science research methods*. Thousand Oaks, CA: SAGE Publications, Inc.

Aiken, L. R. (1976). Update on attitudes and other affective variables in learning mathematics. *Review of Educational Research, 46*, 293–311.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood Cliffs, NJ: Prentice-Hall.

Aldridge, S., & Bobis, J. (2001). Multiple learning contexts: A vehicle for changing preservice primary teachers' mathematical beliefs, knowledge and practices. In J. Bobis, B. Perry, & M. Mitchelmore (Eds.), *Numeracy and beyond: Annual conference of mathematics education research group of Australasia* (pp. 43–49). Sydney: MERGA.

Amit, M., & Fried, M. N. (2008). The complexities of change: Aspects of reform and reform research in mathematics education. In L. D. English (Ed.), *Handbook of international research in mathematics education* (2nd ed.). New York, NY: Routledge.

Anderson, J. (2008). Identifying problem solving in school mathematics: Students' and teachers' perspectives. In J. Vincent (Ed.), *Connected maths* (pp. 14–24). Brunswick, VIC: The Mathematical Association of Victoria.

Anderson, J., Sullivan, P., & White, P. (2004). The influence of perceived constraints on teachers' problem-solving beliefs and practices. Paper presented at Mathematics Education for the Third Millennium: Towards 2010. *Proceedings of the 27th Conference of the Mathematics Education Research Group of Australasia*. Sydney, Australia.

Anderson, V., & Mathematics Education Research Group of Australasia. (2007). *An online survey to assess student anxiety and attitude response to six different mathematical problems*. http://www.merga.net.au/documents/RP32007.pdf

Ashman, D., & McBain, D. (2011). Teacher and preservice teacher beliefs about mathematics teacher education. Paper presented at Mathematics: Traditions and [new] practices. *Proceedings of the 34th annual conference of the Mathematics Education Research Group of Australasia*. Adelaide, SA.

Australian Research Council, National Health and Medical Research Council, and Universities Australia. (2007. *National statement on ethical conduct in human research*. Canberra, ACT: Australian Government.

Babbie, E. R. (2010). *The practice of social research* (12th ed.). Belmont, CA: Wadsworth Cengage.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Barbour, R. S., & Schostak, J. (2005). Interviewing and focus groups. In B. Somekh & C. Lewin (Eds.), *Research methods in the social sciences* (pp. 41–48). London: SAGE Publications.

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education, 20*, 481–486.

Barrows, H. S., & Bennett, K. (1972). The diagnostic (problem solving) skill of the neurologist: Experimental studies and their implications for neurological training. *Archives of Neurology, 26*(3), 273–277.

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. New York: Springer Publishing Company.

Bates, A. B., Latham, N., & Kim, J.-a. (2011). Linking preservice teachers' mathematics self-efficacy and mathematics teaching efficacy to their mathematical performance. *School Science and Mathematics, 111*(7), 325–333.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report, 13*(4), 544–559.

Becker, H. S. (1996). The epistemology of qualitative research. In R. Jessor, A. Colby, & R. A. Shweder (Eds.), *Ethnography and human development: Context and meaning in social inquiry*. London: The University of Chicago Press.

Bennett, A. (2004). Case study methods: design, use, and comparative advantages. In D. S. Sprinz & Y. Wolinsky-Nahmias (Eds.), *Models, numbers, and cases: Methods for studying inter-national relations* (pp. 19–55). Ann Arbor: University of Michigan Press.

Beswick, K. (2006a). Changes in preservice teachers' attitudes and beliefs: The net impact of two mathematics education units and intervening experiences. *School Science and Mathematics, 106*(1), 36–47.

Beswick, K. (2006b). The importance of mathematics teachers' beliefs. *Australian Mathematics Teacher, 62*(4), 17–22.

Beswick, K. (2007). Teachers' beliefs that matter in secondary mathematics classrooms. *Educational Studies in Mathematics, 65*(1), 95–120.

Beswick, K., Watson, J., & Brown, N. (2006). *Teachers' confidence and beliefs and their students' attitudes to mathematics*. Paper presented at the Mathematics Education Research Group of Australasia. http://www.merga.net.au/documents/RP42006.pdf

Blackwell, L. A., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development, 78*(1), 246–263.

Block, J. (1982). Assimilation, Accommodation, and the Dynamics of Personality Development. *Child Development, 53*(2), 281–295.

Boaler, J. (2013). Ability and mathematics: The mindset revolution that is reshaping education *Forum, 55*(1), 143–152.

Boaler, J. (2016). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. San Francisco, CA: Jossey-Bass.

Board of Studies NSW. (2002). *Mathematics K-6 Syllabus*. Sydney, NSW: Board of Studies.

Board of Studies NSW. (2009). *Music 1: Stage 6 syllabus*. Sydney: Board of Studies NSW.

Board of Studies NSW. (2012). *Mathematics K–10 Syllabus*. Sydney, NSW: Board of Studies NSW.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*(10), 873.

Bohlmann, N., & Weinstein, R. S. (2013). Classroom context, teacher expectations, and cognitive level: Predicting children’s math ability judgments. *Journal of Applied Developmental Psychology*, *34*, 288–298.

Boud, D. (Ed.) (1985). *Problem-based learning in education of the professions*. Sydney: Higher Education Research and Development Society of Australasia.

Boud, D., & Feletti, G. (Eds.). (1997). *The challenge of problem-based learning* (2nd ed.). London: Kogan Page Ltd.

Brown, A., Westenskow, A., & Moyer-Packenham, P. (2012). Teaching anxieties revealed: Pre-service elementary teachers’ reflections on their mathematics teaching experiences. *Teaching Education, 23*(4), 365–385.

Bruner, J. S. (1966). *Toward a theory of instruction*. Cambridge, Mass: Belknap Press of Harvard University.

Bruner, J. S. (1997). Celebrating divergence: Piaget and Vygotsky. *Human Development, 40*, 63–73.

Bryman, A. (2012). *Social research methods* (4th ed.). Oxford; New York: Oxford University Press.

Burnette, J. L., & Finkel, E. J. (2012). Buffering against weight gain following dieting setbacks: An implicit theory intervention. *Journal of Experimental Social Psychology, 48*(3), 721–725.

Burnette, J. L., O'Boyle, E. H., VanEpps, E. M., Pollack, J. M., & Finkel, E. J. (2013). Mind-sets matter: A meta-analytic review of implicit theories and self-regulation. *Psychological Bulletin, 139*(3), 655.

Bursal, M., & Paznokas, L. (2006). Mathematics anxiety and preservice elementary teachers' confidence to teach mathematics and science. *School Science and Mathematics, 106*(4), 173–180.

Cady, J. A., & Rearden, K. (2007). Pre-service teachers' beliefs about knowledge, mathematics and science. *School Science and Mathematics, 106*(2), 237–245.

Campbell, S. (2010). Comparative case study. In A. J. Mills, G. Durepos, & E. Wiebe (Eds.), *Encyclopedia of case study research* (pp. 175–176). Thousand Oaks, California: SAGE Publications.

Cannon, R., & Newble, D. (2000). *A guide to improving teaching methods: A handbook for teachers in university and colleges*. London, UK: Kogan Page.

Clarkson, P. C., FitzSimons, G. E., & Seah, W. T. (1999). Values relevant to mathematics? I'd like to see that. In D. Tynam, N. Scott, K. Stacey, G. Asp, J. Dowsey, H. Hollingsworth, & M. B. (Eds.), *Mathematics: Across the ages* (pp. 129–132). Melbourne: Mathematics Association of Victoria.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher*, *23*(7), 13–20.

Cohen, D., & Crabtree, B. (2006). Semi-structured interviews. *Qualitative research guidelines project.* Retrieved from http://www.qualres.org/HomeSemi-3629.html

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education* (5th ed.). New York, NY: Taylor & Francis.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). London; New York, NY: Routledge.

Collopy, R. (2003). Curriculum materials as a professional development tool: how a mathematics textbook affected two teachers' learning. *The Elementary School Journal*, *103*(3), 287–311.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: SAGE Publications.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Thousand Oaks, CA: SAGE Publications.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Crows Nest, NSW: Allen & Unwin.

Daniels, H. (2001). *Vygotsky and pedagogy*. London: Routledge.

Darling-Hammond, L. (2006). Constructing 21st-century teacher education. *Journal of Teacher Education, 57*(3), 300–314.

Darling-Hammond, L., & Lieberman, A. (Eds.). (2012). *Teacher education around the world: Changing policies and practices*. New York, NY: Routledge.

Davey, A. (1972). The explanation of learning. In K. Dixon (Ed.), *Philosophy of education and the curriculum* (pp. 165–202). New York, NY: Pergamon Press Ltd.

DeBellis, V., & Goldin, G. (1997). The affective domain in mathematical problem solving. In E. Pehkonen (Ed.), *Proceedings of the Twenty-First Annual Meeting of PME, Vol. 2* (pp. 209–216). Lahti, Finland: University. of Helsinki.

DeBellis, V., & Goldin, G. (2006). Affect and meta-affect in mathematical problem solving: A representational perspective. *Educational Studies in Mathematics, 63*(2), 131–147.

Denzin, N. K. (2001). The reflexive interview and a performative social science. *Qualitative Research, 1*(1), 23–46.

Dewey, J. (1916). *Democracy and education: An introduction to the philosophy of education*: The Macmillan Company.

DeWitt, P. (2015, December 6). The problem with having a 'growth mindset'. Retrieved from http://blogs.edweek.org/edweek/finding_common_ground/2015/12/the_problem_with_having_a_growth_mindset.html

Di Martino, P., & Zan, R. (2001). *Attitude toward mathematics: some theoretical issues*. Paper presented at the 25th Conference of the International Group for the Psychology of Mathematics Education, Utrecht, The Netherlands.

Di Martino, P., & Zan, R. (2010). ‘Me and maths’: Towards a definition of attitude grounded on students’ narratives. *Journal of Mathematics Teacher Education, 13*(1), 27–48.

Di Martino, P., & Zan, R. (2011). Attitude towards mathematics: A bridge between beliefs and emotions. *ZDM, 43*(4), 471–482.

Di Martino, P., & Zan, R. (2015). The construct of attitude in mathematics education. In B. Pepin & B. Roesken-Winter (Eds.), *From beliefs to dynamic affect systems in mathematics education* (pp. 51–72). Springer International Publishing.

Diefenbach, T. (2009). Are case studies more than sophisticated storytelling?: Methodological problems of qualitative empirical research mainly based on semi-structured interviews. *Quality and Quantity, 43*(6), 875–894.

Diener, C. I., & Dweck, C. S. (1978). An analysis of learned helplessness: Continuous changes in performance, strategy, and achievement cognitions following failure. *Journal of Personality and Social Psychology, 36*(5), 451–462.

Dinham, S. (2013). The quality teaching movement in Australia encounters difficult terrain: A personal perspective. *Australian Journal of Education, 57*(2), 91–106. doi:10.1177/0004944113485840

Druckman, D., & Bjork, R. A. (1994). *Learning, remembering, believing: Enhancing human performance*. Washington, D.C: National Academy Press.

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development*. Hove, East Sussex: Psychology Press.

Dweck, C.S. (2006). *Mindset: the new psychology of success*. New York, NY: Ballantine Books.

Dweck, C. S. (2008). *Mindsets and math/science achievement*. New York, NY: Carnegie Corp. of New York–Institute for Advanced Study Commission on Mathematics and Science Education.

Dweck, C. S. (2014). Teachers' mindsets: "Every student has something to teach me". *Educational Horizons, 93*(2), 10–15.

Dweck, C. S. (2015, September 22). Carol Dweck revisits the 'growth mindset'. Retrieved from http://www.edweek.org/ew/articles/2015/09/23/carol-dweck-revisits-the-growth-mindset.html

Dweck, C. S., Chiu, C., & Hong, Y. (1995). Implicit theories and their role in judgments and reactions: A world from two perspectives. *Psychological Inquiry, 6*(4), 267–285.

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review, 95*(2), 256–273.

Dweck, C. S., & Reppucci, N. D. (1973). Learned helplessness and reinforcement responsibility in children. *Journal of Personality and Social Psychology, 25*(1), 109–116.

Dweck, C. S., Walton, G. M., & Cohen, G. L. (2014). *Academic tenacity: mindsets and skills that promote long-term learning*. Seattle, WA: Bill & Melinda Gates Foundation.

Education Week (Producer). (14 March, 2016). *The journey to a growth mindset: Carol Dweck's live keynote presentation*. Retrieved from https://www.youtube.com/watch?v=kuq91hqUvBg

Eng, C. S. (2000). *Problem-based learning – Educational tool or philosophy.* Paper presented at the Asia-Pacific Conference on Problem-Based Learning, Singapore.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by males and females. *Journal for Research in Mathematics Education 7*(5), 324–326.

Feynman, R. P., Leighton, R., & Hutchings, E. (1985). *"Surely you're joking, Mr. Feynman!": Adventures of a curious character*. New York: W.W. Norton.

Fielding, N. (2010). Mixed methods research in the real world. *International Journal of Social Research Methodology, 13*(2), 127–138.

Finegold, M., & Gorsky, P. (1991). Students' concepts of force as applied to related physical systems: A search for consistency. *International Journal of Science Education, 13*(1), 97–113.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry, 12*(2), 219–245. doi:10.1177/1077800405284363

Foddy, W. (1993). *Constructing questions for interviews and questionnaires: Theory and practice in social research*. Cambridge, UK; New York, NY, USA: Cambridge University Press.

GarCía-Cepero, M. C., & McCoach, D. B. (2009). Educators' implicit theories of intelligence and beliefs about the identification of gifted students.*Universitas Psychologica, 8*(2), 295–310.

Gauvain, M., & Cole, M. (2008). *Readings on the development of children* (5th ed.). Worth Publishers.

Georgiou, S. N. (2008). Beliefs of experienced and novice teachers about achievement. *Educational Psychology, 28*(2), 119–131.

Gerring, J. (2004). What is a case study and what is it good for? *The American Political Science Review, 98*(2), 341–354.

Gibboney, R. A. (2006). Intelligence by design: Thorndike versus Dewey. *Phi Delta Kappan, 88*(2), 170–172.

Gijbels, D., Dobchy, F., Bossche, P. V. d., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research, 75*(1), 27–61.

Gillham, B. (2003). *The research interview*. London: Continuum.

Glassman, M. (2001). Dewey and Vygotsky: Society, experience, and inquiry in educational practice. *Educational Researcher, 30*(4), 3–14.

Goldin, G. A. (2002). Affect, meta-affect, and mathematical belief structures. In G. C. Leder, E. Pehkonen, & G. Törner (Eds.), *Beliefs: A hidden variable in mathematics education* (pp. 59–72). The Netherlands: Kluwer: Dordrecht.

Gonida, E., Kiosseoglou, G., & Leondari, A. (2006). Implicit theories of intelligence, perceived academic competence, and school achievement: Testing alternative models. *The American Journal of Psychology, 119*(2), 223–238.

Green, T. F. (1971). *The activities of teaching*. New York: Mcgraw-Hill.

Grootenboer, P. (2008). Mathematical belief change in prospective primary teachers. *Journal of Mathematics Teacher Education, 11*(6), 479–497.

Grootenboer, P., & Hemmings, B. (2007). Mathematics performance and the role played by affective and background factors. *Mathematics Education Research Journal, 19*(3), 3–20.

Grootenboer, P. J., Lomas, G., & Ingram, N. (2008). The affective domain and mathematics education. In H. Forgasz, A. Barkatsas, A. Bishop, B. Clarke, S. Keast, W. T. Seah, & P. Sullivan (Eds.), *Research in mathematics education in Australasia 2004–2007* (pp. 255–269). Rotterdam: Sense.

Gubrium, J. F., & Holstein, J. A. (2000). Analysing interpretive practice. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 487–508). Thousand Oaks, CA: SAGE Publications.

Handal, B., & Herrington, A. (2003). Mathematics teachers' beliefs and curriculum reform. *Mathematics Education Research Journal, 15*(1), 59–69.

Hannula, M. (2002). Attitude towards mathematics: Emotions, expectations and values. *Educational Studies in Mathematics, 49*(1), 25–46.

Happy & Well. (Producer). (2013, October 20). Carol Dweck "Mindset – The new psychology of success" at Happiness & Its Causes 2013. Retrieved from https://www.youtube.com/watch?v=_X0mgOOSpLU

Harden, R. M., & Stamper, N. (1999). What is a spiral curriculum? *Medical Teacher, 21*(2), 141–143.

Hartas, D. (2010). The epistemological context of quantitative and qualitative research. In D. Hartas (Ed.), *Educational research and inquiry: Qualitative and quantitative approaches* (1st ed.). London: Continuum International Publishing Group.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Oxford, UK: Routledge.

Hattie, J. (2012). *Visible learning for teachers: Maximizing impact on learning*. Oxford, UK: Routledge.

Hawera, N. (2004). *Addressing the needs of mathematically anxious preservice primary teachers*. Paper presented at the Mathematics Education Research Group of Australasia. http://www.merga.net.au/documents/RP332004.pdf

Herrera, T. A., & Owens, D. T. (2001). The "new new math"?: Two reform movements in mathematics education. *Theory into Practice, 40*(2), 84–92.

Heyvaert, M., Maes, B., & Onghena, P. (2013). Mixed methods research synthesis: Definition, framework, and potential. *Qual Quant, 47*, 659–676. doi:10.1007/s11135-011-9538-6

Hiebert, J., Gallimore, R., Garnier, H., Givvin, K. B., Hollingsworth, H., Jacobs, J., . . . Stigler, J. W. (2003). *Teaching mathematics in seven countries: Results from the TIMSS 1999 Video Study*. Washington, DC: Department of Education, National Center for Education Statistics.

Hiebert, J. S., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 371–404). Charlotte, NC: Information Age Publishing.

Hobson, A., & Townsend, A. (2010). Interviewing as educational research method(s). In D. Hartas (Ed.), *Educational research and inquiry: Qualitative and quantitative approaches* (pp. 223–238). London: Continuum International Publishing Group.

Hong, Y.-y., Chiu, C.-y., Dweck, C. S., Lin, D. M.-S., & Wan, W. (1999). Implicit theories, attributions, and coping: A meaning system approach. *Journal of Personality and Social psychology, 77*(3), 588–599.

