OLD HABITS DIE HARD:
Overcoming Uncertainty to Facilitate Contemporary Learning Outcomes

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DECLARATION

I, Marguerite Joyce O'Bryan, hereby declare that this thesis contains only my original work towards the award of the degree Doctor of Philosophy. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except where due acknowledgement has been made in the text of the thesis. The thesis is fewer than the maximum limit of 100,000 words in length exclusive of tables, references, and appendices.

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<td>ACARA</td>
<td>Australian Curriculum, Assessment and Reporting Authority</td>
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<td>CAS</td>
<td>Computer Algebraic System</td>
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<tr>
<td>IT</td>
<td>information technology</td>
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<tr>
<td>IB</td>
<td>International Baccalaureate</td>
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<tr>
<td>IUM</td>
<td>Innovative Uncertainty Model</td>
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<tr>
<td>LMS</td>
<td>Learning Management System</td>
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<tr>
<td>LOC</td>
<td>locus of control</td>
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<td>MUHREC</td>
<td>Monash University Human Research Ethics Committee</td>
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<tr>
<td>MYP</td>
<td>Middle Years Programme</td>
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<tr>
<td>P21</td>
<td>Partnership into 21st Century Skills</td>
</tr>
<tr>
<td>PC</td>
<td>personal computer</td>
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<tr>
<td>PD</td>
<td>professional development</td>
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<tr>
<td>SAC</td>
<td>school-assessed coursework</td>
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<tr>
<td>SMART</td>
<td>specific mathematics assessment that reveals thinking</td>
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<tr>
<td>VCE</td>
<td>Victorian Certificate of Education</td>
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<td>VCAA</td>
<td>Victorian Curriculum and Assessment Authority</td>
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ABSTRACT

This qualitative study sought to understand mathematics teachers’ use of digital technology in their classroom lessons, to investigate the pedagogical advantages that ensued, and to contribute to research knowledge about the facilitating factors and obstructions to the uptake of digital technology in the mathematics classroom. When this study commenced in 2012, a prevailing perspective in the area of digital integration for educational purposes influenced the direction of the study to focus on mathematics teacher beliefs behind digital uses. “Teachers’ own beliefs and attitudes about the relevance of technology to students’ learning were perceived as having the biggest impact on their success” (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012).

The cultural pressure on teachers to include digital technology usage came from many directions: government authority, the school, colleagues, parents, and students. In order to represent teacher beliefs and their subjective responses to the social pressure to change, the study’s complex theoretical framework was built from Bourdieu’s (1977) field theory and the psychology of risk-taking. Field theory accounted for the education environment including its purposes and rewards, and the cultural norms and dispositions of its inhabitants. The psychology of risk-taking accounted for the uncertainty that change engendered in teachers’ psyches and their individual responses to digital innovations.

After plodding along in an ever-evolving digital, educational, and social environment and collecting data that supported previous research but not especially new ideas, the study was diverted by recent neuropsychology findings. Evidence emerged to support the notion that the introduction of digital innovation to a regular mathematics lesson gave rise to a conflict between teacher habitual and goal-directed behaviours. The cognitive conflict was mediated by certainty. Innovations were vulnerable to being overrun by regular classroom practices that provided comfortable surety for the teacher. Factors that allowed the teacher to avoid, or take control of, the cognitive conflict were identified. Findings raised issues for current mathematics pedagogical practices and mathematics performance. Results are applicable to educational innovation in general and not limited to mathematics pedagogical change due to the introduction of digital innovation.
CHAPTER 1
INTRODUCTION TO THE STUDY

The study on which my PhD thesis is based followed a discovery–learning paradigm—a personal, internal, constructivist environment (Levin & Wadmany, 2006). The journey traversed a complex research framework with ideas that permeated my waking life and my dreams to reveal an intuitive but unexpected result. My daily nonacademic routines were affected, and these in turn contributed to the study’s conclusions. As such, outside the research boundary, a secondary story unfolded and is told here in the form of chapter book-ends as ideas were transferred from the study to the rest of my life and vice versa.

1.1 Introduction

This thesis describes a study of mathematics teacher pedagogical practices and their actions taken to use and perhaps integrate digital technology into classroom lessons. The aims of the study were to understand how and why mathematics teachers used digital technology in their lessons, if the uses were new, developing, or well established, and how the uses provided pedagogical advantage or benefit.

In order to use digital technology, the participant teachers needed to consider change to traditional teaching practices that previously had not included digital technology. The study did not rely merely on external factors such as technology access or school support as facilitating or obstructing digital technology use, which has been well researched (refer to the Literature Review, Chapter 2). Instead, the focus was primarily on the beliefs of teachers and ensuing actions in updating their pedagogical approaches with digital innovation.

At the commencement of this study, various general digital technology options had been established in schools to address teacher and student administration, organisation, and communication tasks. The study’s interest however was on digital technology uses
that facilitated mathematical conceptual understanding and application for the achievement of mathematical learning outcomes rather than any other purpose. This perspective was chosen to address the evolution of mathematics education in response to digital technology developments and the future needs of students. Bishop (1996) noted that computer developments were not only changing the way we think about mathematics teaching, they were changing the nature of mathematical activity itself. In what ways, if any, had mathematics teachers responded to digital technology developments and the contemporary needs of students, and how were these changing the nature of mathematical activity?

The term “integration” was used in this study to refer to the process of combining features of technology and features of mathematical pedagogy into an integral whole. The term “digital technology” refers to any technology that uses binary electronic circuitry. A “digital system” comprises software and hardware components (internal and external) used to transform data into a digital solution. When digital systems are connected, they form a “network” (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2015). Digital technology in the mathematics classroom refers to multimedia, both the hardware and software of calculators; presentation technologies such as projectors, interactive whiteboards, and television; mobile technologies; computers; and networks and communication technologies in general.

The research problem is that, despite seemingly compelling pressure to change (Bennison & Goos, 2010), the integration of digital technology in mathematics lessons has been slow, and mathematics teachers have seldom opted to include digital technology in the teaching and learning of mathematical concepts (Goos & Bennison, 2008). Mathematics teachers have been reluctant to integrate new ideas into their lessons, and perhaps they were resistant to change in general (Bingimlas, 2009).

Ertmer et al. (2012) told of many articles recommending strategies to facilitate meaningful integration and the types of barriers encountered. The authors found that teachers’ own beliefs and practices about the relevance of the technology to student learning were having the biggest impact on successful integration and suggested that professional development be directed at facilitating change in teachers’ beliefs and attitudes. These research findings were still relevant and the problem was real in my teaching experience when I began this study in 2012.
1.2 Research Context

This study was conducted in an era when digital technologies were perceived as having huge potential for the transformation of school education (Castells, 2001), and educators had had more than a decade to realise that potential for mathematics education in the 21st century. For over 30 years, education leaders and researchers had been predicting and discussing transformation. The forecasts anticipated that technology would become rapidly integrated into every level of education, challenging educators to adapt to a new pedagogy emerging from the social order that was represented by the internet and other communication technologies (Castells, 2001).

Pressure to change arose first with the relentless technology evolution, which started with the Industrial Revolution and continued into the Information Age. Political, social, and educational pressures to prioritise learning outcomes such as critical thinking and information management have been drivers for change in Australia and around the world (ACARA, 2008). Massive financial investment in digital technologies has consolidated change, which in turn has provided additional pressure to use the technology and the tools to transform teaching and learning. Success in bringing digital technology into the classroom has been recorded in many national education systems (Rutkowski, Rutkowski, & Sparkes, 2011).

Identification of a new contemporary skillset accompanied the development of digital tools. In the United States, the Partnership into 21st Century Skills (P21) Framework (2002) identified desirable skills including creativity, critical thinking, communication, and collaboration, and skills in using information, media, and technology. In Australia, ACARA developed the new Australian Curriculum guided by the 2008 Melbourne Declaration on Educational Goals for Young Australians (ACARA, 2008). ACARA described the characteristics of successful learners as deep and logical thinkers, creative, innovative, and resourceful and committed to “All young Australians become successful learners, confident and creative individuals, and active and informed citizens” (ACARA, 2008, p. 9).

These ideals resonated with the logical thinking and the problem-solving processes promoted by mathematics, while mathematics education with digital understanding raised the possibility for innovative and experimental digital strategies to be incorporated into the mathematics curriculum: “The potential for digital technologies
to enhance student’s mathematics learning is widely recognised, and use of computers and graphics calculators is now encouraged or required by secondary school mathematics curriculum documents throughout Australia” (Bennison & Goos, 2010, p. 31).

In 2008, the Australian Federal Government provided digital support for the national curriculum by launching the Digital Education Revolution (Department of Education and Training, 2013). The government’s aim was to contribute to sustainable and meaningful change that would prepare students to live and work in a digital world. Digital Education Revolution initiatives included the National Secondary School Computer Fund, providing the funding for one-to-one computing for all students in Years 9 to 12 in all Australian schools, and the installation of the National Broadband Network to deliver high speed internet access to schools and homes and provide access to innovative online education and training. The actions of government in providing funding for digital initiatives in schools resulted in political pressure on teachers to use digital technology in lessons.

A review of literature, discussed in more detail in Chapter 2, revealed a mixture of responses to the pressure for digital use. Bingimlas (2009), citing international references, indicated that there was a general teacher resistance to digital technology use, and significant research had been devoted to identifying the obstacles encountered by teachers. Becta (2010) identified one teacher’s obstacles: “Maths demands a lot of exposition and teaching from the front. Poor-quality equipment creates problems. Blocked websites are a disruption” (p. 83). Despite the social and political pressure, research and teacher interest in using digital technology in mathematics classrooms was slow to develop.

1.3 My Background

The catalyst to embark on this study was my perception that some mathematics teachers were reluctant to try out new ideas in their lessons a personal conflict that had developed in my pedagogical approaches to teaching traditional mathematics and contemporary computing lessons.

I first programmed a computer in 1968 at secondary school in the United States. I returned to Australia to major in mathematics and then computing at university. I
enjoyed a significant career in the information technology (IT) industry as a programmer, system analyst, and manager. Impeded by a perception of “glass ceiling”, I switched careers in 2001 to education, and I have been a teacher of secondary school mathematics and computing ever since. My role as an e-learning coordinator influenced my perceptions and conflict.

At the commencement of this study, my teaching strategies for computing lessons included inquiry-based learning projects, student-centred choice and negotiation, and projects in conjunction with external organisations. I provided scaffolding, guidance, and challenges in the classroom. By contrast, my mathematics lessons were traditional by agreement with my subject teacher colleagues and based on instruction, uniformity, and repetition. I believed in the effectiveness of teacher collaboration and agreement but was unhappy with my contrasting teaching approaches.

I did experiment with using digital technology in my mathematics lessons. I found it mysteriously challenging to identify the pedagogical purpose of digital components in mathematical tasks. The time and effort required to develop or to find software that was engaging, meaningful, or an improvement on known teaching and learning approaches was often prohibitive. When I did manage to find a satisfactory application, I found it challenging to position new strategies into the agreed, tried and true, curriculum. I had great difficulty in persuading colleagues to trial digital applications in their lessons.

Digital technology use was not the only difficult change for the mathematics teachers at my school. The school had implemented the International Baccalaureate (IB) Middle Years Programme (MYP) in 2007 (IB, 2014). Comprehensive initial training for all teachers was an imperative of the program. However, the change to IB MYP practices remained elusive for mathematics teachers as a whole. These teachers appeared to be more successful in adapting the IB philosophy to their teaching rather than their teaching to the IB philosophy. All the mathematics teachers at the school received additional IB training in 2013 when the school became an IB World School. Despite this training, the adjustment to IB philosophy remained a challenge for mathematics teachers.

One requirement for the World School was to promote the IB “learner profile” (IB, 2013), a list of 21st century student attributes. The list included “risk-taking”, which
was described as being resourceful and resilient with new ideas. The mathematics teachers at my school agreed as a group to avoid promoting risk-taking in their lessons. I found this interesting from the perspective that teachers also needed contemporary learning attributes such as risk-taking in order to take their place in a changing world.

The juxtaposition of continuing traditional approaches, digital technology challenges, and the avoidance of risk-taking by mathematics teacher colleagues led me to question how well the teachers were managing contemporary change in general and to launch a study of these issues.

1.4 Definition of Uncertainty

The term risk-taking, in the sense of “the practice of taking actions which might have undesirable consequences” (Collins Dictionary, 2017), appeared to raise negativity with my teacher colleagues and then with this study’s participants. I sought a more palatable phrase, and the term “facing uncertainty” was chosen. Hubbard (2009) suggested a distinction between uncertainty and risk. Uncertainty was the existence of more than one possible consequence to an action where the true outcome/state/result/value was not known. Risk was a state of uncertainty where a probable outcome involved loss, catastrophe, or other undesirable consequence. While seemingly focused on positive or neutral consequences to digital technology use, this study remained attuned to the possibility of risk when teachers were facing uncertainty.

1.5 Positioning the Study Within Mathematics Education Research

The introduction of digital technology into mathematics lessons represented a change from traditional pedagogical practices, for example, from my childhood. Digital technology change began with the experiments of entrepreneurs and was spread by the diffusion of good ideas (Rogers, 1995). Then the speed and complexity of digital evolution overtook the change processes, and cultural pressure based on social, political, and educational concerns emerged as the primary driver for digital technology use in school classrooms (Wilson, Sherry, Dobrovolny, Batty, & Rider, 2002). Digital innovation research in the general classroom, and reflected in a smaller way in the mathematics classroom, focused on the complexities of digital infrastructure in schools, teacher professional development, and preservice teacher training.
Obstacles to digital use were recognised with causes separated into extrinsic factors over which the classroom teacher had little control, and intrinsic obstacles that challenged the individual teacher (Ertmer, 1999). In particular, when all other obstacles had been removed, teacher beliefs remained a significant barrier (Ertmer, 2005). Many research findings concluded that teachers did not understand digital technology purposes (Roblyer & Edwards, 2000; Wilson et al., 2002). Other research findings suggested teachers needed to find purpose (Gibson & Tavalin, 2000). My interest was drawn to the role of teacher beliefs in choosing to use or not use digital technology in the classroom and the reasons for making these choices.

Despite the obstacles, research has shown that the use of digital technology for some purposes has been successful. In particular, Computer Algebraic System (CAS) calculators (Pierce & Stacey, 2004), spreadsheet software (Thomas, 2006), and the internet (Loong, 2003) have become established tools in Australasian classrooms. Pedagogical practices have continued to evolve in the mathematics classroom. Teachers have seemed hesitant about digital technology use even while the factors contributing to reluctance have also evolved.

Since 2006, the digital landscape has changed dramatically in terms of availability and variety of digital devices, social expectations, and educational policy (Geiger,Forgasz, Tan, Calder, & Hill, 2012). This trend was reflected in the digital technology resources made available in my school about this time with the adoption of interactive whiteboards in classrooms, an intranet (eWorkspace, intranet, 2001) Learning Management System (LMS), and numerous computer laboratories that were ultimately replaced by personal laptops for teachers and students.

Research into the influences of digital technology on mathematics education has expanded to include issues in the learning environment, and gender and affect issues for teachers and students in relationship to digital technology use. Research results have conflicted in terms of the value that mathematics teachers place on the use of digital technology. Teacher beliefs, the culture of schools, and the organisation of time and resources are significant issues in digital technology use for mathematics lessons (Goos & Bennison, 2008; Pierce & Ball, 2009). This study included a focus on school education culture as a pivotal factor in understanding the use of digital technology for pedagogical purposes.
1.6 Conceptualising the Problem From a Beliefs Perspective

The study began with a significant focus on the beliefs of mathematics teachers in classroom practice. Simmons et al. (1999) described the mathematics classroom as a complex matrix of culturally based beliefs—the teacher’s personal beliefs, beliefs about the nature of mathematics, the nature of teaching and learning, and about the self as a teacher. The environment reflects the beliefs and expectations of the school, students, and community. Digital technology adds beliefs about technology to this mix (Forgasz, 2002; Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010).

General research into teacher pedagogical beliefs has covered a range of aspects. Teachers’ enacted beliefs in the classroom do not necessarily match their stated beliefs (Judson, 2006; Ottenbreit-Leftwich et al., 2010; Pajares, 1992). A hierarchy of beliefs mediates contradictory teacher behaviour (Rokeach, 1968; Watson, 2006). In the case of mathematics teacher beliefs, research has shown that teachers are likely to adopt beliefs about mathematics and mathematics education from different ideologies (Ernest, 1991).

Research into teacher beliefs and the integration of digital technology has found competency, outcome expectations, interest, confidence, and willingness to change to be facilitating factors (Niederhauser & Perkman, 2008). These interpersonal factors link teacher behaviour to the beliefs underpinning the psychology of uncertainty/risk-taking, such as self-efficacy, control purpose, and benefit (Priest, 1993). A limited number of research articles have related teacher uncertainty and risk-taking to digital technology in educational practices (see Section 2.4.4). This complexity of pedagogical beliefs added weight to my interest in teacher beliefs and the use of digital technology.

1.7 Research Problem and Research Questions

My personal experience of teaching mathematics lessons contains elements of problems that have been recognised in relevant literature. Newly acquired access to a wide range of digital technology, increased pressure to use it, and confusion about digital purpose had all emerged at my school. The findings of research studies and solutions to problems had not filtered into the school, or perhaps we, the teachers, had overlooked them. However, the literature showed that the problems existed in a wider context than just my school, and further research in this area was warranted.
The research problem I identified is that, despite seemingly compelling pressure to change, some mathematics teachers seldom opted to use digital technology in the teaching and learning of mathematical concepts and for contemporary student learning outcomes. These teachers were reluctant to try out new ideas in their lessons, and perhaps they were resistant to change in general.

Research questions were derived from the literature review detailed in Chapter 2. The literature review focused my attention on gaps, inconsistencies, and ideas about how to proceed, for example. However, in the manner of discovery learning, I chose a generic set of research questions that afforded me the opportunity to conduct further research without pre-empting what I might find. The following questions guided my study.

1. How is digital technology being used in mathematics lessons in a secondary school mathematics lesson, and for what pedagogical purposes?

2. Which teacher beliefs facilitated or obstructed mathematics teachers using or directing the use of digital technology in their secondary school mathematics lessons?

3. What mathematical pedagogical practices no longer make sense in a contemporary secondary school mathematics learning environment?

1.8 Significance of the Study

The significance of the study lies in the importance of gaining a better understanding of the role of digital technology in mathematics education. Unless mathematics teachers respond to societal, cultural, and political education requirements and the needs of the contemporary student, they risk irrelevance and obsolescence in their profession.

Findings of this study may prove relevant to initial teacher training programs and professional development activities for in-service teachers. Further insight into the development of student understandings, application of mathematical concepts, and how these might need to change for a digital society would be a significant outcome.
1.9 Thesis Outline

This thesis is laid out in the following order. Following this introductory chapter, Chapter 2 reports on the research literature related to obstacles and facilitating factors to digital technology uptake in education in general and mathematics education in particular, the integration of digital technology in the classroom, teacher beliefs and habits, and teacher change. Gaps in current research knowledge related to the study are identified and lead to the formulation of the research questions guiding this study.

Chapter 3 describes the theoretical framework against which the study was conducted. The framework was constructed from a social cultural model of mathematics education and the psychology of risk-taking theory. Chapter 4 describes the methodological design of this study. Data collected from three individual Victorian Certificate of Education (VCE) teacher participants and one group of Year 7 teachers are described in Chapters 5, 6, 7, and 8.

Chapter 9 presents an analysis of the data used to identify the beliefs of teachers, patterns of digital technology use, and obstructive and facilitating factors to digital technology uptake. Chapter 10 provides a theoretical discussion of emergent ideas and shifts the focus from what teacher practices do not make sense to why they do not make sense.

The thesis concludes with Chapter 11 in which answers to the research questions and an outline of the implications for teacher practice and future educational research are discussed. Limitations inherent in the research design are discussed with the research findings and conclusions at the end of this report. A glossary of acronyms and terms used in this research report are presented at the beginning of this thesis to facilitate easy reference by the reader.
My sport is table tennis, first played in my youth. I returned to table tennis competition 10 years ago after a significant layoff. I recommenced with a limited game, offset somewhat by a stinging forehand drive left over from my youth. I challenged myself to be better at table tennis in my 50s than in my 20s and sought coaching, and dedicated practice. I became better at table tennis, and then I plateaued. I believed this was a common problem but solutions suggested by my coach did not seem to help. How could I improve my match play? Had I reached the limit of my potential? Was I too old to learn new skills? I had a problem. There were questions to be answered.
CHAPTER 2
LITERATURE REVIEW

In my spare time, I thought about how to change my table tennis game and discussed my frustration with friends. Someone suggested I read a book called *Choke* (Beilock, 2010) to improve my table tennis performance. *Choke* addressed the psychology of performance in playing sport, sitting a mathematics test, and interviewing for a new job. This popular book on the psychology of performance under stress introduced a behavioural connection between performing mathematics in a test and performing table tennis in a match.

2.1 Introduction

Chapter 1 provided an introduction to this study of teachers’ beliefs about the use of digital technology in mathematics lessons. Factors that contributed to the structure and flow of this research were triggered by my own experiences and background. The research problem was situated in an overview of the then current and relevant mathematics education research environment. Issues considered important to the success of integrating digital technology found in literature included teacher beliefs, digital technology purpose and value to mathematics learning outcomes, and reliable, accessible technology. This chapter addresses in detail the pertinent ideas from research literature that informed the study.

A literature review of digital technology use in schools was undertaken to investigate the research problem presented in Chapter 1. The review focused on the use of digital technology in mathematics classrooms, teacher practices and change in digital technology use, teacher beliefs and dispositions related to pedagogical practices, and the consideration of teachers facing uncertainty and perhaps risk in using digital technology. The literature review led to the formulation of research questions and the development of a theoretical framework and methodological approach used to identify contributing factors for answering the research questions.
A search of literature published both in print and online used a series of search terms to find out what was known and understood about the use of digital technology in pedagogical practices. The research strategy grew from using original search terms such as “integration of technology”, “obstacles”, “education”, “classroom”, and “mathematics” and took into account variations of words and usage such as “implementation”, “adoption”, “use”, “uptake”; “computers”, “digital technology”, “ICT”, “calculators”, “interactive white boards”, “internet”; “barriers”, “obstructions”, and “facilitating factors to technology integration”; “teacher change”, “teacher identity”, “teacher beliefs”; “learning outcomes”, “purpose”, “uncertainty”, and “risk-taking”.

Bingimlas (2009) noted that the literature on the integration of technology in subject-specific areas such as mathematics was limited at the time, and after an initial investigation, I concurred. It seemed prudent, therefore, to study the integration of technology in the broader context of the general classroom, then compare and contrast these findings in the mathematics school education domain in order to identify mathematics-specific factors.

This research considered all digital technologies, either in use in the classroom or suitable for classroom adoption, as a possible contributor to student learning achievement. This was to ensure that digital technology learning benefits were not overlooked when the technology was perhaps used in unexpected ways. In addition, the processes of integration, the pedagogical uses and effects, teacher behaviour and changes in behaviour, how obstructions might be addressed, and what has been learnt are issues that have been investigated in research literature dating from about 1995 to 2012. There were some exceptions, such as Rokeach (1968), who provided a foundation stone for understanding beliefs and was cited by many researchers in literature.