Hoyle, C. (1992). Mathematics teaching and mathematics teachers: A meta-case study. *For the Learning of Mathematics, 12*(3), 32–44.

Hughes, L. (2008). Identifying situational factors that contribute to mathematics anxiety in middle school students. Crawley WA: University of Western Australia, 2008.

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods, 18*(1), 3–20. doi:10.1177/1525822x05282260

Jackson, K. A. (2015). *Math anxiety and attitudes in pre-service elementary teachers* (Doctor of Education, Rowan University). Retrieved from http://hdl.handle.net/10927/1168

Job, V., Walton, G. M., Bernecker, K., & Dweck, C. S. (2013). Beliefs about willpower determine the impact of glucose on self-control. *Proceedings of the National Academy of Sciences, 110*(37), 14837–14842. doi:10.1073/pnas.1313475110

Jones, B. D., Bryant, L. H., Snyder, J. D., & Malone, D. (2012). Preservice and inservice teachers' implicit theories of intelligence. *Teacher Education Quarterly, 39*(2), 87–101.

Jones, B. D., Byrd, C. N., & Lusk, D. L. (2009). High school students' beliefs about intelligence. *Research in the Schools*, *16*(2), 1–14.

Jones, L. (2007). *The student-centered classroom*. New York, NY: Cambridge University Press.

Jonsson, A.-C., Beach, D., Korp, H., & Erlandson, P. (2012). Teachers' implicit theories of intelligence: Influences from different disciplines and scientific theories. *European Journal of Teacher Education, 4*, 1–14. doi:10.1080/02619768.2012.662636

Junker, N. M., & van Dick, R. (2014). Implicit theories in organizational settings: A systematic review and research agenda of implicit leadership and followership theories. *The Leadership Quarterly, 25*(6), 1154–1173.

Kennedy, M. M. (1999). The role of preservice teacher education. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of teaching and policy* (pp. 54-86). San Francisco, CA: Jossey Bass.

Kilpatrick, J. (2014). History of research in mathematics education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 267–272): Springer Netherlands.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: A Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experimental, and Inquiry-based Teaching. *Educational Psychologist*, 41(2), 75-86.

Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). *Taxonomy of educational objectives: The classification of educational goals. Handbook II: Affective domain*. New York: Holt, Rinehart, and Winston.

Kuiper, J. (1994). Student ideas of science concepts: alternative frameworks? *International Journal of Science Education, 16*(3), 279–292.

Kurtz-Costes, B., McCall, R. J., Kinlaw, C. R., Wiesen, C.A., & Joyner, M. H. (2005). What does it mean to be smart? The development of children’s beliefs about intelligence in Germany and the United States. *Applied Developmental Psychology*, *26*, 217–233.

Kvale, S. (1996). *Interviews: An introduction to qualitative research interviewing*. Thousand Oaks, CA: SAGE Publications.

Lambdin, D., & Walcott, C. (2007). Changes through the years: Connections between psychological learning theories and the school mathematics curriculum. In G. Martin, M. Strutchens, & P. Elliott (Eds.), *The learning of mathematics: Sixty-ninth yearbook* (pp. 3–25). Reston, VA: The National Council of Teachers of Mathematics, Inc.

Lappan, G., & Theule-Lubienski, S. (1992). Training teachers or educating professionals? What are the issues, and how are they being resolved? In D. Robitaille, D. Wheeler, & C. Kieran (Eds.), *Selected lectures from the 7th international congress on mathematical education* (pp. 249–261). Quebec City, Quebec: Les Presses de l’Universite Laval.

Lawrence, M. C., Jill Neumayer, D., Toya Jones, F., Masako, N., Patricia, F. C., Toni, M. S., . . . Youyoung, C. (2014). Teacher characteristics associated with mathematics teachers' beliefs and awareness of their students' mathematical dispositions. *Journal for Research in Mathematics Education, 45*(2), 246–284.

Le Cornu, R. (2015). *Key components of effective professional experience in Initial teacher education in Australia*. Melbourne, VIC: Australian Institute for Teaching and School Leadership.

Lea, S. J., Stephenson, D., & Troy, J. (2003). Higher education students' attitudes to student-centred learning: Beyond 'educational bulimia'? *Studies in Higher Education, 28*(3), 321.

Leder, G. C. (1987). Attitudes towards mathematics. In T. A. Romberg & D. M. Stewart (Eds.), *The monitoring of school mathematics* (Vol. 2, pp. 261–277). Madison: Wisconsin: Centre for Education Research.

Leder, G., & Grootenboer, P. (2005). Affect and mathematics education. *Mathematics Education Research Journal, 17*(2), 1–8.

Leggett, E. L. (1985). *Children's entity and incremental theories of intelligence: Relationships to achievement behavior*. Paper presented at the annual meeting of the Eastern Psychological Association, Boston, MA.

Leith, S. A., Ward, C. L. P., Giacomin, M., Landau, E. S., Ehrlinger, J., & Wilson, A. E. (2014). Changing theories of change: Strategic shifting in implicit theory endorsement. *Journal of Personality and Social Psychology, 107*(4), 597–620. doi:10.1037/a0037699

Leondari, A., & Gialamas, V. (2002). Implicit theories, goal orientations, and perceived competence: Impact on students' achievement behavior. *Psychology in the Schools, 39*(3), 279–291.

Lerman, S. (2000). A case of interpretations of social: A response to Steffe and Thompson. *31*(2), 210–227.

Leroy, N., Bressoux, P., Sarrazin, P., & Trouilloud, D. (2007). Impact of teachers' implicit theories and perceived pressures on the establishment of an autonomy supportive climate. *European Journal of Psychology of Education, 22*(4), 529–545.

Levy, S. R., & Dweck, C. S. (1999). Children's static versus dynamic conceptions of people on stereotype formation. *Child Development, 70*(5), 1163–1180.

Levy, S., Stroessner, S., & Dweck, C. S. (1998). Stereotype formation and endorsement: The role of implicit theories. *Journal of Personality and Social Psychology, 74*, 1421–1436.

Lewin, C. (2005). Elementary quantitative methods. In B. Somekh & C. Lewin (Eds.), *Research methods in the social sciences* (pp. 215–225). London: SAGE.

Loewenberg Ball, D. (1988). *Unlearning to teach mathematics*. Retrieved from College of Education, Michigan State University: http://eric.ed.gov/?id=ED302382

Lomas, G., Grootenboer, P., & Attard, C. (2012). The affective domain and mathematics education. In B. Perry, T. Lowrie, T. Logan, A. MacDonald, & J. Greenlees (Eds.), *Research in mathematics education in australasia 2008–2011* (pp. 23–37). SensePublishers.

Lombardi, J. (Producer). (2010, June 19). Ernst von Glasersfeld on teaching and radical constructivism. Retrieved from https://www.youtube.com/watch?v=YozoZxblQx8

Macpherson, I., Brooker, R., & Ainsworth, P. (2000). Case study in the contemporary world of research: Using notions of purpose, place, process and product to develop some principles for practice. *International Journal of Social Research Methodology, 3*(1), 49–61.

Madni, A., Baker, E. L., Chow, K. A., Delacruz, G. C., & Griffin, N. C. (2015). Assessment of teachers from a social psychological perspective. *Review of Research in Education, 39*(1), 54–86. doi:10.3102/0091732X14558203

Majeed, A. A., Darmawan, I. G. N., & Lynch, P. (2013). A confirmatory factor analysis of attitudes toward mathematics inventory (ATMI). *The Mathematics Educator, 15*(1), 122–136.

Major, C. R., & Palmer, B. (2001). Assessing the effectiveness of problem-based learning in higher education: Lessons from the literature. *Academic Exchange Quarterly, 5*(1).

Mandler, G. (1984). *Mind and body: Psychology of emotion and stress* (1st ed.). New York: W. W. Norton.

Mandler, G. (1989). Affect and learning: Causes and consequences of emotional interactions. In D. B. McLeod & V. M. Adams (Eds.), *Affect and mathematical problem solving* (pp. 3–19). New York: Springer.

Marin, N., Benarroch, A., & Jimenez Gomez, E. (2000). What is the relationship between social constructivism and Piagetian constructivism? An analysis of the characteristics of the ideas within both theories. *International Journal of Science Education, 22*(3), 225–238.

Martin, B. L., & Reigeluth, C. M. (2013). Affective education and the affective domain: Implications for instructional-design theories and models. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (Vol. 2, pp. 485–509). Hoboken: Taylor and Francis.

Mason, J. (2004). Semistructured Interview. *The SAGE Encyclopedia of Social Science Research Methods.* Retrieved from http://dx.doi.org/10.4135/9781412950589

Maybin, J., Mercer, N., & Stierer, B. (1992). "Scaffolding" learning in the classroom. In K. Norman (Ed.), *Thinking voices: The work of the National Orucy Project*. London: Hodder and Stoughton for the National Curriculum Council.

McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. *Handbook of research on mathematics teaching and learning*, 575–596.

McLeod, D. B., & McLeod, S. H. (2002). Synthesis – Beliefs and mathematics education: Implications for learning, teaching, and research. In G. C. Leder, E. Pehkonen, & G. Törner (Eds.), *Beliefs: A hidden variable in mathematics education?* (Vol. 31, pp. 115–123). Netherlands: Springer.

McLeod, S. A. (2009). Attitude Measurement. Retrieved from http://www.simplypsychology.org/attitude-measurement.html

McNeill, P., & Chapman, S. (2005). *Research methods* (3rd ed.). Milton Park, Abingdon: Routledge.

Meaney, T., & Lange, T. (2010). *Pre-service students' responses to being tested on their primary school mathematical knowledge.* Paper presented at Shaping the Future of Mathematics Education: 33rd Annual Conference of the Mathematics Education Research Group of Australasia, Fremantle.

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco, CA: Jossey-Bass.

Mertens, D. M., & Hesse-Biber, S. (2012). Triangulation and mixed methods research: Provocative positions. *Journal of Mixed Methods Research, 6*(2), 75–79. doi:10.1177/1558689812437100

Molden, D. C., & Dweck, C. S. (2000). Meaning and motivation. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 131–159). San Diego, CA: Academic Press.

Monash University (2011). Bachelor of Medicine/Bachelor of Surgery course outline. Retrieved from http://www.med.monash.edu.au/medical/northernvic/course-outline.html

Morris, H. (2001). Issues raised by testing trainee primary teachers' mathematical knowledge. *Mathematics Teacher Education and Development, 3*(2001), 37–47.

Moust, J., Berkel, H. V., & Schmidt, H. (2005). Signs of Erosion: Reflections on Three Decades of Problem-based Learning. *Higher Education*, 50(4), 665 - 683.

Mueller, C. M., & Dweck, C. S. (1998). Praise for intelligence can undermine children's motivation and performance. *Journal of Personality and Social Psychology, 75*(1), 33–52.

Naroth, C., & Luneta, K. (2015). Implementing the Singapore mathematics curriculum in South Africa: Experiences of foundation phase teachers. *African Journal of Research in Mathematics, Science and Technology Education*, 1–11.

National Council of Teachers of Mathematics. (2000). *Principles and standards of school mathematics executive summary*. Reston, VA: National Council of Teachers of Mathematics.

Nebulajr (Producer). (2009, April 15). Richard Feynman Thinking Part 1 of 2. Retrieved from https://www.youtube.com/watch?v=lr8sVailoLw

Neneh, N. B. (2012). An exploratory study on entrepreneurial mindset in the small and medium enterprise (SME) sector: A South African perspective on fostering small and medium enterprise (SME) success. *African Journal of Business Management, 6*(9), 3364–3372.

Nicol, C., & Krykorka, F. (2016). The Place of Problems in Problem Based Learning: A Case of Mathematics and Teacher Education. In M. Filipenko & J. A. Naslund (Eds.), *Problem-Based Learning in Teacher Education* (pp. 173-186). Cham: Springer International Publishing.

Nussbaum, A. D., & Dweck, C. S. (2008). Defensiveness versus remediation: Self-theories and modes of self-esteem maintenance. *Personality and Social Psychology Bulletin, 34*(5), 599–612. doi:10.1177/0146167207312960

Nyikos, M., & Hashimoto, R. (1997). Constructivist theory applied to collaborative learning in teacher education: In search of ZPD. *The Modern Language Journal, 81*(4), 506–517.

O'Leary, Z. (2004). *The essential guide to doing research*. London: SAGE.

Ommundsen, Y., Haugen, R., & Lund, T. (2005). Implicit theories in organizational settings: A systematic review and research agenda of implicit leadership and followership theories. *Scandinavian Journal of Educational Research, 49*(5), 461–474.

Palys, T. (2008). Purposive sampling. *The SAGE encyclopedia of qualitative research methods* (Vol. 2, pp. 697–698). Los Angeles: SAGE.

Payne, S. C., Youngcourt, S. S., & Beaubien, J. M. (2007). A meta-analytic examination of the goal orientation nomological net. *Journal of Applied Psychology, 92*(1), 128–150. doi:10.1037/0021-9010.92.1.128

Peters, J. (2006). *Engaging student teachers through the development and presentation of problem-based scenarios*. Paper presented at the AARE Conference, Adelaide. http://www.aare.edu.au/06pap/pet06136.pdf

Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 257–315). Reston, VA: National Council of Teachers of Mathematics.

Piaget, J. (1928). *Judgment and reasoning in the child*. Patterson, NJ: Littlefield, Adams & Company.

Piaget, J. (1953). *The origins of intelligence in children*. London: Routledge and Kegan Paul.

Piaget, J. (1970). *Science of education and the psychology of the child*. New York: Orion Press.

Pretzlik, U., Olsson, J., Nabuco, M. E., & Cruz, I. (2003). Teachers' implicit view of intelligence predict pupils' self-perception as learners. *Cognitive Development, 18*(4), 579–599.

Purposive sampling. (2012). Retrieved from http://dissertation.laerd.com/purposive-sampling.php

Pyett, P. M. (2003). Validation of qualitative research in the "real world". *Qualitative Health Research, 13*(8), 1170–1179. doi:10.1177/1049732303255686

Ragin, C. C. (1987). *The comparative method: Moving beyond qualitative and quantitative strategies*. Berkely, CA: University of California Press.

Rattan, A., Good, C., & Dweck, C. S. (2012). "It's ok – Not everyone can be good at math": Instructors with an entity theory comfort (and demotivate) students. *Journal of Experimental Social Psychology, 48*, 731–737.

Riegle-Crumb, C., Morton, K., Moore, C., Chimonidou, A., Labrake, C., & Kopp, S. (2015). Do inquiring minds have positive attitudes? The science education of preservice elementary teachers. *Science Education, 99*(5), 819–836.

Rollings-Carter, F. (2000). Learner autonomy. Retrieved from http://www.learnnc.org/lp/editions/linguafolio/5574

Romero, C., Master, A., Paunesku, D., Dweck, C. S., & Gross, J. J. (2014). Academic and emotional functioning in middle school: The role of implicit theories. *Emotion, 14*(2), 227–234. doi:10.1037/a0035490

Rowley, J. (2014). Designing and using research questionnaires. *Management Research Review, 37*(3), 308–330.

Ruggiero, S., Cartelli, A., Duprè, F., & Vicentini-Missoni, M. (1985). Weight, gravity and air pressure: Mental representations by Italian middle school pupils. *European Journal of Science Education, 7*(2), 181–194.

Saldana, J. (2011). *Fundamentals of qualitative research*. Retrieved from http://UNE.eblib.com.au/patron/FullRecord.aspx?p=665394

Sandelowski, M. (2014). Unmixing mixed-methods research. *Research in Nursing & Health, 37*(1), 3–8.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. In A. Walker, H. Leary, C. E. Hmelo-Silve, & P. A. Ertmer (Eds.), *Essential readings in problem-based learning*. West Lafayette, IN: Purdue University Press.

Savin-Baden, M. (2000). *Problem-based learning in higher education: Untold stories*. Buckingham: Society for Research into Higher Edication Open University Press.

Savin-Baden, M., & Major, C. H. (2004). *Foundations of problem-based learning*. New York: Society for Research into Higher Education Open University Press.

Schmidt, J. A., Shumow, L., & Kackar-Cam, H. (2015). Exploring teacher effects for mindset intervention outcomes in seventh-grade science classes. *Middle Grades Research Journal, 10*(2), 17–32.

Schmude, M. J., (2011). EDME145 Primary Mathematics 1: Numeracy. Retrieved from http://moodle.une.edu.au/course/view.php?id=1799

Schulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher 15*(4), 4–14.

Seligman, M. E. P. (1992). *Helplessness: On depression, development, and death*. New York, NY: W. H. Freeman.

Seligman, M. E. P., Maier, S. F., & Solomon, R. L. (1971). Unpredictable and uncontrollable aversive events. In E. R. Brush (Ed.), *Aversive conditioning and learning* (pp. 347–400). New York, NY: Academic Press.

Shively, R. L., & Ryan, C. S. (2013). Longitudinal changes in college math students' implicit theories of intelligence. *Social Psychology of Education, 16*(2), 241–256.

Silver, D. (2011). Using the 'zone' to help reach every learner. *Kappa Delta Pi Record, 48*(1), 28–31.

Simon, M. A. (1994). Learning mathematics and learning to teach: Learning cycles in mathematics teacher education. *Educational Studies in Mathematics, 26*(1), 71–94.

Simon, M. A. (2008). The challenge of mathematics teacher education in an era of mathematics education reform. In B. Jaworski & T. Wood (Eds.),*The International Handbook of Mathematics Teacher Education* (Vol. 4, pp. 17–29). Rotterdam, The Netherlands: Sense Publishers.

Skott, J. (2001). The emerging practices of a novice teacher: The roles of his school mathematics images. *Journal of Mathematics Teacher Education, 4*(1), 3–28.

Slater, M. J., Spray, C. M., & Smith, B. M. (2012). "You're only as good as your weakest link": Implicit theories of golf ability. *Psychology of Sport and Exercise, 13*(3), 280–290.

Smith, M. S., & Friel, S. N. (2008). Cases in Mathematics Teacher Education. In M. S. Smith & S. N. Friel (Eds.), *Cases in Mathematics Teacher Education: Tools for Developing Knowledge Needed for Teaching* (pp. 1-8). Association of Mathematics Teacher Educators.

Speer, N. M. (2005). Issues of methods and theory in the study of mathematics teachers' professed and attributed beliefs. *Educational Studies in Mathematics, 58*(3), 361–391.

Stacey, K. (2010). *Mathematics teaching and learning to reach beyond the basics*. Paper presented at Make it count: What research tells us about effective mathematics teaching and learning, Melbourne.

Staddon, J. (2014). *The new behaviorism* (2nd ed.). New York, NY: Psychology Press.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: SAGE Publications.

Stake, R. E. (2000). Case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 435–453). Thousand Oaks: SAGE Publications.

Sun, K. L. (2014). *Math teacher mindset and classroom practices.* Paper presented at the The Joint Meeting of PME 38 and PME-NA 36, Vancouver, Canada.

Swan, M. (2005). *Improving learning in mathematics: Challenges and strategies*. Department for Education and Skills Standards Unit.

Tapia, M., & Marsh, G. E. (2000). *Attitudes toward mathematics instrument: An investigation with middle school students*. Paper presented at the annual meeting of the Mid-South Educational Research Association, Bowling Green, KY.

Tapia, M., & Marsh, G. E. (2002). *Confirmatory factor analysis of the attitudes toward mathematics inventory*. Paper presented at the annual meeting of the Mid-South Education Research Association, Chattanooga, TN.

Tapia, M., & Marsh, G. E. (2004). An instrument to measure mathematics attitudes. *Academic Exchange Quarterly, 8*(2).

Tapia, M., & Marsh, G. E. (2005). Attitudes toward mathematics inventory redux. *Academic Exchange Quarterly* (22 September).

Taplin, M. (2008). Mathematics through problem solving. Retrieved from http://www.mathgoodies.com/articles/problem_solving.html

Tempelaar, D. T., Rienties, B., Giesbers, B., & Gijselaers, W. H. (2015). The pivotal role of effort beliefs in mediating implicit theories of intelligence and achievement goals and academic motivations. *Social Psychology of Education, 18*(1), 101–120.

Terry, C., Jones, G., & Hurford, W. (1985). Children's conceptual understanding of forces and equilibrium. *Physics Education, 20*(4), 162–185.

Thadani, V., Breland, W., & Dewar, J. (2015). Implicit theories about teaching skills predict university faculty members' interest in professional learning. *Learning and Individual Differences, 40*, 163–169.

Thien, L., Darmawan, I. G., & Ong, M. (2015). Affective characteristics and mathematics performance in Indonesia, Malaysia, and Thailand: What can PISA 2012 data tell us? *Large-scale Assessments in Education, 3*(3), 1–16.

Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 127–146). New York: Macmillan Publishing.

Thorndike, E. L. C. (1927). The law of effect. *The American Journal of Psychology, 39*(1/4), 212–222.

Tigelaar, D. E. H., Dolmans, D. H. J. M., Wolfhagen, I. H. A. P., & van der Vleuten, C. P. M. (2004). The development and validation of a framework for teaching competencies in higher education. *Higher Education, 48*(2), 253–268. doi:10.1023/B:HIGH.0000034318.74275.e4

TIMSS Video Mathematics Research Group. (2003). Understanding and improving mathematics teaching: Highlights from the TIMSS video study. *Phi Delta Kappan*, 768–775.

Tobias, S. J. (2002). *A learner centred approach to mathematics education for preservice teachers.* (Doctor of Philosophy), La Trobe University, Bundoora, VIC.

Tomlinson, S. (1997). Edward Lee Thorndike and John Dewey on the science of education. *Oxford Review of Education, 23*(3), 365–383.

University of New England. (2011). EDME145 Primary Mathematics 1: Numeracy. Retrieved from https://my.une.edu.au/courses/2011/units/EDME145

van den Heuvel-Panhuizen, M. (2010). Reform under attack – Forty years of working on better mathematics education thrown on the scrapheap? No way! . Paper presented at Shaping the Future of Mathematics Education. *Proceedings of the 33rd Annual Conference of the Mathematics Education Research Group of Australasia* , Freemantle.

Viennot, L. (1979). *Le raisonnement spontané en dynamique élémentaire*. Paris: Hermann.

Vincent, J., & Stacey, K. (2008). Do mathematics textbooks cultivate shallow teaching? Applying the TIMSS video study criteria to Australian eighth-grade mathematics textbooks. *Mathematics Education Research Journal, 20*(1), 82–107.

von Glasersfeld, E. (1990). Chapter 2: An exposition of constructivism: Why some like it radical. *Journal for Research in Mathematics Education. Monograph, 4*, 19–210.

von Glasersfeld, E. (2005). Thirty Years Constructivism. *Constructivist Foundations, 1*(1), 9–12.

Vygotsky, L. S., & Cole, M. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Walton, H. J., & Matthews, M. B. (1989). Essentials of problem-based learning. *Medical Education, 23*(6), 542–558.

Wass, R., & Golding, C. (2014). Sharpening a tool for teaching: The zone of proximal development. *Teaching in Higher Education, 19*(6), 671–684.

Watts, D. M. (1983). A study of schoolchildren's alternative frameworks of the concept of force. *European Journal of Science Education, 5*(2), 217–230.

Watts, D. M., & Zylbersztajn, A. (1981). A survey of some children's ideas about force. *Physics Education, 16*(6), 360–365.

Webb, E. J., Campbell, D. T., Schwartz, D., & Sechrest, L. (1966). *Unobtrusive measures: Nonreactive research in the social sciences*. Chicago, US: Rand NcNally.

Welch, T. (2007). Introduction to teaching mathematics through problem solving. Retrieved from http://cnx.org/content/m14800/1.1/

Wertsch, J. V. (1984). The zone of proximal development: Some conceptual issues. *New Directions for Child and Adolescent Development, 1984*(23), 7–18.

White, A. L., Way, J., Perry, B., & Southwell, B. (2006). Mathematical attitudes, beliefs and achievement in primary pre-service mathematics teacher education. *Mathematics Teacher Education and Development, 7*(2005/2006), 33–52.

Wiersma, W., & Jurs, S. G. (2009). *Research methods in education: An introduction* (9th ed.). Boston, MA: Pearson.

Willis, J. W. (2007). World views, paradigms, and the practice of social science research. *Foundations of qualitative research: Interpretive and critical approaches* (pp. 1–27). Thousand Oaks, CA: SAGE Publications, Inc.

Wilson, C. L. (2015). *The effect of implicit self-theories of intelligence on task persistence and performance in an adult sample: Test of a structural model* (Doctor of Philosophy), Colorado State University, Fort Collins, Colorado.

Wyness, M. (2010). Children's and young people's participation within educational and civic settings: A comparative case study approach to research. In D. Hartas (Ed.), *Educational research and inquiry: qualitative and quantitative approaches*. London: Continuum International Publishing Group.

Yates, S. (2009). Teacher identification of student learned helplessness in mathematics. *Mathematics Education Research Journal, 21*(3), 86–106.

Yazan, B. (2015). Three approaches to case study methods in education: Yin, Merriam, and Stake. *The Qualitative Report, 20*(2), 134–152.

Yin, R. K. (1984). *Case study research: Design and methods*. Beverly Hills, Calif.: SAGE Publications.

Yin, R. K. (2009). *Case study research: Design and methods*. Los Angeles: SAGE Publications.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Los Angeles: SAGE Publications.

Young-Loveridge, J. (2010). Two decades of mathematics education reform in New Zealand: What impact on the attitudes of teacher education students? Paper presented at Shaping the Future of Mathematics Education. *Proceedings of the 33rd Annual Conference of the Mathematics Education Research Group of Australasia*, Freemantle, Western Australia, Australia.

Zan, R., Brown, L., Evans, J., & Hannula, M. (2006). Affect in mathematics education: An introduction. *Educational Studies in Mathematics, 63*(2), 113–121.

Zan, R., & Di Martino, P. (2009). *Different profiles of attitude toward mathematics: the case of learned helplessness.* Paper presented at the 33rd Conference of the International Group for the Psychology of Mathematics Education, Thessaloniki, Greece.

APPENDICES

APPENDIX 1

ATMI AND ITI SURVEYS

information for participants and Consent

Information sheet for participants

Dear Student,

I wish to invite you to participate in my research on problem-based learning (PBL) in mathematics education. The details of the study follow and I hope you will consider being involved. I am conducting this research project for my Master of Education at the University of New England. My supervisors are Associate Professor Stephen Tobias and Dr Pep Serow of University of New England. Steve can be contacted by email at stobias@une.edu.au or by phone on 02 6773 2573. Pep can be contacted by email at pserow2@une.edu.au or by phone on 02 6773 2378.

Aim of the Study
PBL is an innovative approach to learning. While mostly used in medicine, PBL has found its way into law, architecture, engineering. This study wishes to investigate the experiences of preservice primary teachers participating in an 11-week long mathematics education unit (EDME145) at UNE.

Participants
You are being invited to particpate in the study because you are over 18 years old, and are enrolled in EDME145 (Primary Mathematics 1: Numeracy). These are the only requirements for particpants involved in this study.

What data will be collected?
For this part of the study, we would like to collect your attitude towards mathematics and beliefs about intelligence. There are also some general background information required, such as your name and mode of university study. The data will be kept on a password-protected computer in Dr Steve Tobias' office for five (5) years following thesis submission and then it will be destroyed.

Research Process
Your responses will be strictly kept confidential. The data collected in this study will used in a dissertation and may also be presented at conferences and/or written up in journals. No identifying information of participants will be included in the publications.

Participation in this study is completely voluntary. You may withdraw from the project at any time by closing down the webpage. There will be no disadvantage if you decide not to participate or withdraw. It is unlikely that this research will raise any personal or upsetting issues, but if it does, you may wish to contact the UNE Counselling service (02 6773 2897).

This project has been approved by the Human Research Ethics Committee of the University of New England (Approval No. HE11/126, Valid to 13/07/2012)

Should you have any complaints concerning the manner in which this research is conducted, please contact the Research Ethics Officer at the following address:

Research Services
University of New England
Armidale, NSW 2351.
Telephone: (02) 6773 3449
Facsimile (02) 6773 3543
Email: ethics@une.edu.au

Thank you for considering this request and I look forward to gaining your support for the project.

Regards,

Martin Schmude
Mathematics Education
University of New England
Email: mschmud2@une.edu.au
Ph: 6773 2943

Consent form for participants

If you are feel happy to proceed, please continue by selecting your option below. As the teacher/researcher, Marty will not see any of the data until after the unit has been completed. If you are unclear about any of the above information, please contact Dr Neil Taylor with your query, before you continue. His contact details are:

Dr Neil Taylor
02 6773 5064
ntaylor6@une.edu.au

- ◯ YES, I have read and understand the above information and I DO GIVE PERMISSION to use my data anonymously for research purposes. I understand that I may withdraw at any time. I understand that my responses may be published using a pseudonym (fake name). I confirm that I am over 18 years of age.
- ◯ NO, I have read and understand the above information and I DO NOT GIVE PERMISSION for my responses to be used anonymously for research purposes OR I am not yet over 18 years of age. [You have chosen to not participate and can now close this webpage]

Background information

First name

Last name

UNE student number

UNE email address

Mode of university study

- ◯ On-campus (internal)
- ◯ Off-campus (external)

Attitude towards mathematics

Please select the value that most suits what you believe.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
Mathematics is a very worthwhile and necessary subject.	◯	◯	◯	◯	◯	◯
I want to develop my mathematical skills	◯	◯	◯	◯	◯	◯
I get a great deal of satisfaction out of solving a mathematics problem	◯	◯	◯	◯	◯	◯
Mathematics helps develop the mind and teaches a person to think	◯	◯	◯	◯	◯	◯
Mathematics is important in						

everyday life	○	○	○	○	○	○
Mathematics is one of the most important subjects for people to study	○	○	○	○	○	○
High schools mathematics courses are very helpful no matter what I decide to study at university	○	○	○	○	○	○
I can think of many ways that I can use mathematics outside of school	○	○	○	○	○	○

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
Mathematics is one of my most dreaded subjects	○	○	○	○	○	○
My mind goes blank and I am unable to think clearly when working with mathematics	○	○	○	○	○	○
Studying mathematics makes me feel nervous	○	○	○	○	○	○
Mathematics makes me feel uncomfortable	○	○	○	○	○	○
I am always under a terrible strain in a mathematics class	○	○	○	○	○	○
When I hear the word mathematics, I have a feeling of dislike	○	○	○	○	○	○
It makes me nervous to even think about having to do a mathematics problem	○	○	○	○	○	○
Mathematics does not scare me at all	○	○	○	○	○	○

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
I have a lot of self-confidence when it comes to mathematics	○	○	○	○	○	○
I am able to solve mathematics problems without too much difficulty	○	○	○	○	○	○
I expect to do fairly well in any mathematics class	○	○	○	○	○	○
I am always confused in a mathematics class	○	○	○	○	○	○
I feel a sense of insecurity when attempting mathematics	○	○	○	○	○	○
I learn mathematics easily	○	○	○	○	○	○
I am confident that i could learn advanced mathematics	○	○	○	○	○	○
I usually enjoyed studying mathematics at school	○	○	○	○	○	○

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
Mathematics is dull and boring	○	○	○	○	○	○
I like to solve new problems in mathematics	○	○	○	○	○	○
I would prefer to do an assignment in mathematics than write an essay	○	○	○	○	○	○
I would like to avoid using mathematics at university	○	○	○	○	○	○
I really like mathematics	○	○	○	○	○	○
I am happier in a mathematics						

class than any other class	○	○	○	○	○	○
Mathematics is a very interesting subject	○	○	○	○	○	○
I am willing to take more than required amount of mathematics	○	○	○	○	○	○
	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
I plan to take as much mathematics as I can during my education	○	○	○	○	○	○
The challenge of mathematics appeals to me	○	○	○	○	○	○
I think studying advanced mathematics is useful	○	○	○	○	○	○
I believe studying mathematics helps me with problem solving in other areas.	○	○	○	○	○	○
I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in mathematics	○	○	○	○	○	○
I am comfortable answering questions in mathematics class	○	○	○	○	○	○
A strong mathematics background could help me in a professional life	○	○	○	○	○	○
I believe I am good at solving mathematics problems	○	○	○	○	○	○
	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree

Intelligence survey

This section of the questionnaire has been designed to investigate ideas about intelligence. There are no right or wrong answers. We are simply interested in your ideas.

Using the scale below, please indicate the extent to which you agree or disagree with each of the following statements.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
You have a certain amount of intelligence, and you can't really do much to change it.	○	○	○	○	○	○
Your intelligence is something about you that you can't change very much.	○	○	○	○	○	○
No matter who you are, you can significantly change your intelligence level.	○	○	○	○	○	○
To be honest, you can't really change how intelligent you are.	○	○	○	○	○	○
You can always substantially change how intelligent you are.	○	○	○	○	○	○
You can learn things, but you can't really change your basic intelligence	○	○	○	○	○	○
No matter how much intelligence you have, you can always change it quite a bit.	○	○	○	○	○	○
You can change even your basic intelligence level considerably.	○	○	○	○	○	○

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree

Intelligence

Select the sentence that is most true for you.

- I usually think I'm intelligent
- I wonder if I'm intelligent

Thinking of your previous answer (shown below), use the slider to show how true the statement is for you.

	Very true for me		True for me		Sort of true for me	
	5	4	3	2	1	0
${q://QID27/ChoiceGroup/SelectedChoices}						

Select the sentence that is most true for you

- When I get new work at university, I'm usually sure I will be able to learn it.
- When I get new work at university, I often think I may not be able to learn it.

Thinking of your previous answer (shown below), use the slider to show how true the statement is for you.

	Very true for me		True for me		Sort of true for me	
	5	4	3	2	1	0
${q://QID29/ChoiceGroup/SelectedChoices}						

Select the sentence that is most true for you

- I'm not very confident about my intellectual ability
- I feel pretty confident about my intellectual ability

Thinking of your previous answer (shown below), use the slider to show how true the statement you chose is for you.

	Very true for me		True for me	Sort of true for me	
	5	4	3	1	0
${q://QID31/ChoiceGroup/SelectedChoices}					

Goals

For the next question, there is no right answer - different students make different choices. Just select the one you would prefer.

Over the semester, we have different kinds of problems we will work on in the unit. Which problems would you like?

- ◯ Problems that aren't too hard, so I don't get many wrong.
- ◯ Problems that I'll learn a lot from, even if I won't look smart.
- ◯ Problems that are pretty easy, so I'll do well.
- ◯ Problems that I'm pretty good at, so I can show that I'm smart.

Please select the choice that best reflects your choice.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
If I knew I wasn't going to do well at a task, I probably wouldn't do it even if I might learn a lot from it.	◯	◯	◯	◯	◯	◯
Although I hate to admit it, I sometimes would rather do well in a class than learn a lot.	◯	◯	◯	◯	◯	◯
It's much more important for me to learn things in my classes than it is to get the best grades.	◯	◯	◯	◯	◯	◯

If I HAD to choose between getting a good grade and being challenged in class, I would choose ...

- ◯ Good grade
- ◯ Being challenged

Aspects of intelligence

Complete the following sentence. There is no right or wrong answer, we are interested in what you believe.

I define 'intelligence' as ...

[ ]

Who is more intelligent?

- ◯ Someone who works hard
- ◯ Someone who doesn't have to work hard

Complete the equation by entering the percentage you believe is true. The two numbers must add to 100.

INTELLIGENCE (100%) =

[0] % effort + [0] % ability

Thank you

Thank you for telling us your thoughts about mathematics and intelligence.

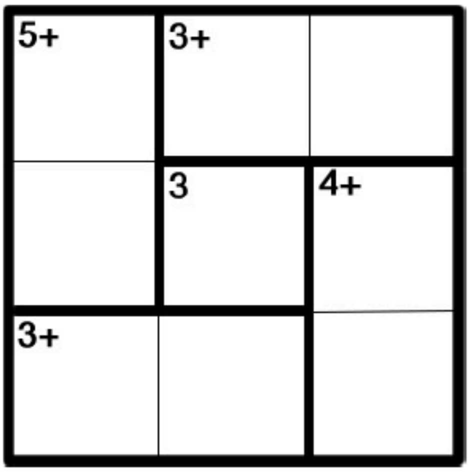
If you have any queries about the unit, please contact Marty. If have any queries about the research, please contact Steve.