Four dominant themes (each with a number of subthemes) emerged from the literature reviewed: integration of digital technology in school lessons; teacher practice and change; beliefs, values, and habits; and facing uncertainty. These themes are discussed in the following sections in the context of both general classroom and mathematics classroom environments.
2.2 Integration of Digital Technology in School Lessons

2.2.1 Meaning and purpose of digital technology integration

2.2.1.1 General classroom perspective

Digital technology integration has been the topic of extensive research and continued to attract interest at the time this literature review commenced in 2012 and beyond the study’s data collection conducted in 2015 (Ertmer, et al., 2012; Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2016). For more than 30 years, new technologies have been emerging from an infant and dynamic information and communications technology industry (Zhao, Pugh, Sheldon, & Byers, 2002). In the early days, while some technology was designed specifically for classroom use, more often than not it was purposefully adapted from commercial sources. Technology was appropriated and used in ways not anticipated by inventors (Baker, 2003; Kierl, 2002). Other technologies evolved, and some were soon replaced. Laser disc hypermedia and instructional television in education environments became obsolete despite being deemed successful early on (Zhao et al., 2002).

A review of the literature indicated a lack of uniformity in definitions and processes related to digital technology use, adoption, or uptake in a rapidly evolving environment. In the early days, technology for education was described in terms of the use of chalk and blackboards but came to mean the use of some device or set of equipment, particularly computers (Roblyer & Edwards, 2000). The meaning and purpose were not explicitly stated but rather implicitly assumed or expressed in vague, general terms such as “using technology to make learning better and more productive” (Roblyer & Edwards, 2000, p. 12).

Wilson and his colleagues (2002) recognised three distinct models of technology uptake in educational settings: behavioural, diffusion, and cultural. The behavioural model favoured use over purpose. Studies on the purchasing of hardware and software, usage statistics, and fair distribution were more important than why and how the technology was employed (Berge & Mrozowski, 1999; Sandholtz, Ringstaff, & Dwyer, 1997).

The diffusion model was based on innovation diffusion and rational choice (Wilson et al., 2002). Rogers (1962) coined the term innovation to mean “new idea”
and diffusion as its rate of spread. He initially applied the concept of innovation diffusion to the uptake of a new strain of corn when information about its merits seeped through the population. The fourth edition of his book *Diffusion of Innovations* (Rogers, 1995) featured digital technology and was a popular starting point for many education researchers. Rogers defined the innovativeness of people or organisations as a measure across five dimensions categorised as innovators, early adopters, early majority, late majority, and laggards. He described innovation adoption as a five-stage process: knowledge, persuasion, decision, implementation, and confirmation. This description resonated with my professional understanding of the stages of a digital technology project methodology – feasibility study, cost-benefit analysis, goals, objectives and success criteria, implementation methodology and sometimes quality assurance.

From 1995 to 2000, there was a research shift in education environments from purposeful innovation diffusion to cultural assimilation of digital technology. Gibson and Tavalin (2000) reported on digital technology adoption in schools based on the diffusion model and suggested that the last step was teachers finding purpose for the new technology. The idea of technology uptake based on merit had been overrun.

The cultural model represented adoption due to cultural forces, such as mandated reform and changing student needs, and followed a process of cultural assimilation (Wilson et al., 2002). The benefits emerged after the digital technology was adopted and perhaps adapted by the user (Baker, 2003). Rogers (2000) defined integration as a medium measure of acceptance without much effect on the status quo. Success came with sustainability or endurance of the technology over time (Wilson et al., 2002). With sustainability, the innovation typically became valued and supported as part of the institution’s culture (McAlister, Dunn, & Quinn, 2005; Schneider, Brief, & Guzzo, 1996).

Belland (2009) believed that, in general, digital integration had not been achieved. He proposed an objective, cultural, and sustainable definition from the perspective of the school rather than the teacher: “Technology integration is the sustainable and persistent change in the social system of the K-12 schools caused by the adoption of technology to help students construct knowledge” (Belland, 2009, p. 354).
To summarise, the definition of the term “integration of technology” has been lacking or implicitly suggested to be the use of technology. The definition evolved to include ideas about purpose, innovation diffusion, cultural assimilation, and sustainability, with distinct stages seen from the perspectives of the digital technology, the individual teacher, or the school. It was expected that fully integrated technology would significantly affect learning and the culture of the school.

2.2.1.2 Mathematics perspective

Research literature based on the mathematics classroom reflects similar confusion to that outlined in Section 2.2.1.1. Early on, research focused on teachers’ use with limited comment on purpose (Loong, 2003; Manoucherhi, 1999; Simonsen & Dick, 1997).

A longitudinal study over 10 years conducted by Thomas (2006) examined the changing nature of how teachers used computers in the mathematics classroom and their perceptions of obstacles to computer use. Thomas’ study was initiated by doubts about the learning value of computer technology for mathematics, but it focused on usage issues. The findings determined that use of digital technology in mathematics remained low despite increased numbers of computers and frequency of use in schools. Obstacles to use were identified in detail. Only 8% of mathematics teachers believed digital technology to be educationally advantageous, but these advantages were not discussed. Over the 10 years of the study, there was a significant decrease in the use of mathematics-specific software, but the reasons for this were not mentioned. One finding of McAlister et al. (2005) was to ensure that common goals in the pedagogical use of digital technology in the mathematics classroom were understood.

2.2.1.3 Meaning and purpose

My professional experience of objective approaches to digital technology implementation was in stark contrast to the approaches to digital technology uptake outlined in the literature. I found several problems in what I had read.

Roger’s (1995) diffusion theory was insufficient for the complexity of digital technology and the pace of change at the time, especially when digital innovation is compared to the simplicity of a new strain of corn. The multiplicity of computing issues, such as access and reliability, attached to a single application muddied the
environment as there was often more than one new idea in play. I call this the ripple effect of digital technology uptake. Ripple effect was not well understood by researchers and educators. Furthermore, sustainability of digital technology innovation was also problematic given that digital technology was rapidly changing.

My perception of digital technology integration is an evolving process of teacher use in lessons for more efficient and/or more effective pedagogical outcomes. An initial stage of the process is to identify the pedagogical purpose and benefit. The teacher knowingly selects, justifies, uses, and evaluates student achievement of existing or new learning outcomes. I consider sustainability of pedagogical advantage a more relevant measure of success than sustainability of a digital innovation.

2.2.2 Barriers to digital technology integration

2.2.2.1 General classroom barriers

Extensive research throughout the 1990s around the globe but particularly in North America found that obstacles or barriers reduce the role of digital technology in classrooms. The most common barriers were identified as time, expertise, access, resources, and support (Fisher, Dwyer, & Yocam, 1996; Leggett & Persichitte, 1998; Means & Olsen, 1994).

Ertmer (1999) at Purdue University Indiana “famously” provided a distinction between first-order barriers, such as equipment, time, training, support, and access, and second-order barriers, such as teacher beliefs about teacher–student roles and traditional classroom practices, suggesting that either could affect integration.

Subsequent research on this topic has focused on extrinsic factors as first-order barriers, and in this way, the complexity of digital technology has been partially addressed. Authors have identified additional issues of technical and financial support, the availability of high-quality content, teacher instructional vision, and technology reliability (Bauer & Kenton, 2005; Brennan, Miller, & Moniotte, 2001; Butler & Sellbom, 2002; Means, Penuel, & Padilla, 2001; Mumtaz, 2000). Zhao et al. (2002) examined a complex process of classroom technology innovation by following a group of teachers for one year as they attempted to implement technology-rich projects in their classrooms. Their findings included a list of 11 inhibiting factors to success.
Teacher resistance to digital integration has been due to intrinsic factors, including lack of teacher knowledge, skills, confidence, and incompatible beliefs about technology and pedagogy, learning to use new technologies, and uncertainty about the worth of new technologies (Butler et al., 2002; Hew & Brush, 2006; Lumpe & Chambers, 2001; Means et al., 2001; Mumtaz, 2000). Ertmer (2005) argued that while extrinsic conditions for technology integration had improved in the United States, several factors pertaining to teacher beliefs were yet to be resolved. She suggested that the final frontier for technology integration in the classroom was addressing the intrinsic influence of teachers’ beliefs.

Research on obstacles to digital technology was not confined to North America. Hew et al. (2006) surveyed 48 studies in a mixture of elementary and secondary schools around the world including Great Britain, Cyprus, Singapore, Australia, New Zealand, and North America. They identified 123 barriers to technology integration.

More recently, Ertmer et al. (2012) told of thousands of articles recommending strategies to facilitate meaningful integration and the types of barriers encountered. The authors found that teachers’ own beliefs and practices about the relevance of the technology to student learning had the biggest impact on successful integration and suggested that professional development be directed at facilitating change in teachers’ beliefs and attitudes. Further details of research into teacher beliefs and digital technology uptake are addressed in Section 2.4.3.

Research on the integration of digital technology in the Australasian domain has reflected similar trajectories on a much smaller scale (Bingimlas, 2009).

2.2.2.2 Mathematics classroom barriers

Increased numbers and varieties of digital devices and the expectations of school communities have reflected increased Australian research output for digital technology use in the mathematics classroom (Geiger et al., 2012). Studies found that both extrinsic and intrinsic factors were obstacles to the use of computers as mathematical tools and that results were sometimes inconsistent with expectations. When more computers became available in schools, teachers did not necessarily embrace digital technology, while some teachers in poorly resourced schools did embrace digital technology (Bennison & Goos, 2010; Thomas, 2006). Problems with equipment and
software continued and teachers’ workloads were obstructive (Fuglestad, 2009; Hudson, Porter, & Nelson, 2008). Professional development linking digital technology opportunities to the learning of mathematical concepts was inadequate (Goos & Bennison, 2008). Mathematics teachers’ obstructions to integrating digital technology in classroom practices were similar to those obstructions found in the general classroom.

2.2.3 Facilitating factors for digital technology integration

2.2.3.1 General classroom facilitators

Successful integration also emerged from the literature, and in many cases, findings were indicative of paying close attention to obstacles. Facilitating factors were divided into features of the technology, characteristics of adopters, and characteristics of a school environment supportive of integration. The many factors found in research about the successful integration of digital technology were indicative of a complex and challenging cultural environment.

The perceived features of digital technology that largely determined its acceptance included simplicity, trial features, visible effect, relative advantage, compatibility with existing practices, technical support independence of the process of adoption on other people, and technology, with only small deviations from school culture and existing practice (Rogers, 1995; Tearle, 2004; Wilson et al., 2002; Zhao et al., 2002).

Characteristics of successful adopters were dissatisfaction with the status quo; existence of knowledge and skills; availability of time; the existence of rewards or incentives; participation; commitment; a philosophy that supported meaningful learning around group projects for students; pedagogical compatibility; compatibility with the values, experiences, and needs of the potential adopters; knowledge of enabling conditions; and a high level of social awareness (Becker & Ravitz, 2001; Ely, 1990; Zhao et al., 2002).

Characteristics of the successful environment were the availability of resources, classroom access to computers and leadership, technology support, and social support. “Adoption of technology depends on shared negotiation of values and priorities” (Wilson et al, 2002).
2.2.3.2 Mathematics classroom facilitators

Hannon (2008) found facilitating factors for the integration of digital technology in the mathematics classroom were access to the technology, mathematics department ethos, key people to experiment and then provide support for colleagues, teacher confidence in using digital technology, ready-to-use resources clearly mapped to mathematics learning objectives, familiarity with content-free applications and national curriculum, teachers’ own learning experiences with digital technology, and expertise.

2.2.4 Summary

This overall picture of the integration of digital technology in general and specifically for mathematics classrooms shows an evolution of obstacles and facilitating factors. When extrinsic obstacles were addressed, intrinsic factors such as teacher knowledge, understanding, and beliefs emerged as the major barrier to integration (Ertmer, 1999; Ertmer 2005; Ertmer et al., 2012). When integration was successful, features of the technology, the teachers, and the school environment came into focus (Becker & Ravitz, 2001; Ely, 1990; Rogers, 1995; Wilson et al., 2002; Zhao et al., 2002). Researchers continued to cite pedagogical purpose and benefit of the technology as influencing factors on the success of technology integration, yet in general, it had been lacking as a measurable objective in research designs reviewed (Goos & Bennison, 2008; Thomas, 2006).