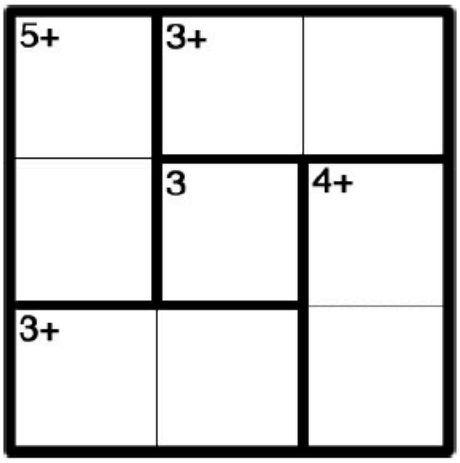
Marty Schmude
mschmud2@une.edu.au

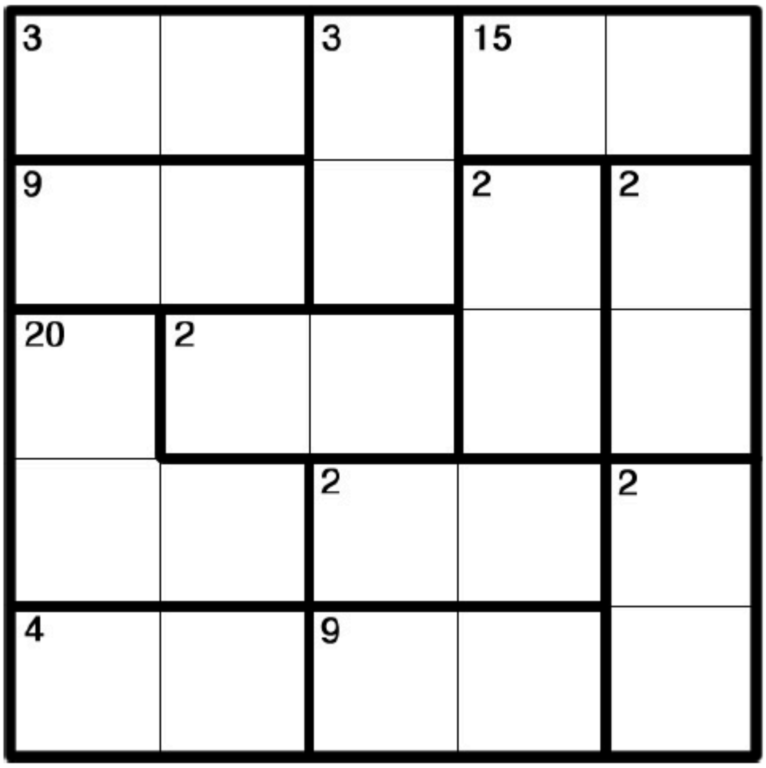
Steve Tobias
stobias@une.edu.au

APPENDIX 2

KENKEN PUZZLES







APPENDIX 3

CRITICIAL MOMENTS QUESTIONNAIRE

Introduction

Introduction

In this task, we would like you to reflect on your mathematics experiences prior to beginning university. In this reflection you are to consider the role of the maths teachers you had, the content of the mathematics, and your experiences as a learner of mathematics. The task will help us gauge your dispositions to learning mathematics and act as a guide to developing your approaches to teaching mathematics to primary students.

We will ask you to describe any 'critical moments' in your mathematics education and how you felt at that time. We would like you to consider three aspects of your mathematics education relating to:

1. the teachers,
2. the mathematics content, and
3. your views as a learner of mathematics.

Your feedback will be summarised and used to provide:

- Information to tutors and course coordinators about the groups needs and expectations
- Group feedback to you, the students in this unit
- Input to our unit review
- Discussion material throughout this unit and the following Mathematics Education units you will complete in Years 2 and 3.

No identifiable data will ever be presented to anyone outside the lecturers in this course.

information for participants and Consent

une
University of New England

Research project

Information sheet for participants

Dear Student,

I wish to invite you to participate in my research on problem-based learning (PBL) in mathematics education. The details of the study follow and I hope you will consider being involved. I am conducting this research project for my PhD at the University of New England. My supervisors are Associate Professor Stephen Tobias and Dr Pep Serow of University of New England. Steve can be contacted by email at stobias@une.edu.au or by phone on 02 6773 2573. Pep can be contacted by email at pserow2@une.edu.au or by phone on 02 6773 2378.

Aim of the Study
PBL is an innovative approach to learning. While mostly used in medicine, PBL has found its way into law, architecture, engineering. This study wishes to investigate the experiences of preservice primary teachers participating in an 11-week long mathematics education unit (EDME145) at UNE.

Participants
You are being invited to participate in the study because you are over 18 years old, and are enrolled in EDME145 (Primary Mathematics 1: Numeracy). These are the only requirements for participants involved in this study.

What data will be collected?
For this part of the study, we would like to collect your responses to the following questionnaire, which asks you to reflect on your past learning experiences in mathematics. For the whole study, we would like to invite you to complete,

- *An attitude-towards-mathematics* survey at the beginning and end of the PBL unit.
- *A PBL questionnaire*, which will be completed near the conclusion of the unit.

All questionnaires and surveys should take approximately 20 minutes to complete. The data will be kept on a password-protected computer in Dr Steve Tobias' office for five (5) years following thesis submission and then destroyed.

The following data is part of the EDME145 unit, but I would like to ask your permission to use the data anonymously for my study.

- *The two unit assignments*, which firstly involves reflecting on your past mathematics learning experiences, and secondly asks for a written assessment report of a student doing some mathematics.
- *The end-of-semester examination*, which involves questions on the work covered throughout the semester.
- *Weekly online activity*, which involves discussions, summaries of weekly scenarios and activities.
- *UNE student evaluations*
- The researcher would also like to take notes of observations during the PBL tutorial sessions (on-campus). This will contribute to the researcher's diary.

A small selection (10-12) of students will be invited twice in the semester, to participate in focus group discussions. The focus group sessions will inquire about the participants' experiences during the PBL unit.

A small selection (approx 10) of students will be invited towards the end of the semester, to participate in a one-to-one interview with the researcher. This interview will inquire about the students' experiences during the PBL unit.

The data will be kept on a password-protected computer in Dr Steve Tobias' office for five (5) years following thesis submission and then it will be destroyed.

Research Process
Your responses will be strictly kept confidential. The data collected in this study will used in a dissertation and may also be presented at conferences and/or written up in journals. No identifying information of participants will be included in the publications.

Participation in this study is completely voluntary. You may withdraw from the project at any time by closing down the webpage. There will be no disadvantage if you decide not to participate or withdraw. It is unlikely that this research will raise any personal or upsetting issues, but if it does, you may wish to contact the UNE Counselling service (02 6773 2897).

This project has been approved by the Human Research Ethics Committee of the University of New England (Approval No. HE11/126, Valid to 13/07/2012)

Should you have any complaints concerning the manner in which this research is conducted, please contact the Research Ethics Officer at the following address:

Research Services
University of New England
Armidale, NSW 2351.
Telephone: (02) 6773 3449
Facsimile (02) 6773 3543
Email: ethics@une.edu.au

Thank you for considering this request and I look forward to gaining your support for the project.

Regards,

Martin Schmude
Mathematics Education
University of New England
Email: mschmud2@une.edu.au
Ph: 6773 2943

Consent form for participants

If you are feel happy to proceed, please continue by selecting your option below.If you have read and understand the research project, please choose your option below and continue. If you are unclear about any of the previous information, please contact Dr Neil Taylor with your query, before you continue. His contact details are:

Dr Neil Taylor
02 6773 5064
ntaylor6@une.edu.au

○ YES, I have read and understand the above information and I DO GIVE PERMISSION to use my data anonymously for research purposes. I understand that I may withdraw at any time. I understand that my responses may be published using a pseudonym (fake name). I confirm that I am over 18 years of age.

- NO, I have read and understand the above information and I DO NOT GIVE PERMISSION for my responses to be used anonymously for research purposes OR I am not yet over 18 years of age.

Background information

First name

Last name

UNE Student number

UNE email address

Mode of university study

- On-campus (internal student)
- Off-campus (external student)

Gender

- Female
- Male

Age group

- 18-19 years of age
- 20-25
- 26-30
- 31-35
- 36-40
- 41-45
- 46-50
- 50+

Block 6

Describe what you believe what mathematics is about.

If mathematics was a food, what would it be and why?

Critical moments survey

We would like to see how your prior experiences of learning mathematics varied during your years at school. In the next section you will be asked to provide details concerning the highs and lows. We would like you to pay particular attention to any significant changes in your experiences.

We understand that it is sometimes difficult to recall all your previous mathematical experiences, so please just choose the closest rating to how you remember feeling about maths that year.

	Kindergarten	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Now (university)
Strongly disliked														
Disliked														
Ambivalent														
Liked														
Strongly liked														
NA - Not applicable														

We would like to know the context in which you identified the high and lows of your experiences in learning mathematics at school.

Think of the positive experiences you had in learning mathematics. Please briefly describe a key positive maths moment or moments while at school. In particular, explain why it was positive in relation to:

1. the teacher,
2. the mathematical content taught, and
3. your perspective as the learner.

Each aspect may not be equally important in your key positive moment.

(approx 250-500 words please)

Think of the negative experiences you had in learning mathematics.
Please briefly describe a key negative maths moment or moments while at school. In particular, explain why it was negative in relation to:

1. the teacher

2. the mathematical content taught
3. your perspective as the learner.

Each aspect may not be equally important in your key positive moment.
(approx. 250-500 words please)

Schooling information

Where did you finish your secondary schooling?

What year did you finish high school (YYYY)?

Highest level of secondary school completed?

- Year 12
- Year 11
- Year 10
- Year 9

Which Year 11 or 12 level of maths did you complete (NSW or equivalent)?

The following maths subjects are generic names for the three levels of mathematics that can be studied in Australian schools.

- General mathematics (lower level)
- Mathematics (middle level)
- Advanced mathematics (higher level)
- Did not do Mathematics in Year 12

Thank you

Thank you for telling us about your experiences while learning mathematics. We will compile this information and provide you with feedback later in the semester.

If you have any queries about the unit, please contact Marty. If your query is to do with the research, please contact Steve.

Marty Schmude
mschmud2@une.edu.au

Steve Tobias
stobias@une.edu.au

APPENDIX 4

PBL EXPERIENCE QUESTIONNAIRE

Introduction

Introduction

Dear Student,

I hope you enjoyed your time with Brenda and Marty studying EDME 145.

You will notice that the work contained

As this approach is different to anything you may have experienced before, we'd appreciate finding out a little more about your learning experiences. The questionnaire should take at most 20 minutes to complete.

Your feedback is completely confidential and will be summarised and used to provide:

- Information to PBL tutors and course coordinators about your needs and expectations
- Feedback to the PBL tutors
- Input to our unit review
- Data for research papers and presentations (see next page)

Thanks

Marty Schmude
Dr Steve Tobias
Dr Pep Serow
Dr Brenda Wolodko

PhD information and Consent

Research project
Information Sheet for Participants

Dear Student,

I wish to invite you to participate in my research on problem-based learning (PBL) in mathematics education. The details of the study follow and I hope you will consider being involved. I am conducting this research project for my Master of Education at the University of New England. My supervisors are Associate Professor Stephen Tobias and Dr Pep Serow of University of New England. Steve can be contacted by email at stobias@une.edu.au or by phone on 02 6773 2573. Pep can be contacted by email at pserow2@une.edu.au or by phone on 02 6773 2378.

Aim of the Study
PBL is an innovative approach to learning. While mostly used in medicine, PBL has found its way into law, architecture, engineering. This study wishes to investigate the experiences of preservice primary teachers participating in an 11-week long mathematics education unit (EDME145) at UNE.

Participants
You are being invited to particpate in the study because you are over 18 years old, and are enrolled in EDME145 (Primary Mathematics 1: Numeracy). These are the only requirements for particpants involved in this study.

What data will be collected?
For this part of the study, we would like to collect your responses to the following questionnaire, which asks you to reflect on your past learning experiences in mathematics. There are also some general background information required, such as what level of maths you completed at school, and your age group. The data will be kept on a password-protected computer in Dr Steve Tobias' office for five (5) years following thesis submission and then it will be destroyed.

Research Process
Your responses will be strictly kept confidential. The data collected in this study will used in a dissertation and may also be presented at conferences and/or written up in journals. No identifying information of participants will be included in the publications.

Participation in this study is completely voluntary. You may withdraw from the project at any time by closing down *the webpage. There will be no disadvantage if you decide not to participate or withdraw. It is unlikely that this research will raise any personal or upsetting issues, but if it does, you may wish to contact the UNE Counselling service (02 6773 2897).*

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Facsimile (02) 6773 3543
Email: ethics@une.edu.au

Thank you for considering this request and I look forward to gaining your support for the project.

Regards,

Martin Schmude
Mathematics Education
University of New England
Email: mschmud2@une.edu.au
Ph: 6773 2943

Consent Form for Students

If you are unclear about any of the above information, please contact Dr Neil Taylor with your query, before you continue. His contact details are:

Dr Neil Taylor
02 6773 5064
ntaylor6@une.edu.au

- ○ YES, I have read and understand the above information and I DO GIVE PERMISSION responses to be used anonymously for research purposes. I understand that I may withdraw at any time. I understand that my responses may be published using a pseudonym (fake name). I confirm I am over 18 years of age.
- ○ NO, I have read and understand the above information and I DO NOT GIVE PERMISSION for my responses to be used anonymously for research purposes OR I am not yet over 18 years of age.

Background information

First name

____

Last name

____

PBL experience

Over this semester, you have participated in a unit that presented extended tasks and challenges at the start of the learning. This is instead of short, repetitive tasks. This approach is known as problem-based learning. Keeping this mind, please answer the following questions.

What 3 things have you most valued about learning through these types of questions?

What aspects of the unit do you feel have been helpful to you?

Block 5

What three (3) things do you feel you have learnt about LEARNING MATHEMATICS during the unit?

What three (3) things do you feel you have learnt about TEACHING MATHEMATICS during the unit?

Please select three (3) or four (4) words from the following list that describe your feeling about LEARNING mathematics.

- ☐ Inspired
- ☐ Challenging
- ☐ Excited
- ☐ Scared
- ☐ Out of my depth
- ☐ Interested
- ☐ Empowered
- ☐ Waste of time

Feel free to add any other words that describe your feelings about LEARNING mathematics.

Change

Do you think that your feelings towards learning mathematics has changed during this unit?

Yes

No

Please describe this change in your feelings in your own words.

Do you feel that your belief towards learning mathematics has changed during this unit?

Yes

No

Please describe this change in your beliefs in your own words.

What do you believe 'mathematics' is?

If mathematics was a food, what would it be and why?

Block 7

Mastery Learning

During the semester, you were introduced to the ideas of mastery learning, performance learning and learned helplessness.

Mastery learning = embrace challenge, learn the work rather than focus on the mark, see getting things wrong as part of the process of learning something new - not a sign of smart/dumb

Performance learning = focus on grade/ pleasing teacher or parent/ avoid challenge/ prefers easy work.

Learned helplessness = the reaction people can have when they believe that the situation is out of their influence (helpless), even if it is not true. A broad term also includes anxiety, fear and the qualities of performance learning.

Describe how this has impacted on you during the semester and if it has changed your perspective on learning (mathematics or in general).

Thank you

Thank you for telling us about your experiences while learning mathematics education using PBL.

If you have any queries regarding the unit, please contact Marty. if you have a query about the research, please contact Steve.

Marty Schmude
mschmud2@une.edu.au

Steve Tobias
stobias@une.edu.au

APPENDIX 5

UNIT EVALUATION (INTERNAL)

Student Unit Evaluation

EDME145: Primary Mathematics 1: Numeracy (Internal
2011 SEM2
Coordinator: Mr Martin Schmude

Enrolments: 113, Total responses: 26, Response Rate: 23%

Overall indicators

	- 1 2 3 4 5 +	
Global Index		av.=4.2 dev.=1
1. Unit Evaluation for:		av.=4.2 dev.=1

Survey Results

Legend

Question text

Relative Frequencies of answers; Std. Dev.; Mean

Left pole	25%	0%	50%	0%	25%	Right pole
Scale	1	2	3	4	5	Histogram

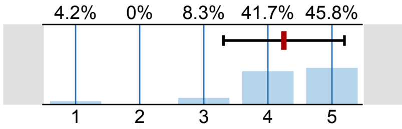
n=Amount
av.=Mean
dev.=Std. Dev.
ab.=Abstention

1. Unit Evaluation for:

		1	2	3	4	5		
1.1) The learning outcomes of this unit were made clear to me	Strongly Disagree	3.8%	3.8%	7.7%	50%	34.6%	Strongly Agree	n=26 av.=4.1 dev.=1
1.2) The unit enabled me to achieve the learning outcomes	Strongly Disagree	3.8%	0%	11.5%	42.3%	42.3%	Strongly Agree	n=26 av.=4.2 dev.=0.9
1.3) The unit was intellectually stimulating	Strongly Disagree	3.8%	0%	7.7%	46.2%	42.3%	Strongly Agree	n=26 av.=4.2 dev.=0.9
1.4) I found the resources provided for the unit (eg online, print) to be helpful	Strongly Disagree	3.8%	0%	15.4%	42.3%	38.5%	Strongly Agree	n=26 av.=4.1 dev.=1
1.5) I received constructive feedback on my work	Strongly Disagree	3.8%	3.8%	11.5%	42.3%	38.5%	Strongly Agree	n=26 av.=4.1 dev.=1
1.6) The feedback I received was provided in time to help me improve	Strongly Disagree	3.8%	0%	15.4%	38.5%	42.3%	Strongly Agree	n=26 av.=4.2 dev.=1
1.7) The overall amount of work required of me for this unit was appropriate	Strongly Disagree	3.8%	0%	7.7%	42.3%	46.2%	Strongly Agree	n=26 av.=4.3 dev.=0.9

1.8) Overall, I was satisfied with the quality of this unit

Strongly Disagree



Strongly Agree

n=24
av.=4.3
dev.=0.9

Comments Report

1. Unit Evaluation for:

1.9) What were the best aspects of this unit?

- - Marty and Brenda were very encouraging and easy to get along with, which made a comfortable working environment.
  - lectures were always very interesting
  - sceneriors and video vaults were a good challenging way to learn
- Excellent tutors and lecturers. Very helpful, approachable, and made learning engaging. Always knew could ask questions at any time. Explained things in ways that were easy to understand. Content was helpful for learning how to teach students. PBL's were great for real life teaching experience.
- I found this unit interesting as it provided me with a real life scenario that I had to find a solution to. This can help me in the classroom when there is a student who is struggling.
- The knowledge taught and making me want to do more maths.
  I loved the way Brenda and Marty worked together for me it work really well.
  I love the fact that both Marty and Brenda participated in the workshops.
- The lecturers were very student centred and provided a range of resources to meet student needs
- The practical activities in tutes each week.
- The small group work with Marty
- This course was very interesting and fun. Both Marty and Brenda made the content easy to understand and it was enjoyable to go to classes and lectures.
- This unit helped explain mathematics and allowed the students a chance to see different ways to teach maths rather than how we were taught in primary school.
- Was really good unit, throughly enjoyed it. Unit work was relevant and educational, Brenda and Marty were really good too
- Well presented
  engaging
  Interesting
- Working independantly from lecturers help. But they did help when asked or when they felt yuo needed the assistance.
- activities each week allowed me to learn + marty and brenda were helpfull at all times!
- everything, loved how everything was on line
- the HANDS ON ACTIVITIES
- the different learning methods needed to teach children.
- the scenarios enabled us to practically apply our learning to a real life situation and enabled us to see the concepts in real life and how they apply to teaching.

1.10) What aspects of the unit are most in need of improvement?

- Clarity for what the unit is to achieve for us.
- Finding specific things online got a little tricky at times.
- I often found it hard to understand where all the areas we were learning about and different activities we were doing all fitted together. I would have liked more obvious links made between what we were learning and how we can use this as a practising teacher.
- It is boring - unengaging
- Some of the different techniques taught could come across as confusing for children.
- Sometimes I felt a little overwhelmed when we had to do both the scenario and the activities, but I managed to get them done.
- explanation of forums
- make ita bit clearer on each topic
- nothing (2 Counts)
- there wasnt much feedback for our group wikis, i didnt know if i was on the right track or not

APPENDIX 6

UNIT EVALUATION (EXTERNAL)

Student Unit Evaluation
EDME145: Primary Mathematics 1: Numeracy (External
2011 SEM2
Coordinator: Mr Martin Schmude

Enrolments: 399, Total responses: 137, Response Rate: 34.3%

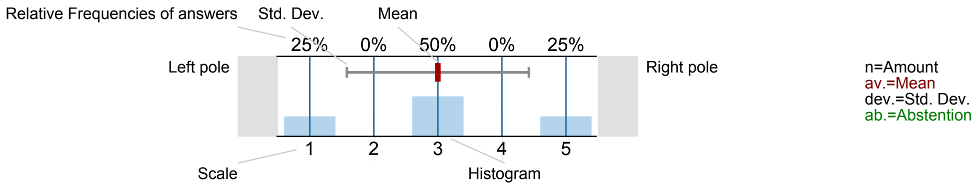
Overall indicators

Global Index	- 1 2 3 4 5 +	av.=4.2, dev.=0.8
1. Unit Evaluation for:	- 1 2 3 4 5 +	av.=4.2, dev.=0.8

Survey Results

Legend

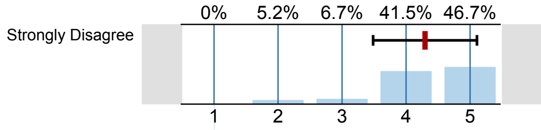
Question text



1. Unit Evaluation for:

		Left pole	1	2	3	4	5	Right pole	n	av.	dev.
1.1)	The learning outcomes of this unit were made clear to me	Strongly Disagree	0%	1.5%	6.6%	51.1%	40.9%	Strongly Agree	137	4.3	0.7
1.2)	The unit enabled me to achieve the learning outcomes	Strongly Disagree	0%	2.9%	9.5%	50.4%	37.2%	Strongly Agree	137	4.2	0.7
1.3)	The unit was intellectually stimulating	Strongly Disagree	0%	2.2%	5.8%	31.4%	60.6%	Strongly Agree	137	4.5	0.7
1.4)	I found the resources provided for the unit (eg online, print) to be helpful	Strongly Disagree	0.7%	4.4%	6.6%	35.8%	52.6%	Strongly Agree	137	4.4	0.8
1.5)	I received constructive feedback on my work	Strongly Disagree	2.9%	12.4%	12.4%	48.2%	24.1%	Strongly Agree	137	3.8	1
1.6)	The feedback I received was provided in time to help me improve	Strongly Disagree	2.9%	7.3%	13.9%	46%	29.9%	Strongly Agree	137	3.9	1
1.7)	The overall amount of work required of me for this unit was appropriate	Strongly Disagree	3.6%	7.3%	11.7%	51.8%	25.5%	Strongly Agree	137	3.9	1

1.8) Overall, I was satisfied with the quality of this unit



n=135
av.=4.3
dev.=0.8

Comments Report

1. Unit Evaluation for:

1.9) What were the best aspects of this unit?

- - expertise of lecturers
  - interesting topics in lectures
  - idea of problem based learning
  - information provided and topics covered as overview of subject
  - variety of activities
  - concept of working in offline groups
  - being able to relisten to lectures (see below)
  - quick email response by lecturers to enquiries
  LECTURERS WERE EXCELLENT - ICT NOT

- Activities, Lectures, Forums...all good.

- All of it.
  The lecturers where great, got back to you very quickly with any problems, where enthusiastic and very helpful.
  I really, really liked the fact that lectures where online as well as slides and all of the info needed. It really helped with my learning.
  Thanks, thanks and many thanks

- Being able to see children doing assessments such as in the video vault. And the lectures.
  I find it hard to answer the above question, I recieved constructive feedback on my work, because if I wrote a direct question on the forum of course it was answered but my actual work on the wikis with which I really needed feedback on I recieved nothing and I had a group that offered no help as well so I gave up doing the activities which is where I would've learnt the outcomes better. But with no support or feedback it was useless.

- Brenda and Marty were fantastic

- Brenda and Marty worked really well together!

- Brenda and Marty's supportive attitude to students

- Committed, dedicated lecturers. Engaging, interesting resources that actively demonstrated how to be a brilliant teacher. Amazing modelling of efficient team teaching. Extremely prompt feedback on Moodle.

- Definitely the practical hands-on teaching of Marty and Brenda. Took us back to basics and gave us a deep understanding of maths in an easy to learn manner

- Engaging and fun presentation of material, especially the use of problem based learning scenarios.

- Everything

- Filmed lectures
  Tutorial videos - made for us!
  Interesting and relevant resources
  PBL approach
  Lecturers personal, positive, enthusiastic approach and obvious understanding of the learner's needs
  I felt that I truly learnt the content, in a way in which I will retain it
  By far the best unit I have studied at UNE

- Great feedback from teachers.

- Great lectures and fantastic lecture's. Kept everything interesting and engaging.

- Hands on activities to learn the content

- How hopeful Marty and Brenda were. No question was to much for them, even if the same question was ask 100 times they answered it 100 times. They are a credit to the teaching staff. Very valuable members of staff

- I am grateful to Marty and Brenda for the time and effort they have put into this unit. Their passion for mathematics and teaching has truely been inspirational.

- I believe I ave learned that which is necessary to begin math teaching and feel my own understanding has reached greater depth.Both mathematically and pedagogically.

- I enjoyed all lectures provided by both lecturers.

- I enjoyed the lectures

- I enjoyed the video lectures, they are much more interesting to listen to and watch, rather than just audio. It makes a difference being able to see what the lecturer is explaining and referring to when they say 'look at this'.

- I enjoyed very much Marty and Rhonda as lectures. They made it so simple and clear to follow instructions on a numeral problem etc.
- I like the first two assignments. The first encouraged self-insight and the realisation that a person's attitude (based on previous experiences in maths learning) to mathematics could negatively or positively future teaching of the subject. The second assignment was relevant in that it involved interpretation and use of an assessment (sort of 'hands on').
- I liked the lectures, they relly helped to explain things. This came in handy for the assignment too.
- I love the way Marty teaches. He has a great tallent in getting his students motivated and interested in his lectures. He provided us with some really fantastic resources which will be really helpfull to me in my future years teaching. What a great unit.
- I loved the video lectures. As an external student these are wonderful to experience.

  I loved the review lecture to help us prepare for the exam. If I do not get a mark to my liking I have nobody to blame but myself.
- I loved watching the lectures and using the visual aids along with it. I also enjoyed using wikis on moodle.
- I really enjoyed Marty's lectures. They were very interesting and informative.
- I really enjoyed that there was more than just readings and a lecture each week. Much more stimulating and, I would assume, engaging for all types of learners.
- I really enjoyed this unit and it wasn't as daunting as I thought it was :)
- I really enjoyed this unit. The lecturers were fantastic and went out of their way to help and make it enjoyable
- I thought the lectures were fantastic. I learnt how to work out mathematical problems/amend my knowledge of how to more effectively learn for myself and how to apply it in my teaching.
- It was very hands on and taught us why maths is taught the way it is
- Knowledge, approachability and enthusiasm of lecturers, quick answers to queries,
- Lecture material was online and easiliy accessable.
Task were out forward in a clear manner.
Instruction and explainations were clear and helpful.
- Lectures were appropriate and I found it very helpful in learning how to tea.ch maths and what steps to follow in beginning to teach maths.Loved the way it was set out clearly week by week.
- Lectures where easy to access. Help was always around.
- Marty
- Marty and Brenda and their lectures, really good exercises and assignment, test was a fair assessement of expected outcomes.
- Marty and Brenda are so passionate and it really makes them GREAT teachers. Even during the lectures, it didn't feel like we were being 'lectured' it felt like we were being taught. I have learnt so much about mathematics not only for my future students, but also for myself. Thank you so much.
- Marty and Brenda did a great job of presenting this unit. They provided humor and generated a great deal of interest.
- Marty and Brenda inspired me to think outside the box when it comes to lesson plans. Their PBL approach scared me at first though it did assist with the learning outcomes. Thank you for all your time and energy. You really can tell when someone is passionate and makes that extra effort.
- Marty and Brenda take the time to provide a video of the lecture which is easy to follow
- Marty and Brenda taught this unit based on the Problem Based Learning teaching model. This model is very student driven and enquiry and exploration lead us to the answers. It is very challenging, but very rewarding at the same time.
- Marty and Brenda were dedicated to teaching, and this made me more motivated to study, they have great personalities and a passion for what they teach. Whenever I needed help their reponses were very quick.
- Marty and Brenda were fantastic lecturers, who were genuinely passionate about their subject.
- Marty and Brenda were practical lecturers with information that related to a real life classrooms. Lots of relevant information and lots of activities you could particiapte in that were not assessable, but were halpeful if you had the time to do them ... allowing you to get the most out of the course as you were able without breaking your back.
- Marty and Brenda's very informal, approachable approach and attempts to add fun into the content :). Lots of video case studies and interactive materials to demonstrate and engage.
- Marty's random tangents that made learning fun!
- Overall the lectures and the assignment, which really helped our thought processes and achieving the learning outcomes. Within Moodle, the activities set for us were very thought provoking and the organisation of the whole unit was brilliant. We could see that that Brenda and Marty put a lot of effort into setting up this unit.

- Posts on Moodle were answered promptly and the weekly activities were relevant to the unit
- Providing the audio, video and slides of the lectures made it easier to complete the subject and to achieve the learning outcomes. I enjoyed the assignment as it was based on analysing a students level of understanding and being able to apply the learning outcomes.\
- Stimulating and inspirational
- Taught simple ways of working out math problems so we can teach children
- The best aspect was giving practical examples of how to teach maths in a classroom environment and how to evaluate a students understanding of maths.

  Another aspect is that our lecturers Marty and Brenda were always happy to answer questions and quick to give advise where needed.
- The content of this unit was very interesting. Maths can seem like a boring or daunting subject at times but this course had me interested and wanting to paricipate and complete work and assignments.
- The content was presented in an interesting and accessible way. The activities were engaging and the language used was such that any difficult concepts could be easily understood.
- The different types of information was great especially the trivial points that were made. I now understand where maths has come from and it is amazing how it is used in every day life.
- The enthusiasm of the lecturers and the problem based learning and their flexibility when it was not feasible to get it all done
- The filmed lectures was really great. the activities, videos and you tube clips were engaging and entertaining. Martin was great to listen to and made me feel like I was near.
- The friendly relaxed banter between the two staff.
  THe quick to phone when i felt i had a problem.
  Brenda was so very very kind and helpful , full of support.
  Really thankful i had such a keen teacher.
- The great video lectures for external students, lots of examples and the ability to watch with actual demonstrations.
- The lecturers
- The lecturers - they were awesome. Nothing was too much trouble, they answered all questions, they helped all issues and very extremely approachable and went above and beyond any other course as far as what they did for their students.
- The lecturers integrated current and real life contexts in their lectures
- The lecturers tried to make the unit interesting by doing a variety of activities
- The lecturers were passionate about the subject
- The lecturers were very engaging and positive and I found that what they had to say was relevant to primary schools today.
- The lecturers' enthusiasm and attitude. Problem based learning was excellent.
- The lectures
- The lectures and the online activities.
- The lectures in this unit were amazing and really interactive. Marty and Brenda provided really interesting and practical ideas and spoke in terms that were easy to understand and not too confusing. I really enjoyed the lectures and information I received in this unit.
- The lectures were amazing! Marty and Brenda made me wish I was an internal student because I can imagine how motivated I would have been if participating in tutorials and workshops. I love their passion and energy for this subject, It has helped me change my personal views about maths.
  Marty, thanks for showing us short clips of some of the elements, this REALLY helped with understanding.
- The lectures were good, but not very detailed - they seemed to be aimed at a very base level. The use of humour made the lectures and tasks enjoyable. The exam preparation information was very good. I found the review forum to be the most useful part of the unit. THe scenarios would have been good if we were given the information upfront as how to complete them - I like this practical aspect of the unit.
- The lectures were very informative.
- The lectures were well delivered and interesting.
- The ordered progression through the unit as displayed by moodle
- The prescribed text was great, the chapters short and easy to read. I loved it! The lectures were also
  Informative and easy to understand. I enjoyed learning how to teach mathematics especially since in my scoop years everything was

pretty much rote learning.

- The recording of lectures definitely helped me to learn.
- The teachers were very involved and happy to help - even as an external student I felt that there was a lot of assistance.
- The teachers! They are some of the best teachers i've ever had (and this is my third degree). They were very encouraging, engaging, patient, and they made not only this course fun, but showed us how maths can be really interesting and fun for all.
- The time and dedication that went into planning and teaching the topics. They were creative, straight forward, useable in future classes and FUN, I could see children enjoying doing the activites themselves
  The feedback was only really given in Moodles forums, and not in the groups wikis.
- The unit co ordinator spoke with respect & his lectures were entertaining.
- The variety of topics covered and the dynamic way we were taught was a highlight for me. I loved that Marty and Brenda could laugh at themselves and include extra pieces that made me laugh helped me to feel more comfortable studying this topic. The content was very helpful in both teaching me what I missed at school and the way I will teach it to my future students. Brilliant unit! I also loved that I could see the lectures and that I had the slides for later revision!
- The video lectures provided very clear instruction , information and motivation.
- The video lectures were very informing and interesting. This is the first unit I have completed that has provided video lectures.
- The videos of lectures that internal students attended on the various topics. I found that these lectures which on occasion included student participation were very helpful in understanding topics inf the unit.
- The videos of lectures were informative and engaging as an external student. The inclusion of the video scenarios was extremely useful in applying the knowledge to 'real-life situations'.
- The videos to talk through CMIT etc. It was a lot easier to understand via a video demonstration
- The way the information was presented to us. Also the learning styles we were educated about gave me a great insight into how I learn. I found this a educational unit that was fun and prioivided me with a wealth of information and education.
- The way the lecturers worked together, and communicated with passion and clarity.
- There was lots of practical advice (mostly in lectures) about strategies to solve common math problems, how to identify misunderstandings of students and what resources can be used to assist in clarifying these misunderstandings.
- This has been my most enjoyable unit so far. I came to this unit with a . Major vase of Maths phobia, to the point that I wouldn't open the moodle page for weeks. The topics covered in this unit have been engaging and stimulating. I actually used the lectures as a reward for completing other tasks....
- This unit provided a view of mathematics in terms of the teaching of it. There was a lot of imformation provided for each topic and the method of delivering the topics made it easy to understand.
- This unit was just brilliant. Marty in particular seemed to go to so much effort to teach us - with so much enthusiasm! This was a practical unit which gave me a lot of confidence to go out and teach. The unit also taught me a lot about the theory. Brilliant unit - thank you!
- This unit was made interesting each week, and made maths a whole lot more appealing. well done.
- Very creative, information and highly interesting presentation of maerial. Lectures were really interesting and assisted with understanding and intrgrating the information.

  The PBL aspect was interesting, and enjoyed using the scenarios for learning.

  I valued being able to see how the content of maths could be taught in highly engaging ways.
- Very interesting, teachers replied quickly to forums and emails. Was very understanding in regards to assignments.
- Work was engaging.
- Yes very relevant.
- fantastic and extensive resources, great support, fun activities, difficult but rewarding challenges, clear explanations. EVERYTHING.
- great feedback and the lecturers where always responding very quickly on moodle. Moodle was really well monitored and proved to be a great discussion area for external students.
- i have become a mastery learner
- i loved the lectures and some of the group work
- loved the stimulating nature of the activities provided, they gave me a lot of good ideas working as a teachers aide.
- the clear structured lectures

- the fun relaxed approach by all lecturers
- the lectures were fantastic
- the lectures were very good, informative and set up the week to go and find more information. After some initial hiccups, I liked the concept of the group work, but found it very hard to engage with remotely
- the practical work and the discovery learning
- the resources provided and the imput from the lectures.
- the video Lectures!!!! I loved seeing Brenda and Marty on video for the lectures as it made me feel like I was really there. Was more interactive which made me concentrate more on the content being taught. I wish all the lectures were like that.

1.10) What aspects of the unit are most in need of improvement?