Further to the idea of pedagogical advantage, a gap in the research that became evident to me was the absence of the particular aim of integrating digital technology for contemporary learning outcomes. Noting the lack of pedagogical connections, findings have been expressed as “connections to mathematics” (Fuglestad, 2009, p. 192) or “meeting their teaching objectives” (McAlister, et al., 2005, p. 77) without specific reference to new pedagogical demands. Researchers had come to identify that digital technology integration would be more successful if the integration was linked to pedagogical advantage, but they had neglected the need for new pedagogical goals.

There have been thousands of articles in the past 30 years recommending strategies to overcome barriers and facilitate meaningful integration. Judson (2006) wrote, “Specific to the relationship between technology integrated practices and teacher beliefs, research is limited” (p. 584). Ertmer and her colleagues (2012) found that
teachers’ own beliefs and practices about the relevance of digital technology to student learning had the biggest impact on successful integration and suggested that professional development be directed at facilitating change in teachers’ beliefs and practices. The focus of researchers shifted to the concept of teacher change to enable the uptake of digital innovations in the classroom.

2.3 Teacher Change for Digital Upsurge

The issues addressed in this section on teacher change include the debate over the effect of pedagogical approach on digital technology use in in-service teacher professional developmental activities, preservice teacher training, and the concept of teachers facing the uncertainty of new ideas.

2.3.1 Pedagogical approach and digital technology use

2.3.1.1 General classroom

Research into the influence of pedagogical beliefs on digital integration success resulted in mixed findings. The debate centred on directed teaching, constructivism, and a hybrid of the two. Roblyer and Edwards (2000) found that no particular teaching method was more favourable to integration and gave examples of successful digital technology use for each of these methods.

Windschitl (2002) found that teachers who explicitly professed a constructivist epistemology often found themselves drawn back into instructional practices in their lessons, whether digital technology was involved in the lesson, or not. From a slightly different angle, Judson (2006) put forward the idea that teachers with a constructivist pedagogical approach were more likely to integrate digital technology, but their stated beliefs did not necessarily match their enacted beliefs. Baylor and Ritchie (2002) found that when teachers used constructivist approaches and were open to change, they found success in using digital technology to facilitate higher order thinking strategies. These results suggested that constructivist approaches were often beneficial but not sufficient to ensure digital technology success.

Researchers (Frederick, Schweizer, & Lowe, 2006; Judson, 2006; Salomon, 2002; Thorburn, 2004) studied the introduction of digital technology as a means of achieving
constructive pedagogical approaches. In general, this was reported as creating confusion for teachers.

Despite approaching the problem from different angles, research could not consistently make a link between digital technology uptake and a constructivist preference either professed or enacted (Teo, Chai, Hung, & Lee, 2008).

2.3.1.2 Mathematics classroom

With respect to mathematics classrooms, it seemed that traditional teaching approaches had dominated and digital technology use was limited. Levin and Wadmany (2006) summarised literature to report that typically, mathematics teachers used linear, authoritative, teacher-centred methods in lessons, disregarded computers, and resisted efforts to move the dominant paradigm towards student-centred learning. Authors (Goos, Galbraith, Renshaw, & Geiger, 2003; Nisbet & Warren, 2000) found that many mathematics teachers were resistant both to constructivist approaches and to the integration of digital technology.

More recently in Australia, there had been a growing interest in researching collaborative approaches to the learning and teaching of mathematics facilitated by digital tools (Beatty & Geiger, 2010; Gadanidis & Geiger, 2010). Baker (2009) found that Australian teachers had difficulty applying constructivist theories to designing digital activities.

Basing research on a single angle, such as constructivist versus transmission teaching, had not produced consistent results. However, it was possible that an element of constructivist pedagogy practice was compatible with digital technology use, but it remained elusive. If, as authors had suggested, mathematics teachers retained traditional pedagogical practices, these mathematics teachers were disadvantaged in using digital technology to support learning outcomes.

2.3.2 Professional development

Researchers in the United Stated turned their focus to in-service teacher professional development and preservice teacher training. Research recommendations included teacher skills training, changing teacher practices, understanding teacher
beliefs better, and improving the identification of learning outcomes (Ertmer, 2005; Fuglestad, 2009; Roblyer & Edwards, 2000; Thorburn, 2004).

Change theory was mentioned spasmodically and then more frequently as research into the integration of technology progressed. Many authors (Ertmer, 2005; Levin & Wadmany, 2006; Nisbet & Warren, 2000; Pajares, 1992) cited Guskey (1986) had made a connection between teacher change and student learning outcomes. Success in the classroom in improving learning outcomes led to a change in teachers’ attitudes and beliefs (Guskey, 1986). Focus for teacher professional development shifted to understanding the characteristics of digital applications and how they might promote learning outcomes (Fitzallen, 2005; Thorburn, 2004).

Based on sociological and social theories, Wilson et al. (2002) suggested the process of teacher adoption of digital technology lay in a deeper appreciation of the rules and structures underlying the technology and how that related to personal pedagogical practice: “approaches to technology adoption may move past descriptive lists of conditions, or even stage theories of linear progress – toward a deeper understanding of underlying processes and relationships” (p. 300).

Research findings suggested that the difficulty with integrating digital technology was more complex than characteristic conditions or staged processes. The complexity of change led Earle (2002) to suggest an incremental process characterised by teacher confidence, competence, and creativity. He acknowledged that innovation to institutionalisation took decades.

Professional development strategies emerged from research findings on teacher digital technology use in the classroom. One suggestion promoted teacher participation in communities of practice, which included ongoing public conversations among stakeholders—teachers, administrators, and parents—on pedagogical expectations and the ways in which these could be realised using technology. Other suggestions included the transformation of classroom practices through new tools and methods, experimentation, reflection, and mutual support. Additional findings indicated that the process of change was initiated by focusing on the teacher’s personal and real practice and self-reflection, pedagogical coaching, peer observation of experienced technology practitioners in classrooms, and the slow introduction of technology tools (Alagic & Palenz, 2006; Anstey & Clarke, 2010; Ertmer, 2005; Hunter, 2010).
2.3.2.1 Mathematics perspective

Research in Australia progressed along similar lines. For example, Bennison and Goos (2010) subscribed to Guskey’s (1986) understanding of teacher change in the context of changed student learning outcomes. Australasian mathematics teachers expressed the need for professional development activities that helped them meaningfully integrate digital technology into lessons to improve student learning of specific mathematical topics, as well as assist with different types of learning (Goos & Bennison, 2008; Hudson et al., 2008; Thomas & Chinnappan, 2008).

Hunter (2010) highlighted the power of family, community, and cultural values in the change process. She mentioned the importance of collaborative interactions between teachers but acknowledged that critical colleagueship was also effective in the context of a trusting relationship that honoured personal experiences and local context. Chapman and Heater (2010) found that the shift from traditional to inquiry-based teaching of mathematics required foundational change of self and practice. Bennison and Goos (2010) favoured the concept of Valsiner’s (1997) zones for the dynamic context of how teachers learnt from their own experiences.

Ideas were plentiful in the research community. The variety of approaches was indicative of the difficulty of reaching consensus amongst mathematics education researchers. However, a number of themes emerged related to the needs of in-service teachers and change needed for digital technology use. These themes included a shift from traditional to constructivist pedagogical approaches, sensitivity towards personal teacher values and priorities, collegial support and collaboration, purposes for digital technology related to specific mathematical topics, and success of use based on student learning outcomes. To that list, I would add contemporary outcomes for mathematics learning in a digital age.

2.3.3 Preservice training

Similarly, there was significant research into the training of preservice teachers in the use of technology in general and in the mathematics classroom in particular. In the early 2000s, research attention was drawn to a serious absence of adequate exposure of preservice teachers to digital technology use in the classroom (Bauer et al., 2005; Kay, 2006).
Belland (2009) espoused the theories of Bourdieu (1977), who defined “habitus” as the set of dispositions to appreciate or do certain things. He suggested that preservice teachers’ habitus lacked exposure to digital technology and this had affected their reception of technology integration. Preservice teacher training and in-service professional development did not provide enough exposure to technology to transform existing habitus (Bauer et al., 2005; Kay, 2006; Sugar, Crawley, & Fine, 2004). Belland’s arguments focused attention on the behaviour of preservice teachers and preservice teacher educators, underpinned by their dispositions. Belland suggested that habitus could be used to study the situation of digital technology uptake in the classroom.

I further investigated Bourdieu’s (1977) theories in research literature. Habitus, field, and cultural capital were constructs that comprised Bourdieu’s field theory: a sociocultural theory of behaviour in which institutional objectives are interpreted and enacted by institution members (Webb, Shirato, & Daniher 2002). Bourdieu drew an analogy for field theory in playing a game. Similar to a game, social fields are constructed with specific structures and rules, and the relative smoothness of the game often depends upon the players accepting and following these rules (Nolan, 2012). As the player continues to engage in the game, the rules become natural and unquestionable, resulting in a “feel for the game” which no longer requires the deliberate act of thinking carefully about each and every move before acting (Nolan, 2012).

Applying the theory to the classroom field, the smoothness of mathematics education has been enhanced by teachers following the rules of traditional practices, and after a while, these practices had become habitual to the teacher and enacted without question.

Needless to say, I was entranced by Bourdieu’s field theory and enjoyed thinking about teaching practice as playing a game.

2.3.4 Summary

Research literature has shown that the process of using digital technology in mathematics lessons required change by teachers. Change took time and contained challenges. Knowing that digital technology use contributed to the achievement of
student learning outcomes was desirable but was not essential to confront the uncertainty of innovation. Nor were the pedagogical approaches, the availability of technology, and the general support for the process of integration essential factors. These conditions affected digital technology uptake by teachers in individual ways.

Changing teacher practice happened in stages. It happened in and out of the classroom. Many professional development models to facilitate teacher change had been devised, but there was no clear way forward. The focus of this study narrowed to the idea that teacher beliefs and habits influenced the uptake of digital technology. The first step was to understand more about beliefs and habits.

2.4 Beliefs and Habits

2.4.1 Definitions and meanings

The focus of this study was on beliefs and habits, rather than any other teacher disposition, and the following provides an understanding of what this might mean.

Rokeach (1968) described belief systems as consisting of beliefs and belief substructures: attitudes and values. All beliefs have a cognitive component representing knowledge, an affective component representing emotional connotations, and a behavioural component representing the precursor to action. Beliefs have an episodic core that links the information received with its context and emotional impact. As such, they are personal, rather than universal. Values are considered deeply imbedded beliefs with predictable behaviour outcomes. An attitude is a group of beliefs about a construct such as politics. Beliefs underpin attitudes, and the study of beliefs contributes to the understanding of attitudes.

In a review of emotions, attitudes, and beliefs, McLeod (1992) suggested that these describe a continuum from emotions to beliefs, representing a decreasing level of affect and increasing levels of knowledge. In terms of action, the continuum represents decreasing levels of intensity of response and increasing levels of response stability. McLeod’s research suggested a process for the development and change of a belief.

Mature beliefs underpin stable responses to situations and repeated consistent responses lead to the development of habits: unconscious routines or actions. Habits
shortcut the thinking process (Duhigg, 2012). Old habits cannot be extinguished, but they can be changed through raising awareness of what is happening, and then changing the routine (Duhigg, 2012).

2.4.2 Beliefs about mathematics pedagogy

In his book *Philosophy of Mathematics Education*, Ernest (1991) wrote about mathematics teacher beliefs. Ernest put forward five ideologies of mathematics education based on mathematical philosophies, ontological and epistemological beliefs, and ethical principles. While his ideologies have been generalised, Ernest believed that teachers develop their own personal version, usually based on one dominant ideology but borrowing ideas from others. Ernest confirmed that reaching agreement on what is important and valuable for mathematics learning could be difficult for some teachers due to conflicting and inconsistent beliefs.

According to Pajares’ (1992) study, when a teacher encountered an entanglement where beliefs did not fully overlap or connect, cognitive reasoning did not necessarily address the problem. When uncertain about the appropriate course of action, teachers reverted to what they knew best. “People grow comfortable with their beliefs, and these beliefs become their ‘self,’ so that individuals come to be identified and understood by the very nature of the beliefs, the habits, they own” (p. 318).

Unchanging beliefs helped provide personal meaning to individuals and allowed them to identify with one another and form social connections. In other words, Pajares suggested that to change beliefs is a challenge to the teacher’s identity and to the social connections that had been formed around those beliefs.

Nisbet and Warren (2000) suggested that mathematics teachers’ beliefs form a mosaic of complementary visions about themselves: their role, their students, the subject matter, and the school. These beliefs may contain conflicting elements.

The literature revealed to me that there were conflicting beliefs about professional practice among teachers, but also within an individual teacher. I had found my own teaching practice to be indicative of this idea.
2.4.3 Beliefs about digital technology

Beliefs related to the role of computers teaching and learning mathematical skills and concepts guided the use of digital technology in mathematics lessons (Forgasz, 2002). These belief constructs were often referred to in terms of affordances and constraints. Affordance related to potential digital action, while constraint described the structure of the digital action (Thomas & Chinnappan, 2008).

Specific digital technology affordances for mathematics pedagogy have been identified. Calder (2010) found that spreadsheets gave students the potential to interact with multiple representations and to receive immediate feedback. The graphics calculator gave students the opportunity to explore various calculus concepts such as derivatives or convergence of a series (Kissane & Kemp, 2008). Computer game affordances included higher order thinking or problem-solving skills (Verenikina, Herrington, Peterson, & Mantei, 2010). More generally, Pierce and Ball (2009) found that most teachers perceived digital usage benefits in terms of increasing motivation, deepening mathematical understanding, and providing enjoyment.

Goos et al. (2003) provided an alternative understanding of digital technology use and the different ways in which technology entered into the mathematical practices of secondary school classrooms. They found the technology to be more than just a passive tool. Rather it was able to reshape interactions between the teacher, the student, and the technology. Goos et al. described the role of digital technology using an analogy of master, servant, partner, and extension of self. The authors wrote that while the teacher’s own pedagogical beliefs and values shaped technology-mediated learning opportunities, technology use could distort that shape. In other words, digital technology functioned independently or dependently as an agent that could facilitate or obstruct student learning in the classroom. This idea suggests that digital use in the classroom constitutes an influence on mathematics teaching and learning.

2.4.4 Intrapersonal beliefs and digital technology integration

A small number of researchers had investigated digital technology integration from the perspective of teacher intrapersonal beliefs. These beliefs included self-efficacy and outcome expectations, interest, and personal traits such as self-confidence and willingness to change (Niederhauser & Perkman, 2008). Self-efficacy is the belief that
one has the skills and confidence to produce a desired outcome. Self-efficacy was considered highly important for learning, as it affected the choice of learning tasks, amount of effort, emotions, goal setting, persistence, and achievement (Bandura, 1986). Outcome expectations described an attitude towards anticipated personal rewards of an action. These could be internal or external affects such as self-satisfaction or respect from others. Expectations were important in providing incentive to act. A person’s interest in situations developed when they believed themselves efficacious and receptive of facilitative outcomes (Bandura, 1986).

Further, useful constructs used by Ajzen (1991) grouped beliefs attached to a certain behaviour in terms of characteristics; behavioural beliefs were related to outcomes, normative beliefs were related to normal social expectations, and control beliefs were related to the opportunities or resources needed for the behaviours. An important control belief was the locus of control (LOC) that referred to an individual’s perception of the causes of future events and whether control of the outcome was perceived to be internal or external to the individual (Joos, Lim, & Lim, 2013).

Findings from research conducted along these lines suggested that intentions to implement digital technologies in the classroom were related to teacher beliefs about the personal value of incorporating these technologies, ease of use, high self-efficacy, and the ability to meet the needs/expectations of digital age students, as well as affording students anytime/anywhere access to learning and interaction (Ottenbreit-Leftwich et al., 2010; Prestridge, 2012; Sadaf, Newby, & Ertmer, 2012).

The research literature suggested that many beliefs played a part in the implementation of digital technology: teachers’ personal beliefs of competency, confidence, control, expectation, success, and personal reward, and professional beliefs on student learning outcomes within the context of the subject matter, demands for contemporary skills, and the need for resources. This research offered scope for studying the beliefs of teachers in relation to the use of digital technology in the mathematics classroom. In particular, setting goals by way of learning outcome expectations had a significant role in the process. The next step was to investigate beliefs in more detail in order to understand the nuances and effect of risk taking with digital technology on existing beliefs.
2.5 Facing Uncertainty

2.5.1 Uncertainty about digital use

The IB “learner profile” (IB, 2013) called the disposition to initiate innovation risk-taking. The learner profile promotes risk-taking for students as learners: “We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change” (p. 1).

These ideas apply equally to teachers as they approach the unfamiliar territory of digital technology use in the classroom, not only as a teacher but also as a learner. Teachers need to take risks to explore new digital options, but do they have the necessary independence of spirit?

Wilson et al. (2002) agreed that digital technology innovators were adventuresome and willing to take risks. They also compared the adoption process of digital technology with a staged model for personal change in overcoming addictive behaviours (Prochaska, DiClemente, & Norcross, 1992). Individuals moved back and forth between stages as they slowly committed to change and integrated the changed behaviours into their everyday routines. The value of this research lay in identifying a process of change for teachers and providing a sense of the spiralling conduct required to achieve it.

In general, the terms risk, risk-taking, and risk aversion within the context of technology integration seldom arose in the research papers I read. Vannatta and Fordham (2004) studied predictors of technology uptake and found that teachers needed to be risk-takers. Hagner and Schneebeck (2001) suggested four “waves” for specifically understanding teachers and their potential for new technologies’ uptake: entrepreneurs, risk-aversive teachers who were fearful of loss of teaching effect, reward seekers, and reluctant teachers who believed in the superiority of traditional methods. Mathematics teachers bound to traditional methods were reluctant to use new digital technology.

Niederhauser and Perkman (2008) suggested that intrapersonal factors such as self-efficacy, outcome expectations, and interest played a central role in whether teachers chose to integrate technology into their instructional practices, or not.
The three studies mentioned identified that risk aversion, intrapersonal factors, and the difficulty of beliefs change may have obstructed digital technology uptake by mathematics teachers. When commenting on Brownlee’s (2000) idea that extrinsic changes were effectively reversible while intrinsic changes were irreversible, Ertmer (2005) wrote that it was impossible for teachers to return to previous routines and habits: “As such, these types of changes are riskier for teachers, as well as more difficult to achieve” (p. 26).

2.5.2 A model of uncertainty

Intrinsic to the innovative, diffusive, or cultural uptake of digital technology in the mathematics lesson was the possibility of risk or at least facing uncertainty. A simple action such as setting an exercise of using an iPad app to learn multiplication tables conjured up a variety of conscious or unconscious unknowns for the mathematics teacher: Would students use the app when requested or be distracted by other iPad apps? Did the app improve multiplication skills? How could you tell if use of the app improved multiplication skills, or not? The state of questioning, experimenting, and unknown outcomes of a new strategy was an example of an example of “facing uncertainty”.

A model of uncertainty adapted from an outdoor education and psychological risk-taking model developed by Priest (1993) provided insight into student risk-taking and the teacher’s role in facilitating a successful learning outcome for an outdoor education activity. Priest’s model was founded on the idea that students could use personal competence to influence the probability of success in an outdoor adventure provided that their perceptions of competence and any risk were correct. Priest’s model linked elements such as risk, challenge, control, competence, motivation, and self-efficacy. The aim of the model was to assist outdoor educators to become more astute to the students’ perceptions of risk and competence (Priest, 1993).

Climbing a rock-wall was a typical outdoor education activity. Priest’s (1993) model explained learning through a positive feedback loop to bring about change in student beliefs with a successful activity and an alternative negative feedback loop when confidence or competence or control were insufficient for the given task. The student needed to understand expected outcomes in order to assess success of the activity. The model accounted for the situation where the student identified the effect
of external factors not under their personal control. The model acknowledged the role of educator guidance and peer support as external factors. The skilled outdoor educator used knowledge and experience to maximise learning benefits for the students from the feedback loops.

Priest’s model evoked the same intrapersonal beliefs that had emerged in the literature reviewed for this study in Section 2.4.4. As such, the model, with the teacher in the learner role of using digital technology in the classroom, reflected many of the characteristics of teachers facing the uncertainty of digital technology innovation. These characteristics included self-efficacy, control, purpose, benefit, outcome expectations, and the support of colleagues and professional development (refer to Section 2.4.4).

Additional findings reinforced the importance of teacher self-efficacy to digital technology uptake. Self-efficacy affected performance through choice or avoidance of activity, the amount of effort associated with attempts, and sustainability through stressful situations (Niederhauser & Perkman, 2008). The feedback loop was derived from the idea that self-efficacy expectations influenced performance and performance outcomes influenced by self-efficacy (Bandura, 1977).

Digital technology use in the classroom was under the influence of the teacher but also external factors that may or may not have been under the teacher’s control (Ertmer, 2005). In outdoor education, a common learner misconception was to attribute success or failure to the equipment (Priest, 1993). A similar idea was reflected in learning to use digital technology in the classroom (Joos et al., 2013).

Outcome expectations or perception of successful digital technology use was related to learner intentions. Without intentions, evaluating success was debatable (Ottenbreit-Leftwich et al., 2010; Prestridge, 2012; Sadaf et al., 2012). Colleagues, whether supportive or critical, influenced the process of digital technology innovation (Ajzen, 1991).

In other words, the teacher could use a new digital technology idea in the classroom if their competence and confidence, control, and intentions were sufficient to overcome the uncertainty of outcome expectations. A sense of success, control,
gains made, and collegial support increased self-efficacy and ensured that the new idea could be repeated.

One difference between the outdoor education student in a learning activity under guidance and the teacher using innovative digital technology in the classroom is that the teacher has been most often alone in the classroom constrained by other duties and/or without a guiding educator on hand to facilitate digital technology teacher learning. Teacher colleagues in a team-teaching environment, for example, or the students in the classroom may take over the guidance role.

Priest’s model contributed a sense of how uncertainty worked for the individual learner and the role of the learner guide or teacher. Successful outcomes reduced uncertainty and increased learning.

2.6 Research Questions

Research into digital technology integration and use has been important in highlighting several factors: that the teacher role was inextricably linked to pedagogical outcomes, that the beliefs of teachers were fundamental to the process of learning to use digital technology, and that increased certainty for teachers was found in improved learning outcomes for students.

Some mathematics teachers lacked the background and experience to use digital technology in their classes despite pressure, professional development, and peer collaboration. The use of digital technology was inconsistent and lacked agreement among mathematics teachers. Despite this, some mathematics teachers have been successful in using digital innovations such as spreadsheets and calculators for statistical, algebraic, graphical, and general computations for pedagogical advantage to varying degrees. The questions that arose were why some teachers and not all, and why variance and not consistency?

The literature reviewed led to the consideration of the problem in the context of teachers’ use of digital technology in the complex social environment that is the mathematics classroom. The study focus shifted to how and why mathematics teachers were using digital technology in their lessons, the level of uncertainty faced by the teachers, and the personal and professional beliefs that allowed them to face uncertainty and try out the digital technology in the first place. The interplay of these
beliefs and the extraneous factors that facilitated or obstructed digital technology uptake were addressed in this study by the following research questions:

1. How is digital technology being used in secondary school mathematics lessons and for what pedagogical purposes?
2. Which teacher beliefs facilitated or obstructed mathematics teachers using or directing the use of digital technology in secondary school mathematics lessons?
3. What mathematical pedagogical practices no longer make sense in a contemporary secondary school mathematics learning environment?