- -timing: assumption that adding info to wikis, adding pics to wikis etc was known. videos outlining how to use as well as some content (re how to interpret dept of edu syllabus documents) was helpful but very delayed
  - have a problem with inter and intra rater reliability - seemed that the criteria for main assignment was not particularly clear 1) No indication as to penalty for over the word count ie given a small word count - HD example was way over; 2) a lot of questions re format (eg point form ok?) only discussed/answered as 'not acceptable' on forum, not detailed on criteria. Not reflected in marking. Just seems if criteria more specific and advised to markers, there wouldn't be so much discrepancy.
  - video equipment - can't understand a lecture when they are referring to visuals and the camera doesn't work for several weeks
  - audio - cannot hear when lecturer walks away from lecturn and/or asks questions of audiences, and questions/answers are not repeated = need to change equipment or train lecturers to think of the 'absent' audience at all times during presentations OR give them better aids to communicate - camera/audio etc
  - NO feedback on weekly activities on wiki - just discussions in groups of 6 (in my group 2) about activities - no idea if on the right track or not. mid semester opened wikis but found many groups had not contributed. only in ?week 13 were there responses posted by lecturers re best answers to PBL situations/activities
  - NOTE: eval below re providing answers to questions - only via email as answers or questions to questions in the 'live' lecture could not be heard!
- A little bit more direction in what the learning requirements were early on would have been helpful but by the end of the unit, this was a lot clearer and the help provided in preparing for the exam was fantastic and really appreciated.
- All was pretty good!
- Although the Problem Based Learning has many merits, I feel that more guidance and scaffolding would be beneficial to the students.
- An initial introductory lecture to explain the mode of teaching and the underpinning philosophy of it
- As an external student with limited internet access I found that getting the required information from Moodle a real struggle. There were too many pages of information to flick between and a constant back and forward to read and download. If the information had been in fewer 'pages' it would have been much easier to download and read through offline. In other subjects there were a maximum of 3 pdf's for each week which made it much easier to keep track of the studies and download the information. I found that I fell behind with Moodle initially and the rest of the semester was spent in catch up mode so I couldn't really get into the course.
- Audio lectures put external students at a disadvantage, as we couldn't hear student responses to in class questions, which made things hard to follow. Also when videos were shown in class, external students often had no link to view it & they could not be accessed through the PDF slides.
- Couldnt get the group wiki to work, sorry guys , it will happen im shore.
- Did not get much feedback on the assignment, just a mark and short comment.
- Far too many activities, no weekly feedback given on the answers to the activities (just at the very end), plus we had to work in groups and contribute on wikis but most people didn't do this. It was unfair for those who spent valuable time doing these tasks
- Feedback on groupwork was sparse. I have a friend who did the unit on-campus and felt that the support the internal students received was great. Having said that, however, by the end of the unit, I felt I had a good handle on the content. Fingers crossed, anyway!!!
- Feedback on work submitted to the wiki's on the weekly activities/scenarios. I wouldn't expect individual feedback, but more timely feedback than giving it all at the end of the unit, and just before the exam. It's like flying blind when you don't know if the work you are doing is even halfway correct. It doesn't help that I was the main contributor to my wiki (which I gave up on after a while as no-one else was contributing) and had very little to compare my work to.
- For distance learners there were 2 aspects which were challenging;
  1. Course content was not available in advance in moodle - often it was posted during the week of intended study - this made it difficult to pre-plan activity and try to 'get ahead' on content of periods where I knew I would not be able to complete work
  2. The working group forums were not a practical way for me to work... given other work & family commitments, it was difficult to commit to working at the same schedule/ pace as others in my forum

  Additionally, the text subscribed was of limited value.. sometimes there was little connection between the lectures and textbook. Also Origo handbook was on the textbook list and not refereced once during the course.
- For myself, it was impossible to do all the activities with all the other work I had to do.
- I am a strong believer in pbl but I felt completely let down by it during the course of this unit - a combination of an ineffective team and

technology failure - part way through the unit our wiki appeared to freeze which to my knowledge IT have not been able to repair. It is such a shame that the great efforts of the lecturers were let down by this aspect - there was no positive interdependance in the team work even though they were interesting and valuable exercises contribution was minimal.

- I can truly say that this unit has been wonderful and I cannot think of any improvements
- I couldn't see where I was going, I felt blind. I know I learned but could have used more guidance.
- I dislike the MOODLE application. I just cannot even be bothered to check other students input. Its just too time consuming going through all the entrys. I much prefer last years blackboard system. Easier and more enjoyable.
- I felt as though it took an extremely long time to recieve the marks for one of the assignments. I still am yet to recieve the marked assignment.
- I felt the workload to be excessive & found it most weeks impossible to complete.

  I also feel that participation in the wiki's should be included in the final mark as I was in a group where no other group members contributed & this mean't I received no input or feedback from others. As an external student we rely heavily on others input.
- I felt there was in some ways too much information on the moodle page making it very confusing. Also I felt the subject was not scaffolded to provide vocabulary and mathematical concepts first so as to be able to answer the problem based learning questions leaving you feeling useless from the beginning. If you were unfortunate enough to get a group that did not participate you were left on your own to muddle through. Too much time was spent on the nsw syllabus and cmit which is unfair to those who are unlikely to ever work in NSW. The rubric for the second assignment did not match the requirements.Moodle is very frustrating also as on top of everything else you have 300 posts from people and you cant just hit a tab that says new posts and scroll down to the ones you need, you have to open and close each subject making it very time consuming.On blackboard there was a clear button saying 2 new replies which you could clearly see the answer to a question relating to your problems. Much better.
- I found the group oriented tasks didn't work well, especially with people who didn't participate in the group task leaving work to others. I felt the subject was disjointed and I wasn't sure what I was to study for the exam - was the text book relevant? Did all the subject matter simply come from the lectures and weekly activities?
  I found the course hard to follow through moodle and kept feeling like I was missing something.
- I found the moodle activities in groups etc to be alittle too stressful. At the time I was studying another subject, looking after a 3 yr old, working 5 days a week. I admit I was not an active participant in the group work, I believe it may have been alittle too much for me personally. Although helpful, I didn't have time to log on and complete group activities.
- I really did not enjoy the whole aspect of PBL. I feel that it did not allow me to gain all the knowledge necessary. I felt like we were left to our own devices and not given enough direction for the first assignment. However, I do feel we are being well prepared for the exam. I also understand that the idea of this unit was to work with groups however the group members I worked with did not contribute so this aspect did not work for me, which I feel was a disadvantage.
- I think I would have liked some clear learning outcomes with each weekly topic. Weekly notes to accompany resources would help to intergrate the learning outcomes with the content. At times I felt I was free floating and some kind of weekly topic notes may have helped to centre and focus the learning.

  I really didn't like the text book and felt it didn't relate well with the unit content nor within the Australian context.
- I think next semester I will book myself into the groups that meet up together on set nights as I found myself running a bit behind and no bothering about writing on the wiki as no one else in my group was. but in saying that I still really liked the wiki's I just had to read other groups.
- I think the first (and only) assignment should have been a bit later in the course. It would have been better to have 2-3 small assessments than 2 very large ones.
- I think the work load on Marty and Brenda is enormous and would have liked more direct feedback on my assignment
- I thought the 1st assignment was a valid learning exercise. I appreciated the need to stick to a word limit and this was reiterated several times on the moodle board. I can not begin to tell you, just how inappropriate it was to then post on moodle a copy of a HD assignment that went 1000 words over the word limit. I thought i did a good job of the first assignment. I got a shocking mark, and my feed back does not explain in any way, why I was marked so poorly. I did get the comment that I needed to go into more detail, but I was working to a word limit that I was told we needed to stick to. I thought this assignment was handled rather poorly on many fronts.
- I was disappointed with the structure of the group work when completing weekly assessments. I found the group work and feedback to be ineffective and at times confusing.
- I wish I could have subscribed to the podcasts via iTunes and be able to search for automatic updates. I would have loved to be able to download the video lectures for review as well.

  I enjoyed the weekly tasks that really helped with the exam, but did not like the group Wiki concept. I worked on the tasks at home by myslef and stopped uploading my work to the Wiki as I did not know my group and they did not actively participate making it strange.
- I would like the lectures to be on a podcast.This may have been available but I couldn't work it out. Never had this problem in other units. Don't like the group work, but that's ust a personal thing.
- I'm not sure - as I enjoyed it
- If group work is to be used then I think it needs to be made mandatory and part of the overall mark. As the group assessments were not graded, most students did not contribute which made learning and discussing difficult. Individual feedback on assignments would be nice, so you knew where you went wrong. I don't think a marking criteria coloured in in relevant mark box is good enough, it is too

general.

- Instrctions of assignment needed more clarifications,
- It is just a little difficult to juggle the activities with the demands of full-time study, work and family life! If things are not assessable, they get pushed down the priority list (just the way of things) and I would often miss the opportunity to work collaboratively because by the time I got around to the task everyone had moved-on. This was particularly true during prac.
  It is a shame, because I love the approach, but it does not work so well for the online, over 40s!
  None the less, I did enjoy what I managed to catch.
- It would help if work was put up earlier for each week so external units can have more flexibility in study. Either make wiki work assessable or make more concise individual work due to lack of participation in the wiki.
- K.I.S.
- Making sure that the exam dates given out at the beginning don't change as this happened.
- May be some topics are better covered than others.
- Maybe less weekly activities
- Maybe more of a balance of PBL and traditional teaching style. Learning moodle and taking on the PBL approach was very confronting.
- Moodle layout is a bit cumbersome, hard to find things
- Moodle was confusing, it needs to be more structured. Group work needs improvement, I dont agree with students in my group getting the same mark as me in group work if they decide to contribute very little and on the last day its due. I strongly disagree with that.
- NOTHING! Everything we could possibly have required (and more) was on moodle and so easy to find/well set up.
- Nil (2 Counts)
- None, it was all great.
- None...I thought it was great. I did think the assignment needed to be 2000-2500 words, not 1500 though!
- Nothing, it was fantastic.
- Only thing I can think of is that perhaps the weekly activities in future could be used as an assessment item? I just didn't have time to do them each week but of course would have done them if they were assessed. Now it is the end of the semester I am going back and doing them as I have time. Full-time work, study and a family is a tough mix. Perhaps having weekly activities instead of an exam would teach us even more over the semester and would get us to create or find activities that we could take into the classroom?
- PBLs are an awful idea for off-campus students!

  The quiz that was provided to help gauge students' readiness for the exam was pretty useless as it was completely different to the test paper. Some of the questions on the test paper seemed to come out of left field too.

  Most of the subject seemed to be theoretical with not enough advice provided on how mathematics should best be taught.
- PLEASE consider giving a percentage for participation in the groups for the problem based learning scenarios. I have found in other subjects that a 5 or 10% "participation" mark encourages much more active participation in these kind of groups which means everyone gets more out of them. I started doing the PBLs for the first couple of weeks, but once the others fell away I gave up. I can imagine how great they COULD have been if more people participated. It's been shown in the research that cooperative learning groups are usually more successful if the 'product' is assessed in some way.
- Participation in group activities; perhaps allocate a small percentage of course marks to participating in the group activities
- So much information to be processed at once, especially if you havent studied maths for years. can be very overwhelming.
- Some issues fixed with Moodle would help- like the ability to be notified when Wiki has been altered and a function to read all new forum posts at one, not skipping backwards and forwards.
  I felt that even though the lecturers were on forums, there was not much interaction with weekly activities from the lectures. Maybe additional staff placed on Moodle duties might have helped... there only seemed to be Marty and Brenda until right at the end of the semester. We had ALOT of students in the subject, so made it hard.
  Also, the option to 'place' yourself in wiki groups, rather than being placed in them and being stuck in a group of people that did not want to participate.
- Some work hard to understand at first
- The PBL?wiki component was a tad trying but with externals I am not sure how this can be improved
- The assignment, while meaningful to our future as teachers caused me some distress. The word count was an issue and I felt I could have achieved a better grade had the word count been greater. With that said, I adhered to the word count and was then penalised for not including some information when a HD example of the assignment was posted on Moodle at a thousand words plus over the specified word count. I have encountered this same issue in another unit and feel this disadvantages students.
  Additionally, the assignment hard copy was not returned nor was an electronic marked up copy available. There were a few lines of

feedback and a grade. With the amount of effort and time used to produce an assignment I feel the marking/feedback process should be commensurate. Generalised feedback does not allow me to see the specific areas that require improvement for me to gain better results.

- The group work activities were not successful in the external environment as many students did not participate and there was no common timeframe for participating. With the large number of external students, Marty and Brenda were unable to provide feedback to each of the "groups" which left the possibility of going off-track uncorrected.

- The markers comments need to give more detail not just one line!

- The online structure of the unit. I found the layout to be very confusing, for example, information about structuring your Wiki was in the week 3 "early counting" topic instead of in the unit information section - and didn't appear until week 5. I thought the structure and purpose of the Wiki should have been made very clear from the beginning. I found group work to be very difficult online. I love group work - face to face it works very well. But online, there is a big time lag between when people contribute so the feedback loop is very long and drawn out. Also, for most of the topics I was the only contributor, so I had nothing to compare to until the other groups were openened up. Even then with access to 10 groups Wiki's, I found that for the last few topics there were no contributors to the other Wiki's either. And I had NO INPUT at all throughout the entire semester from the lecturers/tutors. Not once. I was very concerned by a comment that Marty made on one of the forums that "they did not have enough time to get around to everyone". Why not? Don't off campus students pay the same fees as on-campus students? There should be tutors avaialable for off-campus students as well, who can provide feedback/comments on the Wiki's. Structure. The reason students study online is because they have circumstances such as SEVERE TIME PRESSURES, family committments, work commitments, health issues etc (personally, all of these apply!). I need to be able to find the information required quickly. I need to know what is expected of me when tasks are set - and how to structure the tasks. I need information up front - I don't have time to fluff around thinking about what I don't know yet and how to to find out what I need to know. Personally, I have finished the unit with a very weak understanding of early counting, CMIT and the syllabus as this information was not presented very clearly. THe later topics were fine. THe purpose of all of the resources provided was not very clear, for example, what are the "Blackline masters" and how are they used? I have not found a reference to them anywhere in the unit.

- The only thing I found difficult was the constant group work as an external student with my prac and another unit aswell I found it really hard to get back to people and was worried and felt alot of pressure in getting back to other students.

- The problems with IT made it incredibly hard to understand what the lecturer was talking about. Video would have made it better.

- The quality of the online lectures and audio.
  Lectures for each topic.

- The wikigroups did not help me in my learning because many of the students did not participate in them, and hence I felt I was not being supported in my learning

- The workload for this unit was huge, it was very hard to keep up to date and the continual group work was impossible if there were no willing participants in your group wishing to help. The assignment feedback did not help me to understand how I can improve. External students in this course seemed to be at less of an advantage to on campus students as video lectures were not always available.

- The workload was probably a bit too heavy. If you couldn't keep up with the weekly sessions it made it hard to fully understand the concepts.

- There is masses to much content in this unit, had I known how much I would have only taken this unit in one semester rather than 4 units. It was ridiculous the amount of undirected, half explained information to sift through and subsequently just continually get lost in. I found myself directionless in this unit and only truly understood what I was supposed to learn from it in the elevnth hour before the exam when the lecturers in my opinion finally made this clear.

- There was so much to cover in each week. I felt concerned that I did not get a chance to absorb all the information before the next topic came up. I did not even pick up the text book till after the assignments were completed. I am trying to do all that research now to prepare for the exam. I am concerned that I will not do well in the exam as I found it hard to retain the new information.
  Have no solution either as I understand that this unit requires all that content.
  Sorry.

- There was too much content to get through. I found it very easy to get lost and confused.

- They may need to be careful with information overload. Sometimes, it is hard to just log on and have a clear sense of what is the most crucial thing to get done as there was so much to get through and so many new things added. It almost needed a section that showed the latest thing added to Moodle so that you didn't have to scroll through and find the latest addition.

- Up-front instructions/introduction. As my first subject of my course, it was very stressful to figure out what needed to be done with the wikis and scenarios. An intro lecture to welcome and outline the instructions from Marty would have been heplful rather than trying to understand written instructions. No one knew what we were supposed to be doing! Solutions to wiki's/activities sooner, to check progress. A lot of work put into weekly activities and you never knew if on right track! More feedback on the assignment would have been good, rather than just a mark.

- Use of group work. I found this to be useless as I had an inactive group. The group work needs to be either compulsory and graded or allow people to form their own groups if they intend to participate.

- Very tough to do but I felt like I didn't know enough to contribute to the wikis and then when I did, I didn't know if I was on the right track. I'm sure that it would be near impossible to give feedback to as many students as Marty and Brenda had this semester. I didn't like the inductive nature of the scenarios. I much prefer the deductive method of definition, example, example, not the other way around.

- Way way too much reading and weekly activities expected. The most ridiculous amount of groupwork, reading and activities which I found totally impossible to achieve. Having the amount of work constantly hanging over my head actually made me disengage from this subject. I really gave up as it was overwhelming.

- Working out how to engage all students in online activities.
  I admit that towards the end of the unit I participated less in the activities as I found that I could do and think through the problems quite quickly and easily and grasped concepts quickly.
  Actually submitting my responses online didn't seem to be worth my while as there wasn't any internal group discussion or external feedback. I know this isn't the attitude of a mastery learner but I found I could achieve the same outcomes by making dot points as opposed to formal answers on the wiki.
  Don't get me wrong, I loved the activities and did them all but since my answers didn't generate discussion it didn't seem worthwhile to put them up.

- i would say the group work, they expect way too much for weekly exercises considering it's not the only unit everyone is studying

- it seemed a little too dependent on the technology..or rather, the expectation of people's ability to navigate through it all

- it was not fair that some peoplr did not contribute to the group work when this was part of the learning process. Thos of us who started and carried the group (eg 2 people), we just decided to use our time on other subjects rather than doing detailed work on the activitied for posting, We did our own work and didn;t post. Why should others get the benefit of our time at our expense.

- n/a (2 Counts)

- online group work.. not sure about that one. It seems like a good idea, but if your group isn't interested, then it doesn't work, and you miss out.

- the readings were a little unclear - suggest adding the curriculum material and other DET resources

APPENDIX 7

ETHICS INFORMATION TO PARTICIPANTS

School of Education
University of New England
Armidale NSW 2351
Australia

Phone +61 2 6773 4221
Fax +61 2 6773 2445

education@une.edu.au
www.une.edu.au/education

INFORMATION STATEMENT for STUDENTS

Problem-based learning in Mathematics Education

Dear Student,

I wish to invite you to participate in my research on problem-based learning (PBL) in mathematics education. The details of the study follow and I hope you will consider being involved. I am conducting this research project for my Masters of Education at the University of New England. My supervisors are Associate Professor Stephen Tobias and Dr Pep Serow of University of New England. Steve can be contacted by email at stobias@une.edu.au or by phone on 02 6773 2573. Pep can be contacted by email at pserow2@une.edu.au or by phone on 02 6773 2378.