The literature reviewed led to the development of the theoretical framework used to examine the research questions. The next chapter describes the theoretical framework.

_In Choke, it was suggested that under stress, the prefrontal cortex might be filled up with knowledge, instructions, strategies, anxiety, or other emotions. For peak performance, the prefrontal cortex needed room to allow the free passage of autopilot action instructions from one side of the brain to the other._

_My stinging forehand drive was an autopilot action, and I needed space in my working memory to enact a coordinated response to the stimulation for such a shot. Similarly, during a mathematics test, the student needs prefrontal cortex space to allow the mathematics skills to flow._

_I received the message: Stop worrying about a match; stop thinking during the game. This seemed counterintuitive to the strategic thinking needed to outwit the opponent in a game or problem-solve in a mathematics test. It took me a while to get my head around these ideas._
CHAPTER 3
THEORETICAL FRAMEWORK

Choke recommended “mindfulness” for clearing the prefrontal cortex during a game. Mindfulness requires repetitive physical or mental routines with minimal decision-making. During a sporting match, when the pressure is on, counting backwards from 21 by threes helps clear the prefrontal cortex. Writing a list of things, you do well prior to a mathematics test has a similar effect and in addition replaces negative emotions with more positive ones. “Mind-emptiness” would have been a more appropriate term for nullifying cognitive decision-making and worry.

3.1 Introduction

The literature review presented in Chapter 2 identified that research into the integration of digital technology in mathematics lessons has mainly been under the influence of cultural pressure, the complexity of digital technology has been underestimated, and that digital purpose and teacher beliefs are important. The research questions that evolved from the review focused on the pedagogical uses, purposes, and benefits of digital technology in mathematics lessons, the teacher beliefs that initiated and sustained or obstructed use, and the mathematics teachers’ practice that no longer made sense in a changing learning environment. The literature review also provided a context for exploring answers to the research questions.

It became clear that the study would benefit from a theoretical framework to inform and structure an inquiry that considered sociological, psychological, and cultural factors more deeply than most of the literature reviewed. The theoretical framework is based on the sociocultural constructs of Bourdieu’s (1977) field theory embedded with the psychological theory of risk-taking (Priest, 1993). Field theory provided an holistic understanding of a complex social situation, extending beyond the teacher dispositions suggested by Belland (2009) to include the environment and cultural influences acting on the teacher’s practice. Digital technology use in the mathematics classroom has been seen as a cultural change from traditional mathematics pedagogy. In particular,
the teacher has face uncertainty and perhaps risk in introducing digital activities into lessons (Priest, 1993). Using digital technology for pedagogical advantage has been innovative and challenging for the teacher.

In this chapter, the theory behind the theoretical framework is explained, beginning with the beliefs held by teachers about mathematics and mathematics education.

3.2 Sociocultural Context of Mathematics and Mathematics Education

Mathematics education is a complex social process. In the classroom, the teacher’s behaviours stem from personal and professional beliefs about mathematics and mathematics pedagogy (Ernest, 1991). Ernest provided a model of the predominant ideologies that underpin mathematics knowledge and mathematics education.

3.2.1 Mathematics knowledge

The main distinction between mathematics philosophies is the view of mathematical knowledge as being absolutist or fallible (Ernest, 1991). From the absolutist perspective, mathematical knowledge consists of certain truths that cannot be challenged. This view is based on assumptions, rules, and axioms of mathematics and logic, bound up in a formal language and syntax, and established and enduring over a long period of time (Ernest, 1991).

Ernest (1991) cited contradictions in mathematics knowledge that emerged in the early 20th century as weakening the claim of absolutism certainty. Subsequent philosophical approaches have been unconvincing in re-establishing certainty. Ernest agreed that the quest for certainty is inevitably cyclic, as assumptions made to fix problematic areas are intrinsically uncertain. However, a residual absolutist philosophy of certainty “as far as we know” remains in mathematics education practice.

By contrast, fallibilism views mathematical knowledge as fallible, not certain, and not above revision and correction. Rejecting the inadequacies of existing fallibilistic philosophies, Ernest (1991) put forward his own theory, social constructivism, which is a descriptive philosophy aimed at accounting for the nature of mathematics according to well-defined categories: mathematical knowledge, objects, applications, and past and present practices. In developing his philosophy, Ernest drew on multiple previous philosophical understandings. In particular, subjective thought and knowledge were
included in the theory to provide the means for developing new knowledge; it is the cyclic process of objectifying new knowledge required thorough social feedback and reiteration.

The value of Ernest’s philosophy lies in his personal connection of ideas from philosophical research literature that made sense to him. He acknowledged historical practice, constructivist learning for the development of new ideas, the cyclic process of change, and the role of social feedback. His description of social constructivism made sense to me and is the perspective from which I evaluate mathematics and mathematics learning.

3.2.2 Mathematics education

Ernest identified five dominant ideologies of mathematics education based on both ethical and epistemological views. His preferred ideology embraced the social constructivism philosophy with an epistemology that recognised that all knowledge is culture bound, value laden, interconnected, and based on human activity and enquiry. The creation and justification of knowledge were understood to be social and by human agreement. Knowledge was seen to be the key to action and power.

According to this ideology, society is divided and structured by relations of power, culture, status, and the distribution of wealth. Social inequalities arise in terms of rights, life chances, and freedom. Social change is needed to achieve social justice for all. The goal of this position is for the individual to reach their potential, with the aim of education being to empower the individual to take control of their life and participate in social growth and change. “For education this aim means to develop the faculty of independent thought, enabling students to question received knowledge with confidence, whatever the authority of the source, and to accept only that which can be rationally justified” (Ernest, 1991, p. 199).

In addition, Ernest (1991) described four alternative prevailing ideologies that have evolved over time and, combined with social constructivism, provided a model for the prevailing ideologies of mathematics education. Ernest recognised that any individual teacher might borrow beliefs from a number of opposing ideologies under differing circumstances. The result was a complexity of teacher belief systems permeating mathematics education:
The results of meta-mathematics force us to recognise that mathematics is made up of a multiplicity of distinct theories, that these cannot be reduced to a single system and that no one of these is adequate to capture all the truths even in its limited domain of application. (Ernest, 1991, p. 233)

A compelling idea to emerge from this literature is that research conducted from a fixed theoretical perspective is limited. My personal theoretical perspective favours social constructivism and the ideology of mathematics education consistent with fallible relativism (Ernest, 1991). This perspective is reflected in the study through my choices of a personal discovery learning paradigm and a qualitative methodology applied to the social setting of the mathematics classroom with a focus on individual teacher beliefs. However, difference and inconsistency are also acknowledged as legitimate when interpreting the beliefs of teachers. The research objective, to identify if particular teacher beliefs, patterns of beliefs, or lack of belief affected the uptake of digital technology, remains. The need for researcher sensitivity towards alternative views is indicated.

3.2.3 Practical simplification of mathematics education ideology

While Ernest’s (1991) model of mathematics education ideologies was illuminating and useful, it seemed the detail would be unwieldy for this study. Literature revealed authors (e.g., Levin & Wadmany, 2006; Roblyer & Edwards, 2000) who had set the stage for the translation of beliefs into identifiable mathematics teacher practices and vice versa.

Roblyer and Edwards (2000) put forward the following definitions of mathematics education. From a directed learning viewpoint based on absolutism, learning happens when it is successfully transmitted to the learner. It is based on the idea that fundamental truths exist independently of human interpretation and these can be captured and passed on.

By contrast, the fallible viewpoint holds that humans construct all knowledge in their minds through participation in certain experiences; learning happens when one constructs both the mechanisms for learning and the personal version of the knowledge that reflects background, aptitudes, and experiences. The personal version of knowledge is modified through interactions with other experiences and people who confirm or deny veracity and level of understanding (Roblyer & Edwards, 2000).
According to Roblyer and Edwards (2000), the two approaches cater for different educational needs. Transmission through directed learning provides an efficient snapshot approach for teachers faced with large numbers of students and accommodates specific tasks such as skills practice and self-paced training for motivated students. Learning based on constructivism anchors skills to background and experiences, enables group-based cooperative learning, and emphasises engaging activities that introduce higher level skills (Roblyer & Edwards, 2000).

These perspectives link teacher beliefs to teacher actions such as the transmission of information for learning skills and group-based activities for the refinement of learning through social interaction. They provide a basis for identifying where and why the use of digital technology might facilitate the learning process.

Slightly more useful are categories to interpret pedagogical beliefs from mathematics teacher actions derived by Levin and Wadmany (2006, refer to Table 3.1). These categories were more extensive and refined, and represented increasing levels of student learning independence, one of the desirable contemporary learning outcomes. Individual teacher actions may be found in any of the table’s cells.

### 3.2.4 Characteristics of working with digital technology

Levin and Wadmany (2006) also suggested a means of categorising digital technology use in the classroom, based on the work of Habermas (1987). In an evolving digital world, the categorisations seemed somewhat limited. Instead, the use of technology in the classroom was categorised according to teacher-assigned roles. Goos et al. (2003) defined metaphors for working with digital technology and expressed these as master, servant, partner, and extension of self. The characteristics for each category are described as follows.

The teacher assignment of the “master role” to a digital application is characterised by teacher dependence on the technology. The teacher exhibits traits of limited technology competence and uses a narrow range of application functionality. Dependency on the technology is offset somewhat by the teacher’s ability to evaluate outcomes and so make decisions about using the technology based on benefits (Goos et al., 2003).

A “servant role” is assigned to tasks that support the teacher’s preferred teaching methods. Despite the use of digital technology, the classroom tasks remain essentially the
Using digital technology as a fast and reliable replacement for mental or pen-and-paper computations is an example of a servant role.

Table 3.1: Categories of Teachers’ Pedagogical Views

<table>
<thead>
<tr>
<th>Conceptions of Learning</th>
<th>Conceptions of Teaching</th>
<th>Teaching Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviourism</td>
<td>Passing Information</td>
<td>Direct Instruction</td>
</tr>
<tr>
<td>Reality is independent to the learner; learning acquired through the senses</td>
<td>Emphasis on curriculum and exams without concern for understanding</td>
<td>Rigorously developed, highly scripted, structured, drilling, teacher-centred approach; constant teacher–student interactions</td>
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<table>
<thead>
<tr>
<th>Cognitive Constructivism</th>
<th>Transmission of Knowledge</th>
<th>Collaborative Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>External reality knowable to the learner; learning acquired through the senses and cognitive adaption</td>
<td>Emphasis on constructing knowledge and teacher assistance understanding, remembering, and applying knowledge</td>
<td>Students work in small groups towards a common goal; responsible for each other’s learning</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social Constructivism</th>
<th>Meeting Students’ Needs</th>
<th>Cognitive Apprenticeship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-construction of meaning within a social activity; knowledge is bound to context</td>
<td>Teaching informed by a sense of responsibility for students’ individuality</td>
<td>Students work in teams on projects or problems with close teacher scaffolding, modelling, coaching, articulating, reflecting, and exploring</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Radical Constructivism</th>
<th>Independent Learners</th>
<th>Discovery Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning is knowledge construction influenced by the context and relative to the accomplishment of a goal</td>
<td>Teaching emphasis on growth rather than knowledge and skills</td>
<td>Inquiry-based learning model in problem-solving situations in which the learner draws on personal experience and prior knowledge to discover truths to be learnt</td>
</tr>
</tbody>
</table>


Using digital technology in the classroom to facilitate mathematical understanding, explore different perspectives, or mediate discussion are characteristics of a digital technology “partner role”. “Extension of self” describes the role of a digital application
that has become a natural part of the pedagogical repertoire for teacher or student (Goos et al., 2003). The authors suggested the analogy of personification identifies that the technology is an agent to learning, an additional inhabitant of the classroom field with a possible influence on learning outcomes. Responsibility for achieving learning outcomes remains with the teacher and influences the choice of digital technology use (Goos et al., 2003).

The theoretical perspective of mathematics, and digital technology use, mathematics education ideology, and its practical interpretation was established to inform the identification and description of teacher beliefs about mathematics, mathematics pedagogy, and using digital technology in the classroom. The following sections describe the context in which these beliefs and external influences have been observed and evaluated.

3.3 Bourdieu’s Field Theory

In Outline of a Theory of Practice, Pierre Bourdieu (1977) attempted to make sense of the relationship between objective social structures, such as institutions and rules, and the subjectivity of what people do and why they do it. Bourdieu’s field theory constructs of field, habitus, and cultural capital represent cultural stability and account for the relationship between the objectivity of the institution and the subjectivity of its inhabitants (Webb, et al., 2002).

Cultural field is a site of social practice, characterised by the hierarchical structure of institutions, rules, rituals, conventions, designations, and appointments. The field produces certain ideas and activities for the inhabitants, who by their actions both influence and are influenced by the nature of the field (Webb et al., 2002). The field of this study was the mathematics classroom where minute, day-to-day social interactions played out between the field’s inhabitants, who were the teachers, the students, and perhaps the digital agents. The field is subject to external overarching influences that maintain the field. The influences that initiate change need the cooperation of teachers and students to realise change outcomes.

Habitus of an individual is a set of dispositions that include attitudes, beliefs, values, perceptions, and practices formed through the embodiment of an individual’s life history (Nolan, 2012). In general, the dispositions of teachers do not accommodate the use of digital technology in the mathematics classroom (Belland, 2009).
Conflict arising when groups or individuals attempt to determine what is valuable in the field and how it is to be distributed also constitutes the field. The construct, cultural capital, plays a significant part in maintaining a fluid and dynamic field (Webb et al., 2002). Aligning with the powerful players who sustain the status quo is easier for inhabitants than renegotiating the rules and change. Mathematics teachers find it easier to stick with traditional teaching and learning strategies than implement digital change.

The powerful groups or individuals evoking change are not necessary inhabitants of the field but often members of overarching fields of influence (Webb et al., 2002). In the social construction of the mathematics classroom, the imposition of digital technology by government, the school’s uptake and expectations with respect to digital technology, and the expectations of parents and the digital expertise of students are all exerting significant pressure for change (Bishop, 1988). The addition of digital technology to the mathematical education field creates a potential for conflict. Digital technology needs to find its place in the “rules” of mathematics education.

Habitus is durable, but dispositions could always potentially be modified when explanation no longer make sense or self-interest prevails (Webb et al., 2002). Reay (2004) suggested that only by using the technology in the classroom dispositions could be changed and then ultimately the classroom environment would also be changed. Changing teacher dispositions is enhanced by the presentation of more or stronger opportunities to do so, but there is no guarantee that change will take place (Reay, 2004). The mere existence of digital technology, and acquired knowledge and skills, will not necessarily change beliefs about its use.

Gresalfi (2009) suggested that change is more likely to be the result of what happens in the moment of digital technology use in the classroom and how the accrual of such moments shapes subsequent use. The disposition change process for mathematics teachers requires an individual effort by the teacher to try the digital technology in the classroom on numerous occasions and to reflect on uses and outcomes.

This discussion sought to demonstrate that Bourdieu’s constructs provided a useful framework for studying mathematics teachers’ beliefs. Field theory provided the context of mathematics teacher actions, the influences for change, and the processes of change. Habitus accounted for the development of teacher beliefs and habits, honed
over time, perhaps unconscious, grounded in early experiences. Habitus also held the potential for change. Cultural capital accounted for gains and losses associated with change.

### 3.4 Uncertainty and Risk-Taking

To account for the pressure to change, Priest’s (1993) model of risk-taking was used as a template for developing a model of teacher uncertainty about the adoption of digital technology. Based on the work of Prochaska et al. (1992), the Innovation Uncertainty Model is a 3D spiral, with the eustress direction spiralling into a point of certainty and the distress direction spiralling out to abandonment of the innovation. A variable number of attempts are needed to accept or reject an innovation, with the possibility of changing directions on any attempt. A salient aspect is that, when a repeated attempt is made, it is most likely to be at a different position on the spiral due to previous experience.

The Innovation Uncertainty Model that I developed is illustrated in Figure 3.1. A series of linked constructs are described. Featured points indicate where belief-driven action choices might be made. The diagram is not a cross-section of the spiral but rather a means of illustrating decision-making that results in moving in either the eustress or the distress direction on the spiral. Some oscillations may occur, for example, when the teacher felt the lesson was successful but received negative feedback from colleagues. The start of the cycle is not a fixed position but instead indicates that for each individual attempt of a particular digital technology use, the teacher enters the cycle at a point based on the level of uncertainty. The spiralling continues until the teacher is certain enough about the digital technology to sustain its use.

Bourdieu’s field theory relates to the Model in the following way. The cultural pressure to include digital technology in mathematics lessons is an unrelenting, ever-evolving global phenomena. The pressure is outside the Education Institution (Section 1.2) but also inside the participant school which had a mission for innovative digital change (Section 4.2.1.1). Either way a new idea may be personally conceived or has source or influence internal or external to the field.
According to field theory the new idea needs to be individually negotiated by the teacher, where the objectivity of influence on the field meets the subjectivity of the individual (Section 2.3.3). The measure of negotiation is the certainty of teacher belief that underpins the action of trialling the new idea. Certainty is seen in skills, and beliefs in self, in control and in expectations. Successful outcomes bring reward or loss in cultural capital, and are personally perceived.

In Figure 3.1, descriptions of operating beliefs and effect are indicated at the labelled points A to J. Intrapersonal beliefs dominate the process, but the model allows other beliefs to be considered. The model is explained here in the context of teacher adoption of digital technology in the mathematics classroom.

**A.** The mathematics teacher is about to embark on a lesson that includes a digital innovation. Intentions and expectations related to specific benefits have been set, either consciously or unconsciously. The teacher will pursue the innovation under the balance of several beliefs as follows: if the teacher is confident enough in their skill to address the digital task, if the task is either under the teacher’s control or help is close at hand, and finally, outcome expectations of student learning or personal benefits outweigh the uncertainty of the innovation. That is, the digital innovation will occur when the teacher possesses a belief in self to perform a task, a belief that the situation is under control, and a belief in gains to be made in student learning outcomes or personal benefits, and the strength of these beliefs outweigh the uncertainty of the unknown.

**B.** The lesson is complete and the teacher experiences a sense of success, a physiological sensation of eustress, when expectations are realised.

**C.** The teacher attributes success in using the digital technology to self or under self-control. The control belief and self-efficacy are strengthened and certainty is increased.

**D.** The teacher attributes success to external factors, which may lead to a re-evaluation of the task and its dependence on external factors, or the belief in external control remains stable or is strengthened.

**E.** The teacher may receive positive external reinforcement, such as praise from colleagues. Social acceptance increases self-efficacy and certainty. The teacher
may try the same actions again or something more complicated based on increased or the same level of beliefs in self-efficacy and control.

**F.** Alternatively, the task is not complete or appears to fail. The teacher experiences a sense of failure, a physiological sensation of distress, due to thwarted expectations.

**G.** The teacher attributes failure to self or at least under self-control. The control belief is weakened and certainty is decreased.

**H.** The teacher attributes failure to external factors, which lead to a re-evaluation of the task and its dependence on external factors, or the control belief due to external factors is stable or weakened.

**I.** The teacher receives negative reinforcement, such as criticism from colleagues. Social criticism decreases self-efficacy and certainty. The teacher may try the same action again with perhaps increased uncertainty, or with changed actions.

**J.** Whether a success or a failure, if the outcome is attributed to external factors, the teacher may re-evaluate the task in an effort to acquire more control. Professional development or an expert opinion might be sought. Deliberations may result in altered beliefs that allow the teacher to try again.
As a result of adapting Priest’s (1993) model to the context of the teacher using digital technology in the mathematics classroom, several key teacher beliefs were identified: self-efficacy, control of intrinsic and extrinsic digital technology factors, expectation outcomes, and benefits gained, perception of success or failure, and external affirmation or criticism.

### 3.5 Conclusion

The theoretical framework for this study comprised a psychological understanding of the uncertainty a teacher faces when introducing a new digital technology idea into a lesson and a social understanding of the teachers’ dispositions and classroom dynamics where the introduction has taken place. The framework was a means of identifying the teachers’ beliefs about mathematics and mathematics education from intentions, statements, and actions in the classroom; the role that the teacher has assigned to the
digital technology; the influences for change; and any gains or losses made in terms of student learning outcomes and personal or professional teaching outcomes.

The following chapter discusses the methodology used to find answers to the research questions through the collection and analysis of data within this theoretical framework.

_I committed to improving my table tennis using the activities found in Choke and some that I made up myself according to Choke’s mindfulness criteria. In thinking about learning new techniques to improve my table tennis performance, I wondered what new techniques did students need to improve their mathematics performance? I also began to question the nature of mathematics performance in general and mathematics teacher performance in the classroom, and how improvements could be made._
CHAPTER 4
RESEARCH METHODOLOGY

My approach to table tennis improvement was simple—trial and error. I decided to experiment with mindfulness strategies before and during my matches. I would use the break between games to assess progress and change strategic direction if needed. I would try to keep my mind free of strategy during each game.

In Chapter 1, the research problem was identified in terms of the reluctance of some mathematics teachers to use digital technology for pedagogical advantage in the classroom despite compelling and evolving social pressure to do so. Chapter 2 touched on relevant literature about digital technology in mathematics education and the role of teacher beliefs in facilitating or obstructing the use of digital applications. The literature review led to the formulation of the study’s research questions. Chapter 3 described the framing of the study within a context of institutional objectivity meeting individual teacher subjectivity to incorporate digital innovations in the mathematics classroom. The theoretical framework comprised Bourdieu’s (1977) field theory and the psychology of risk-taking as modelled by Priest (1993). The framework provided a sociocultural representation of the minute, day-to-day interactions in the classroom in terms of the environment, the beliefs of the teacher, purpose of use and benefit, and influences on digital innovation. Facing the uncertainty of change was implicated in the teacher’s actions with digital innovations in the classroom.

This chapter presents the research methodology that was designed and implemented to address the research questions. While the theoretical framework belongs to Bourdieu (1977) and Priest (1993), some pedagogical characteristics used in the study were guided by research outcomes reviewed in Chapter 2 (Belland 2009; Ernest, 1991; Goos, et al., 2003; Levin & Wadmany, 2006; Reay, 2004; Webb et al., 2002).

The study aimed to incorporate proven strengths and avoid reported weaknesses in related studies. Every research endeavour is uniquely different one way or another, and this one is no different. Thus, certain aspects in the methodology of this study feature
iterative and personal design, adaptations, and modifications arising from relevant practical considerations.

4.1 Methodology Design

4.1.1 Qualitative study

As a framework, Bourdieu’s (1977) field theory was a means of viewing structure in small-scale interactions and activity within large-scale settings (Reay, 2004). The setting of this study was mathematics education, while the small-scale interactions and activity belonged to the teacher and students in the teaching and learning of mathematics. It was assumed that the teacher was responsible for the use of digital technology in the lesson. The structure sought by the study was the matrix of beliefs that underpinned the teachers’ choices made about the use of digital technology for teaching or for student learning. The participant teachers’ pedagogical practices were the focus of the study whether digital technology was used, or not.

The methodology was conceived as a qualitative study, with an inductive discovery process moving from the collection of fragmentary details through the analysis of patterns, consistencies, and meanings to a connected viewpoint of teacher beliefs (Gray, 2009).