Aim of the Study
PBL is an innovative approach to learning. While mostly used in medicine, PBL has found its way into law, architecture, engineering. This study wishes to investigate the experience of preservice primary teachers participating in an 11-week long PBL mathematics education unit.

Interviews
The interview will last up to 30 minutes. There will be a series of open-ended questions that allow you to explore your views and practices related to your experiences while learning in a PBL environment. These interviews will be audiotape recorded or electronically captured. Following the interview, a transcript will be provided to you if you wish to see one.

The audio files will be kept on CD in a locked filing cabinet in Dr Steve Tobias' office. The transcriptions will be kept in the same manner for five (5) years following thesis submission and then destroyed.

Research Process
Participation is <u>completely voluntary</u>. You may withdraw from the project at any time and there will be no disadvantage if you decide not to participate or withdraw. It is unlikely that this research will raise any personal or upsetting issues but if it does you may wish to contact the UNE Counselling service (02 6773 2897). The data will used in a dissertation and may also be presented at conferences or written up in journals without any identifying information.

This project has been approved by the Human Research Ethics Committee of the University of New England (Approval No. HE11/126, Valid to 13/07/2012)

PLEASE TURN OVER

School of Education
University of New England
Armidale NSW 2351
Australia

Phone +61 2 6773 4221
Fax +61 2 6773 2445

education@une.edu.au
www.une.edu.au/education

Should you have any complaints concerning the manner in which this research is conducted, please contact the Research Ethics Officer at the following address:

Research Services
University of New England
Armidale, NSW 2351.
Telephone: (02) 6773 3449 Facsimile (02) 6773 3543
Email: ethics@une.edu.au

Thank you for considering this request and I look forward to gaining your support for the project.

Regards,

Martin Schmude
Mathematics Education
University of New England
Email: mschmud2@une.edu.au
Ph: 6773 2943

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CONSENT FORM for STUDENTS

Problem-based learning in Mathematics Education

Please clearly write your full name after 'I,', and circle the yes/no answer you want.

I, ..., have read the information contained in the Information Sheet for Participants and any questions I have asked have been answered to my satisfaction.

Yes/No

I agree to participate in this activity, realising that I may withdraw at any time.

Yes/No

I agree that research data gathered for the study may be published using a pseudonym

Yes/No

I agree to the interview being audiotape recorded and transcribed.

Yes/No

....
Student Date

....
Lecturer Date

APPENDIX 8

ETHICS APPROVAL

Ethics Office
Research Development & Integrity
Research Division
Armidale NSW 2351
Australia
Phone 02 6773 3449
Fax 02 6773 3543
jo-ann.sozou@une.edu.au
www.une.edu.au/research-services

HUMAN RESEARCH ETHICS COMMITTEE

MEMORANDUM TO: A/Prof S Tobias, Dr P Serow & Mr M Schmude
School of Education

This is to advise you that the Human Research Ethics Committee has approved the following:

PROJECT TITLE: Problem-based Learning and Mathematics Education.

APPROVAL No.: HE11/126

COMMENCEMENT DATE: 13/07/2011

APPROVAL VALID TO: 13/07/2012

COMMENTS: Nil. Conditions met in full.

The Human Research Ethics Committee may grant approval for up to a maximum of three years.
For approval periods greater than 12 months, researchers are required to submit an application for renewal at each twelve-month period. All researchers are required to submit a Final Report at the completion of their project. The Progress/Final Report Form is available at the following web address: http://www.une.edu.au/research-services/researchdevelopmentintegrity/ethics/human-ethics/hrecforms.php

The *NHMRC National Statement on Ethical Conduct in Research Involving Humans* requires that researchers must report immediately to the Human Research Ethics Committee anything that might affect ethical acceptance of the protocol. This includes adverse reactions of participants, proposed changes in the protocol, and any other unforeseen events that might affect the continued ethical acceptability of the project.

In issuing this approval number, it is required that all data and consent forms are stored in a secure location for a minimum period of five years. These documents may be required for compliance audit processes during that time. If the location at which data and documentation are retained is changed within that five year period, the Research Ethics Officer should be advised of the new location.

[redacted]

Jo-Ann Sozou
Secretary/Research Ethics Officer

13/07/2011

A11/105

APPENDIX 9

PRE-STUDY INTERVIEW QUESTIONS

Interview questions

1. How did things go with Brenda?
2. What is your attitude towards maths? Why?
3. How did you do in maths?

4. When do you feel smart at maths?
5. How do you like to learn maths? Do you prefer to learn things that are easy or things that are really challenging?
    - Why?
    - What made you that way?
6. Imagine you are doing a maths question and it is really hard. How does it make you feel?
7. What do understand challenge to mean?
8. Would you use challenging tasks in your teaching?
    - Why?
    - What about students failing because of a challenging situation?

9. Thinking of the things we've talked about today, how have you felt about the way this unit is being taught?
10. What are your personal goals for this unit?
    - What you are hoping to walk out with and have experienced?
11. On this graph, mark where you feel like you are located at this stage of the semester. Why?

Haven't worked hard at all		I have worked as hard as I can
0	______________________________	10

12. On this graph, mark where you feel the work is located at this stage of the semester. Why?

Easy		Challenging
0	______________________________	10

APPENDIX 10

POST-STUDY INTERVIEW QUESTIONS

POST-STUDY INTERVIEWS

NAME DATE

PBL EXPERIENCES

1. What activities do you recall during EDME 145?
2. Which of those activities was the most significant to you? Why?
3. Which moments during the semester (lecture/tutorial/study) left an impression on you?

During the semester, the work we undertook was extended questions and activities, rather than short, repetitive tasks. We did small group work by looking at scenarios of students in the first term and challenging maths questions in the second term. We also did individual activities throughout the semester.

4. How was this unit different compared to other units you've studied this year, in terms of the kind of approach to learning?

TEACHING AND LEARNING

5. To what extent did you engage in the work during the semester? Why or why not?
6. How important was it to you to learn and understand the work in this unit? Was this challenging?
7. You got mark on your assignment. How do you feel about your mark in relation to yourself as a maths learner?
8. From your experiences this semester, how do you think you learn best?
    - Has that been reinforced by this unit this semester?

CHANGE

1. Describe your attitude to maths.
2. Do you feel as though your attitude towards maths has changed this semester?
3. Did you feel anxious at any time during the semester?
    - What did you do about it?
4. What do you believe is important when learning maths?
5. What are the key aspects of being a good mathematics teacher?

APPENDIX 11

INTERVIEW TRANSCRIPTIONS (SAMPLE)

Gretel pre-interview

Q All right. So thank you very much. And how did things go with Brenda? Was it okay with the puzzles?

A Yes. I didn't like the first one. I had no idea.

Q How did you find that one?

A I found it so frustrating. I couldn't work it out and it was just annoying because it was only one, two, three and you think this should be so easy. And she went, 'you can stop any time.' And I said, ‘no, I can't stop. It's annoying me.’

Q How did it make you feel?

A It frustrated me. I couldn't handle it by the end of it. But then on the last one, I was like, I think I even nearly finished it. I loved it.

Q That was the juicy one that one.

A You just needed to get the hang of it and then it was ok.

Q Now, okay so I have a couple of set questions to ask which I will ask everybody. So okay, what is your attitude toward maths?

A I don't like maths. I've never liked maths. I don't have a good attitude towards maths. I just haven't been good at maths.

Q Okay, so how did you feel like you went in year 12 and year 11, and all through school?

A I just really, if I tried really, really hard I could get a B. I was in Queensland so we had a different schooling system. But for my exams I would study two weeks beforehand and that was my subject that I really dedicated myself to. I didn't give up. I had to try really hard to just get an average sort of mark. But I always tried my best.

Q So you felt like you really studied really hard for it?

A I did study really hard for it.

Q And mostly all the way through school?

A Yes, until the end of year 12.

Q Now when do you feel smart?

A When I get the answer right. Sometimes, like when we had an assignment in Grade 12 for the exams we did maths questions so we did model problem solving for the second hour of our exam and I was the only person in my class who got one of the answers right, so when we got our Maths- Because the teachers mark our exams, we don't have it external. So when we get to the marks back I explained how I got that and that was an exciting moment for me because I usually don't- I actually did better at MAPS though, rather than problem solving.

Q So you enjoyed that?

A Yes.

Q How do you like to learn maths?

A It needs to be broken up quite a lot for me. And if I don't get it I need a teacher that will have the patience to be able to help me with that.

Q So would you prefer to be doing- To be learning things in easier steps or take on a good big challenge?

A Depends if I'm familiar with the area as well. But if it's something I knew about but it's extending on, sort of thing, I'm happy just to go with it. But if it's a whole new concept I like to sort of break it up and go from each sort of part.

Q It makes you feel successful at each bit?

A Yes, and not just have it all in one bit and feel like oh my gosh, I don't know what's going on.

Q Why do you feel that way?

A With maths?

Q Prefer to be learning it with that particular way? I'm sort of thinking the little steps that you mentioned, or the big hump or the big challenge? What do you prefer about the littler steps to learn something new?

A You can gain an understanding sort of faster, but in smaller- At a slower pace. I think that you would probably get it in a quicker amount than what you would having to work it out all the way going across the big- It might be just a bit too daunting sometimes.

Q Has there been a time when you can think of when you did have that big challenge? Was there- So did you have a time that you can think of when there was a time when you had to work really hard. But felt like the lot was really challenging?

A I don't know if this is what you mean, but when I moved schools from a state school to a private school and also from NSW to Queensland I was very behind in my maths and even though I should have learnt it the year before, I didn't. So there was a lot to take on in that year. I felt very behind and there was just general stuff that everyone else knew that I just had no idea about sort of thing.

Q How did that make you feel?

A It was extremely hard and especially because I was at a new school as well. But I was extremely lucky because I had a really, really dedicated teacher and people who struggled she just stayed behind that afternoon and helped us and I got the results from that.

Q So she explained things to you?

A Yes.

Q Now, okay so what does it feel like for you when you're doing a really hard maths question?

A Extremely frustrating. It's also, it sort of like messes with your self confidence as well because you think you can't do it and you're stupid and everyone else understands, why can't you understand. And it's not nice.

Q Not pretty.

A But the best thing is when you do understand it, but then you do feel great.

Q So you were saying it makes you feel like you can't do it. You feel like you're the only one who can't do it. Do you feel like it's your fault that you can't do it?

A That maybe you weren't listening properly or, yeah.

Q Is it something that you feel is permanent?

A Yes and no.

Q Sort of like there is people who can do maths?

A Yes, I believe there is people that- You either click with maths or you don't.

Q And if you don't then-?

A You can try, but-

Q So obviously where I'm coming from is this idea about challenge and things that are hard and things that are easy? What do you understand challenge to mean? So you, no right or wrong answers here. What do you understand?

A Just something that's what you would see as beyond your capabilities of and something that is extremely hard and different to what you would usually be doing. Something that's just a bit challenging from your everyday sort of work.

Q So thinking about teaching, not our teaching, sorry your teaching down the track, what do you see the role as presenting kids with challenges?

A It's definitely important because they can't just do the same old work that they- They can't do the same old work and just keep going with that. They do need to be challenged because that will broaden their, and also help them learn.

Q And so with challenge I suspect there goes failure, or getting things wrong. Those sorts of feelings you were thinking about feeling stupid, or I'm the only who can't do it, how do you feel like if you want to use that in your classroom, how do we deal with students who are going to think that or feel that?

A I think that it's important for example, the teacher that I was speaking about, to give them that little bit of extra attention and be a dedicated teacher and maybe stay behind with them at lunchtimes or after school or something like that to build up their self confidence, because as soon as you don't think you can do it, you don't want to do it. But if you give them that extra care to make them feel like they can actually do it then for the next maths lesson they will be confident and they'll be fine and they'll be wanting to do it.

Q So when you say give kids self confidence, how do you reckon you might do that?

A You just say to them you can do it, you've just got to really focus and break it down, or whatever the situation is.

Q And so what would you say to them about that sort of failing? About getting that wrong?

A You know everyone does get things wrong, and that's the way maths is, there is wrong and right answers, but you can also get it right.

Q Okay, so thinking about everything we've done now, we're basically looking at the unit that we're teaching, and so we're trying to think about all those things we felt about with challenges and taking on a big task as opposed to just little steps, how do you feel about the unit as to how it's being taught so far. And I want you to feel comfortable to say whatever it is that you feel and don't say anything, totally happy to hear anything. So what do you feel about the unit so far?

A Well I was extremely, what's the word, not terrified, but I was pretty nervous about doing maths, again, because it's never been something that I've enjoyed. But I was really surprised at how much I enjoyed it. It's probably my favourite tute, it goes really quickly. Sometimes there's a lot to get through in the tute's and at first, well because I've only just started at UNE this semester and I did four, while I know everyone else has started [nudle] *0:11:05.9 I found it a bit confusing with the triggers and the Wiki and the forum and stuff like that, but once you know what's going on it's okay.

Q And what about having to take on a lot of that work? Would you say that work is hard or is there just a lot of it?

A Oh no, it's not hard, it's just there's a lot to get through. Sometimes you get distracted playing the games and stuff like that and it's a bit hard with groups with people pulling their effort, and other people not pulling their weight and stuff like that.

Q What have you noticed on that front?

A We have one girl who is always away and it's definitely, and there's a few of us who do more than others, and it's just the way it goes.

Q That's probably the most difficult thing about group work. There's that outside area. What are your goals for this year? When you think about what sort of things- What are you wanting to walk out with at the end of this semester having experienced, having learnt, having felt, lessons?

A I want to feel confident to be able to teach maths, definitely. And to know different ways of teaching and the different things that they need to know. I pretty much just want to walk out feeling confident going into maths because it's not something that at the beginning at the semester I was comfortable at going and an area uncomfortable going to.

Q So what do you feel like you need for yourself personally for this unit?

A I need knowledge of how to go about teaching maths and to re-visit different areas which has already been done.

Q As in the content stuff we've done you mean? Or just teaching?

A Yeah, content and what they've learnt. You kind of forget the basic things that just kind of happen when you're younger and you don't know that it's happening so you just forget-

Q Like value stuff.

A Yes. And it's just like even the ways of counting and putting objects out. Those sorts of things. You don't realise at the time that when you're being taught that's what's happening so coming from another perspective so it's good to be reminded of what you sort of need to do.

Q Terrific. Thanks Gretel. I've got two graphs here and basically at this stage of the unit what I want you do is mark where you feel like. So this is about how hard you feel you have to work in the unit. So if you feel like you haven't had to work very hard for it all or if you felt like you're really working pretty hard and working as hard as you can. And then this is where I want you to mark about how hard or easy you're finding the unit. It's the most challenging thing I've done in my life, or it's just straightforward, completely easy. Whatever you feel at this stage of the unit. So how hard you've working or had to work. How hard the unit is.

A How hard the unit is? Probably about there.

Q Terrific. Is there anything that you wanted to-

A No, that's great. Do you need me again?

Q At the end of the semester if that's okay?

A That's fine. Totally fine.

Q That would be great. Thanks Gretel, I really appreciate it. All the best.

END OF TRANSCRIPT

Shaun pre-interview

A ...thirty seven, back in the '80's or whenever I was being taught and I was saying, it's like a lot of it back then was rote learning, here's the instructions, here's how you do it, procedure, do it. That's the thing that stuck out to me.

Q Is that your experience of it Shaun?

A Back when I was in school?

Q Yeah.

A Well see I was average kid, I was dux of my primary and then I went to a selective boys school here in Sydney, Sydney Tech so the hard thing there was, when you go from a dux of your school but you go to Sydney Tech every kids a dux and I was just average Joe Blow. The funny thing is I pulled down my record of achievement the other day, I looked at my Year 12, Year 12 end result I failed forty was my mark.

Q In maths?

A In maths, otherwise I did alright, C was average, first half of the year sixty two then Year 11 sixty two, seventy six, so I did alright but just towards then end must of <over talk>*0:00:56.8

Q Isn't that interesting, that's very interesting.

A So what do we need to do today how do we...?

Q I'm not so sure if you saw on the email I sent you a couple of...

A I've got them here I didn't look at them I just looked at them two seconds...

Q That's fine, what we're going to do is, the first part is going to take about ten minutes so we're just going to work our way through those three puzzles and then after that it's going to be a ten, fifteen minute chat asking you some questions.

A I've just got a lady, I work for Lowes and this lady says to me, just rang me on the phone she said, "I think I've left the toaster on and I'm panicking I've burnt the building down." So she's going to pop in and get the key, so that might be a tiny disruption.

Q Not a worry mate, that sounds fine.

A So when you're ready we can start.

Q We've got two puzzles there which are smaller.

A Hang on, what have I done with the third one, I had the third one and I've just lost it, let me just find, give me two seconds. Okay I found all three.

Q There'll be two smaller ones and if you want to put the third one away just for the moment.

A So I'm just looking at the first one or both?

Q Just the first smaller one either one is fine.

A That's got the five plus in the beginning?

Q That'll be fine. Before we get started Shaun, is it okay if I audio record this?

A That's fine.

Q If you need a copy of it or anything like that I'm the only one who's going to be listening to it, just so I don't have to miss anything.

A That's all good.

Q Have you ever played these before it's called a KENKEN?

A Never heard of KENKEN in my life.

Q This is like those Sudoku puzzles.

A I've never done one.

Q The rules of this one, they're very very simple, in this case it's a three by three grid it's going to use digits one to three. In every row and column and there's not going to be any duplications, so if there's a one in any particular row it's not going to be in that row again. What you'll notice is, you'll see these bold black lines, they're called cages and we have to put in the numbers so that the numbers combine to whatever the operation is. So if you see plus five it'll be those two numbers add together to give five.

A Okay, so it's got plus five so I have to put three and two or four and one?

Q It'll just be using digits one to three though because it's a three by three grid. Now when you're doing this can I just ask you to feel free to think out loud and also just tell us how you feel and what you think as you're going through, when you're ready.

A So I'll just talk out loud what I'm doing?

Q Sure and what you're thinking as you're going and what you're feeling as your going as well.

A So I can use one to and three. I'm looking at the top left one that says plus five so when it says plus five I think of it as plus three and plus four, that means I've got to make those two numbers up to that number?

Q That's right, so plus five will be...

A Make five.

Q That's right.

A So there's already a three down the bottom, so I can put in there three and two, I can put three up the top and two down the bottom, is that good?

Q That's right, you may not at this stage know whether or not it's three at the top or two up the top.

A And the reason for that is?

Q Because it could be either way around but there may be a clue that helps you out about which way around it is. So it could be a two up the top and then a three beneath it or it could be a three up the top and a two beneath it. What you might like to do is just put a two and a three on the line in between them and then you can decide which one goes in later on when you figure out some of the others.

A And the whole point is you can't have two numbers, what's the...

Q So there's no duplications.

A In what?

Q In every row and column, so there'll only be one three in each column and in each row, does that make sense?

A I'm still trying to figure it out. So there's a five, so from the five plus it's got be a two and a three doesn't it?

Q That's right.

A Then for the three it's got to be a two and a one.

Q Correct.

A So the three plus, that'd be two and one, the three doesn't have a plus on it so that's just got to be a three.

Q Well done mate, that's right.

A That's got to be a three, so that's going to help me, the four's got to be a one and a three and the three's got to be a one and a two. So I've got all those now...

Q So working with those clues we just need to figure out which number goes in which box.

A What was the requirement again, that I can't, I've got to have, what is it again?

Q Just the one two and three in every row and column.

A So the three there's helped me, one two and three, one two and three, so one, I might do a bit of trial and error to get me underway, I might do that. I'm just going to do on the left three's there so I'm going to put two above the three plus and then I'm going to put a three there, so there I've three two, therefore then I'm going to try a one. Now if I put the one there then I'm going to put the two there in middle bottom, bottom middle, so

I've got three two three in the middle and one up the top. Therefore I'm going to put, I've got three one two then I'll put a two there therefore one two three, so here's what I've got Marty. How am I going to tell you this, column second column or column row?

Q Just column by column if you like.

A Let's go the first column which up the top has a five plus, I'm going to go with three up the top, two in the middle and one at the bottom. In the middle row that's got three plus at the top I'm going to go one up the top, three in the middle two down the bottom. In the third one on the right I'm going to go with two on the top, one in the middle, three on the bottom and looks to me like I think it's correct.

Q It all works out, because that's the nice part about these actually is that you can find out for yourself whether or not you're right because I'm looking at it here and there's absolutely no duplications.

A That's right so it's three one two, three two one... yep

Q And each cage adds up to what it should be.

A Looks good to me.

Q Nice mate, well done. Do you want to grab the second one and just exactly the same, no dramas with this one is any different, so feel free to get stuck into that one.

A What's this?

Q So this is still just another three by three.

A But it's different, is it that same?

Q It should be different, it might look vaguely similar.

A It's five plus three plus... it's identical, why is that?

Q Hang on, I may have sent you the wrong one.

A You did.

Q Did I just send you two of the same?

A Because they're identical.

Q That's okay, not a worry.

A Do you want to shot it through the email to me?

Q I did didn't I.

A Do you want to shoot the right one through to me now?

Q Alright mate, are you online?

A Yeah I'll just turn the computer on now, that's fine.

Q Sorry about that mate, I didn't notice that was the same one. Here we go.

A Shoot me through the right one, I'll just fire up the printer.

Q There we go mate, just sent it off to you there.

A I've got, you just send through one at 7:50 am the cassette form?

Q That's just an information form and just to let you know what's going on with the interview.

A So this is the right one?

Q So this will be number of that one sorry about that mate.

A That's alright, I'll just wait for this to print, so it's the same idea, one two and three?

Q That's it, one two and three each column and row.

A Here we go, I've got it in front of me, so I've got a four plus, okay here we go, same rules?

Q Yes mate.

A Here we go, this one I've the two in the bottom left, there's my starting point, so I've got four above it so we'd need either one or three for the five we need two and three, for the three we need one two and for the four we need one and three, let's do once again trial and error just see how we go.

So we've got two in the bottom so I'll go with one up the top where it's got the plus four and I'll go with three in the middle and then therefore I'm going to put the three in the top middle up the top, therefore I'm going to put the two, so that's three two, therefore I need the one down the bottom and I've got one two, therefore I'm going to put the three in the bottom right and three two one, one in the right middle and two, so let's see how I go, looks good to me, so I'll just make sure it's alright. Three two, three two one, I think I'm good Marty.

Q Alright mate, go for it Shaun how'd you go?

A I've got in the left hand one it starts with four plus, I've got one at the top three in the middle two down the bottom. In the middle row I've got three up the top two in the middle one at the bottom. On the right one I've got two up the top, one in the middle and three at the bottom.

Q Well done mate, that's good stuff. Now we've got just one more to go.

A The big monster!

Q That's right, looks intimidating doesn't it. This one has the same rules about numbers and rows and columns and no duplications.

A Same rules, what numbers can I use?

Q Because it's a five by five grid, it uses now numbers one to five.

A One, two, three, four, five.

Q The only difference with this one is, is that the numbers don't have any operations on them.

A What does that mean?

Q There's no add or subtract or divide or times, now the thing is that this one can use anyone of those four, so if you see the three in the middle up the top that could be three plus or that could be three times, that means two numbers that multiply to give three or it could be divide or subtract.

A That really gets you thinking.

Q Of course, we won't spend a huge amount of time on this because trying to finish it was not exactly what we're trying to do here, so we'll give you about three, five minutes and then we'll stop after that. So go for it.

A I'm looking if there's any single number box which there isn't in this one, so where it's got two, if for example it says two so it could be either two times one or one plus one?

Q It won't be one plus one because that'll be a duplication in that same column or row.

A But for example, there's one that's got two so it can't be two numbers and one plus?

Q So it won't be one plus one that's right.

A So to do a divide does that mean therefore, that means with twenty divided it'd make it ten by two is that what you mean?

Q Only using digits one to five and so in that...

A Twenty could be four times five.

Q And then there would have to be another one in there just to keep it as twenty though just because there's three boxes for that one.

A There's three boxes for the twenty?

Q That's right.

A But you can only use one operation per box?

Q Per cage as they call them.

A One operation per cage.

Q That's right.

A Are all operations used or it just doesn't matter, just depends what I find?

Q Whatever you figure them out to be, I can tell you it's only those four operations.

A I'm going to four, so I've got to use one two three four five, so where do I start, I'm going to start, this is tricky, I'm going to start in the top left hand corner, so three plus I'm going to try three plus and I'm going to put one and two. So one plus two plus three, now for the nine I'm going to try four and five nine plus, I'm going to try nine plus so I've got four and five. For the twenty to make twenty, it would have to be, to make twenty, how am I going to do that, if I'm going to do twenty but there's five numbers. Tricky one, I'll leave that for now, I'll go to four, I'm going to try four plus which will give me three and one. With a nine, could you do three times three?

Q No that one wouldn't work do you know why?

A Three times three, because there's...

Q Three times three definitely equals nine of course, but there's one rule about the KENKEN that it wouldn't work for, the reason why it's not allowed.

A Fine, so you can't do that, that's fine. So fifteen, looking up the top fifteen I'm to go with times, I'm going to go with three times five is fifteen, three and five. For the nine I'm going to go with nine plus I'm going to go four and five and for the two's, can we do one plus one?

Q No just because that'll be a duplication.

A So we're going to do for the two's then therefore they have to be two times one, two times I'm going to go with for those two times I'm going to have to go with two and one for all those two boxes, two one two one, there's lots of two's there and two and one, so two and one. I can do subtraction can't I?

Q You sure can mate.

A So for three up the top I'm going to minus I'm going to go four and five then I've got a row up the top, somehow I've magically got one two four three five so that would work. Then in the middle, oh there you go so for two I can do minus, I can do three minus one can't I?

Q Sure can.

A So the second row I've got four five one three, I'm going to go, I've got four five one then a two that's second row on the left I'm going to go minus so I'm going to go four five one I'm going to go three minus a one gives me two, so second row I've got four five one three two. I've got a two minus then I've got a two times next to it, so top two rows I've got one two four five three, four five one three two. Bottom row I've got three one four five two, so the bottom row's good, so I've got four plus nine plus then I had the bottom right up two times so I've got three one four five two therefore that's going to be a one so two, four five one three two the second row, four one three two, this is going to be a one.

Q We'll just go for one more minute mate.

A Three there, three two minus three one, stuck here one two, so the twenty, how do we get to twenty, so it's got to be one operation, so two times one, hang on four, one four, there's going to be a two and a three there, two and three, two times three there's got to be, that's tricky, it's got me stumped there. Four one, four five that's got to be a five that's got to be a four, four one that's got to be a three, two times the middle one's got me stumped.

Q That's okay mate, do you want to stop there that was well done, top effort mate, they're tricky aren't they?

A Very when you've got multiple you've got so many things in your mind trying to work them out, that's tricky.

Q It is they're a bit of fun if you've got time. I just want to ask you a couple of questions about it, the first part is just about how you felt and what you thought when you did it and then the next part we're going to ask about is just about maths and learning maths, does that sound okay?

A That's fine.

Q Tell me, how did you feel doing the first two when you did them?

A The first two were, because I've never done one it was just figuring out the concept of how it works and I like playing with numbers, I've been playing with numbers all my life, so I always used to do things in my head, to me that was fun.

Q Was it easy?

A The first one it took my brain a while to figure it out but the second one because I understood the concept and the rules was easier, I did the second one quicker because the brainwave pattern had created itself, therefore it knew where to go.

Q I understand. With that in mind, how did feel when you did the third one, the much harder one?

A The much harder one I was a bit nervous, I was nervous with that one because a bit nervous, just a bit more pressure because you gave me a timeframe so within that timeframe I was trying to figure out what I was doing, a bit of confusion but it was coming together through trial and error that was hard, that one was a lot harder.

Q Did you ever think about giving up?

A Never, no I don't give up, no no no no, not even a thought.

Q Good for you, that's terrific mate. Would you have preferred more of the first ones or one's or once you understood would you prefer more of the more challenging ones?

A I'd much prefer the more challenging one because it's going to get your brain thinking, much prefer it.

Q Quickly just thinking about maths, what's your attitude towards maths, how do you think about maths, what do you like about it do you not like about it?

A I've always enjoyed maths, I've always enjoyed playing with numbers in my head, I've never been exceptionally good at it but I can solve problems, I've enjoyed it. It's never been an issue where I was scared to approach anything.

Q Would you say that's true of most things that you do?

A I'm pretty confident with anything I'll give a go at, I've never been to university in my first degree and back in the day I always never thought I was smart enough, I thought I was dumb and that's just come from a bit of negativity from the father. Always half glass empty kind of guy and nothing was ever good enough so I never thought I was smart enough and then through a few life situations, getting divorced, going through a lot of self analysis I thought, "You can do it," my quote of life. Now once I've got into it I've done seven subjects, five distinctions two high distinctions I've realised I can do it so that's the attitude.

Q So that's the attitude that you feel towards maths as well.

A I enjoy maths, I've never been afraid of it I've always been good with numbers.

Q You said that you've never felt particularly good at it but how did you go with that you mentioned that in Year 12 there was a bit of a drop off?

A I was looking at that because I came dux of my primary so obviously I was doing something right back then and then I was just looking at the things the other day just to see how I went and I've got here University of New South Wales Certificate of Achievement for was that was that a maths one? Was it maths, how do you tell it’s maths Certificate of New South Wales, science competition that was science, pay for those.

We've got Year 7 maths seventy eight, eighty fourth out of one hundred and eighty, we've got seventy two I've got seventy. So I was always just an average kind of student, sixty six, seventy, seventy five, so I always doing alright and then, look at this, here we go, what's this, Year 10 fifty. Just that group average award, fifty, fifty five, so it sort of dropped off towards the end, just had a bit of an issue, I don't know was a long time ago but in a selective school, tough environment.

Q As you said, you go down to being...

A You're just a nobody.

Q Everybody's in the same boat aren't they, everybody's quite talented. Quick question when do you feel smart at maths?

A Do you mean with a particular operation or just in general?

Q Just in general, what sort of occasions would you feel smart at maths?

A With most occasions if I need to add up a shopping list or add up something in my head I normally, I was watching a video of your lecture the other day and you said, "Do it in your head." Generally if I've got something to do I'll try in my head but if it's difficult I'll make a list and do the operation, line them up in business I've had to use it sometimes with doing reports or sales things.

Q Would you say it's when you're doing something difficult and then you figure it out?

A Do I get a sense of achievement or...?

Q Do you feel smart when that happens?

A I've had a shift, as I've said to you in the past, I never felt clever, so I never was confident in anything I did, there was always useful maths in life but now in the last few years I'm much more confident. I'm pretty confident now with anything I do, so I don't see anything that I can't achieve now so with maths if I see a problem I want to know if I don't know how to solve it I want to try to solve it so I can figure out what I'm doing.

Q That's really good mate, how do you like to learn maths, do you have any particular preference or how would you like to teach maths?

A Can you hang on one sec I've just this lady ringing me, one sec… Sorry Marty, you were saying?

Q How do you like to learn maths? How do you like to be taught maths? I suppose by extension, how would you like to teach maths as well?

A The thing that is interesting now with this PBL approach, getting more student led, I like the concept because the trial's going to develop, rather than me just giving them the procedures and how to do it and just saying fill them in, from what I've learnt in the last few years, the pedagogy and the theory and there's a whole *0:29:05.9 development and all the rest of it.

To me if you can get the child, give him the scaffolds and then let him construct the knowledge it's going to be more meaningful because he's going to understand what they're doing rather than me just say, "Here's the procedure, just do it." I think when I teach, as far as I can within the syllabus and all the rest of it, I like the concept of this PBL approach where the student guides and you're there to help them. I can see the benefits, the merits of it.

Q Good Shaun, that's good mate, do you think that you'll use challenging work?

A For the students?

Q For the students.

A One thousand percent and the reason for that is, I've got a nine year old son who's very gifted and he's way above any curve, he's very very clever and I've seen through my experience with him that unless you challenge and push a child they're just going to be cruisy and they're not going to learn, they're not going to develop, they're not going to progress. I will always work, in a perfect world, work in every child's *0:30:22.1 development to get them and push them further, that's what I think.

Q What do you, just briefly, understand, what do you see challenge as?

A In maths or general?

Q In general.

A What do I see challenge as?

Q When you think of challenge what do you think of?

A When I think of challenge I think that using what a person or a child knows, get a person or the student or myself, give them a concept that they know of but in a different format or an abstract form or a way that's going to make them use those existing skills in a new environment that's going to help them to grow positively, grow in an education sense, something that's going to help you progress mentally, use mental strategies, that sort of challenge.

Q So you really have to learn, I suppose if I challenge there's an element of failure of getting things wrong naturally because it's hard. You'll have kids in your class that will probably fail, well will fail, not fail overall, I mean just simply fail at a task or get things wrong. How do you think you might deal with that at this stage of your learning, how do you think you might deal with that in your classroom? If a student's getting things wrong and feeling like they can't do it.

A I've been blessed with patience I have an extreme amount of patience with every aspect of my life, with myself with other people around me. A lesson that I learnt a long time ago is and I've used it in a number of my essays is and I just used it in my essay last week for HSIE; me as a teacher I've got to look through the eyes of the child and link them with their art so I'll give a child the scaffold, I'll give that child extra scaffolding because they'll need it, but if they do fail, I'll do everything in my power to give the child the environment to learn.

There's a plethora of reasons its upbringing, it's a child's home environment, it's the stimulation that either was, or wasn't given, more importantly wasn't given because those children, they might have some learning difficulties or they might have a behavioural problem. You've got to factor in so many factors now, I've got to try and learn, the child's going to come with a blank slate, I've got to learn as much as I can about that child and if I see that they're failing in a certain area I've got to try and analyse, I'll try to have a listening approach for the child, that's how I see things.

You go to the doctor with a symptom, the symptom isn't the problem, it's well what's going on, fake the symptom. That's how I see it so with my children I'm going to try and take a listening approach to understand a bit about them. I've done a bit of work on the development of life stuff, it's taught me all this stuff.

Q That's terrific mate, only got a couple more questions to go, you've already mentioned the unit mate that was good because that was going to be one of the questions.

A What was that?

Q About the unit, about how you're finding the unit, what are your personal goals for this unit, what are you hoping to get out of it personally?

A Get out of it?

Q Get out of this unit?

A I understand how to teach maths, I was never taught maths so I'm starting prac tomorrow, big huge step I'm very excited, nervous.

Q Whereabouts is that mate?

A I'm in Condell Park in Bankstown in Sydney very challenging environment.

Q I was about to say that'll be a good experience.

A Very challenging, so out of this unit from what I understand it's a very pedagogical based subject unit and I'm trying to get out of it an understanding of how to teach maths to students. I'm reading the introduction again chapter in the Heylock. I feel a lot of what those other pre-service teacher was saying, just not thinking smart enough or clever enough to teach it and not understanding, trying to get your head around all the pedagogy name and all the rest of it. The one image that has stuck in my head over this unit so far is that image of the three circles of the content, the student and the pedagogy, so that one stuck in my head. That's my aim, to try and master all three, top of the *0:35:58.2.

Q That's fantastic I know exactly what you're saying. Two last questions, from a scale of zero to ten, how hard do you feel like you are having to work at this unit as far as ten being the hardest thing you've ever done in your life and zero being I'm not working hard at all, where do you feel like you're at?

A Ten.

Q On the scale of zero to ten again, how challenging or easy is this unit so ten being the most challenging?

A Ten, this is based on this being my eighth unit of study and this year was the hardest I've ever done, it's very hard.

Q That's amazing. We've finished the interview. I was wondering whether I might be able to chat to you again later on in the semester?

A You can chat whenever you need to.

Q Towards the end if that's okay.

A I appreciate that.

Q Not a worry mate, have a look at the lecture later on during the week and I think there'll be things that we talk about and you'll resonate very closely with the mastery learners.

A Obviously I should keep this under my wrap that I'm doing this for you?

Q That'd be fine, not a worry, that'd be good. Thanks Shaun, all the best mate.

END OF TRANSCRIPT