Some of these beliefs may have been deeply held and absorbed into the teacher’s value system. Some groups of beliefs may be considered attitudes. Some belief-related actions may have been repeated until the actions had become habits (Section 2.4.1). The characteristics of habitual practice include natural and unquestionable delivery that no longer requires the deliberate act of thinking (Nolan, 2012). Beliefs, values, attitudes, and habits are considered variations of “beliefs” (Section 2.4.1).

4.1.2 Case studies

This research was focused on the practices of individual mathematics teachers as a collection of case studies. Case study field research was considered effective for studying subtle nuances in attitudes and behaviour and for examining social behaviour over time (Babbie, 2013). Inductive theory construction underpinned the case study design and involved first observing aspects of social life and then seeking to discover patterns that may point to “facts”. Multiple cases provided a more rigorous and
complete approach than a single case study due to evidence derived from differing sites and data sources (Babbie, 2013).

In multiple case study analysis, similarities between cases give rise to the development of theory (Babbie, 2013). In this study, individual cases were considered meritorious in their own right and reflective of the different belief structures behind mathematics teaching techniques and the decisions to use digital technology. Both the similarities and differences between cases were examined closely in order to make claims that were applicable to a wider range of pedagogical beliefs.

4.1.3 Data collection

The research data were derived from the practices, histories, and reflections of teachers and collected through observation of teacher practice and dialogue of descriptions, interpretations, verifications, and explanations by the teacher in interviews.

Knowledge of teachers’ practices was gained from observation of classroom lessons. Belief structures could not be directly observed and were apprehended interpretively from a teacher’s intentions, actions, statements and experiences enacted in the classroom (Reay, 2004). The lesson objectives, the style and “smoothness” of lesson delivery, and the way digital technology was used or not used for particular purposes are all examples of classroom activities that provided indications of underlying beliefs.

Field data included descriptions of the classroom site, the lesson dynamics, and influences on the classroom activities. Digital technology usage data related to the concept of “facing uncertainty” were teachers’ intentions, actions, statements, and reflections that indicated confidence, competence, control, learning expectations, perception of success, digital purpose, and benefit to student learning outcomes.

Post-observation interviews conducted with the teacher outside the classroom provided an opportunity to reflect on the lesson, and discuss and validate observation data. Other issues discussed during the interviews included prior exposure to digital use, influences and pressure to use digital technology, and personal experiences of becoming a mathematics teacher.
Story interviews revealed the participants’ reflections on their experience of learning mathematics, on choosing a career in education and using digital technology inside and outside the classroom. Story interviews were planned to be after the lesson interactions, when the teacher participants were feeling more relaxed and happier to chat about themselves. The data collection plan for the individual participant is shown in Table 4.1.

Table 4.1  
Data Collection Plan

<table>
<thead>
<tr>
<th>Phase</th>
<th>Purpose</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introductory meeting</td>
<td>Introduce the planned process; address participant concerns; timetable observation lessons</td>
<td>In person Field notes</td>
</tr>
<tr>
<td>2. 4 x observation lessons</td>
<td>Learning and digital intentions; lesson observation</td>
<td>Email Audio recordings Field notes</td>
</tr>
<tr>
<td>3. 4 x post-observation interviews</td>
<td>Further discussion about incidents of interest; explore interpretations</td>
<td>Audio recordings Field notes</td>
</tr>
<tr>
<td>4. Story interview</td>
<td>Participant experience of becoming a mathematics teacher</td>
<td>Audio recordings Field notes</td>
</tr>
<tr>
<td>5. Final interview</td>
<td>Discuss, confirm, and consolidate data collected and outstanding issues</td>
<td>In person Field notes</td>
</tr>
</tbody>
</table>

4.1.4 Analysis

Analysis encompassed the identification of teacher beliefs about mathematics pedagogy and using digital technology, a comparison of beliefs and behaviour with the objective of finding patterns of beliefs that obstructed or facilitated the use of digital technology, and finally, a comparison of beliefs between participant teachers to identify commonalities and differences.

The means of translating teacher intentions, actions, language, and experiences into mathematics education beliefs were based on categories of teaching and learning approaches and teaching models from Levin and Wadmany (2006) (refer to Table 3.1). It was acknowledged that teachers would not necessarily present with a consistent philosophy or belief system for all their actions, with teachers choosing approaches from a variety of pedagogical philosophies (Ernest, 1991). Refer to Table 4.2 for
pedagogical action examples translated to teacher beliefs about mathematics and mathematics education.

Similarly, translation of digital technology use into digital technology beliefs were found in definitions of role and responsibility that the teacher had assigned to the technology (Goos et al., 2003). Refer to Table 4.3 for digital use examples.

Table 4.2  
**Examples of Pedagogical Action as Pedagogical Belief**

<table>
<thead>
<tr>
<th>Pedagogical Style</th>
<th>Pedagogical Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Belief</strong></td>
<td><strong>Learning Intentions</strong></td>
</tr>
<tr>
<td>Direct instruction</td>
<td>Inverse functions</td>
</tr>
<tr>
<td>Passing information</td>
<td></td>
</tr>
<tr>
<td>Collaborative learning</td>
<td>Self-paced learning within teacher structure</td>
</tr>
<tr>
<td>Transmitting knowledge</td>
<td></td>
</tr>
<tr>
<td>Cognitive apprenticeship</td>
<td>Investigate sine and cosine functions in collaboration</td>
</tr>
<tr>
<td>Meeting students’ needs</td>
<td></td>
</tr>
<tr>
<td>Discovery learning</td>
<td>Explore logarithmic functions drawing on previous experience of graphing functions</td>
</tr>
<tr>
<td>Helping students become independent learners</td>
<td></td>
</tr>
</tbody>
</table>
### Table 4.3  Examples of Digital Action as Role Belief

<table>
<thead>
<tr>
<th>Belief</th>
<th>Digital Intentions</th>
<th>Teacher Says</th>
<th>Use Looks Like</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Master</strong></td>
<td>Reluctant to use</td>
<td>The students have iPads. We use them to practise tables.</td>
<td>Knowledge and competence limited to a narrow range of operations</td>
</tr>
<tr>
<td><strong>Servant</strong></td>
<td>Efficient replacement</td>
<td>Check your answer with Mathematica.</td>
<td>Replaces tasks to achieve efficiency gains without changing the nature of the classroom</td>
</tr>
<tr>
<td><strong>Partner</strong></td>
<td>Develop understanding or explore perspectives; mediate discussions</td>
<td>I’m going to teach you Padlet so that you can collaborate outside the classroom.</td>
<td>New tasks or new ways of approaching old tasks</td>
</tr>
<tr>
<td><strong>Extension of self</strong></td>
<td>Digital benefit normal part of teaching and learning</td>
<td>I can zoom in to see the point of inflection more clearly.</td>
<td>Digital technology seamlessly integrated into practices</td>
</tr>
</tbody>
</table>

The search for patterns in sets of beliefs followed a grounded theory approach in which the analysis of minute incidents led to the development of theory (Grbich, 2007). This research was founded on existing literature such as digital technology integration, the psychology of risk-taking, habitus, and the philosophy of mathematics education, for example, and could not be considered “proper” grounded theory that emerges without preliminary knowledge acquired from existing literature. This does not preclude using grounded theory techniques given that the combined framework of field theory and risk-taking had not been considered before, and the outcomes of this approach were still to be discovered.

#### 4.1.5 Research ethics

This study was designed in accordance with the Australian Code for the Responsible Conduct of Research (2007) and was ethically reviewed and monitored in accordance with the National Statement on Ethical Conduct in Human Research (2007) by the Monash University Human Research Ethics Committee (MUHREC). Before interaction with any participant was made, ethics approval was sought from MUHREC.
as research tasks involved interviews and observation of human behaviour. A copy of
the approval can be found at Appendix 1.

As author of the study, I acknowledged the rights of participants and was
committed to taking care. Information clarifying the purpose of the research, methods,
demands, risks, avenues of recourse, and contact details of researchers was made
available to all participants at the time of their agreement to participate. Data collected
and reported were coded so that the identities of participants and the school where the
research was conducted were not evident.

The participants’ students were not participants in the study but incidental to the
study. The students were afforded ethical consideration and respect. Pseudonyms have
been used to protect the identity of students in reported teacher dialogues.

The participants were treated with integrity, justice, and benefice. Design of the
research reflects this care, and every effort was made to continue this commitment by
conducting data collection and analysis with honesty and integrity and disseminate
results so they may be scrutinised and debated and so contribute to public
understanding. I was committed to conducting research that was beneficial to the
community.

4.2 Methodology Enacted

4.2.1 Selection of participants

In 2014, I sought teacher participants from Australian secondary schools in which
the IB MYP was taught. These schools were targeted because, as part of their
professional commitment, the teachers were trained and expected to teach according to
IB MYP principles and practices. Teacher training was a requirement of the school’s
commitment to the program. The study used a definition of risk-taking from the IB
learner profile (IB, 2013), an attribute to be fostered in students at IB MYP schools. I
assumed IB MYP mathematics teachers would have similar understandings of risk-
taking and a similar sense of its importance.

4.2.1.1 School

Permission was sought and gained from various governing authorities to conduct
research in IB schools that taught IB MYP at secondary level. I then approached
principals from 22 of 24 Australian MYP secondary schools for permission to invite mathematics teachers to take part in the study. Several principals expressed interest and referred me to liaison teachers. In general, the liaison teachers did not respond. Several principals declined. Several principals did not respond. One principal responded positively, the liaison teacher was enthusiastic, but then promoted to a leadership role and unable to commit to the study. I followed up by ringing all non-responding principals and liaison teachers with no success. Eleven months went by as I tried to find a participant school.

I consulted with my supervisor. I thought the term “risk-taking” was off-putting, and my supervisor thought the survey was dated. I decided to pare down the study, leave the survey out of the methodology, and change the term “risk-taking” to “uncertainty”. I had two MYP schools left to invite to participate. Both were large, Catholic all-girls schools in semi-rural Victoria and I was waiting for the Melbourne Catholic Education Office to grant permission to approach the schools. On almost the last working day of 2014, the permission arrived (refer to Appendix 2). When I approached one of the schools in 2015, the principal immediately agreed. The principal assigned the role of research liaison to the school’s curriculum coordinator and nominated four likely teacher participants.

The school catered for approximately 900 students drawn from the local area and from overseas. The school’s mission to be “organisationally and educationally innovative” was reflected in proactive leadership that sought educational innovation in general and opportunities for digital technology application for the school in particular. The participant school had run the IB MYP for several years and was authorised as an IB World School. I had previously taught at this school and was known to the principal, the curriculum coordinator, and all nominated participants. It had not been my intention to conduct research at this school.

4.2.1.2 Participants

The curriculum coordinator negotiated with the nominated teachers to ensure they were fully versed with the requirements and conditions of the study and their rights. Refer to Appendix 3 for a copy of the Teacher Explanatory Statement. Three of these teachers taught senior mathematics. The fourth teacher belonged to a three-person team that taught Year 7 mathematics to their combined classes. I asked the other members of
the team if they would also like to participate in the study, and they agreed and were
duly briefed by me.

Six teachers agreed to participate in the study: Sarah, Tamara, and Alan were
senior mathematics teachers who all taught the subject VCE Unit 1–2 Mathematical
Methods (CAS) in 2015. The VCE Unit 1–2 subject was a precursor to a final year
(Year 12) school mathematics subject VCE Unit 3–4 Mathematical Methods (CAS).
Most of the students in participants’ classes were in Year 11, while some came from
Year 10. The teachers and I agreed that I would observe lessons for this subject.

Luci, Bec, and Helen taught Year 7 mathematics classes. The teachers and I agreed
that I would observe the three-class combination lessons. Halfway through data
collection, Luci became indisposed and unable to teach for the remainder of the year.
A substitute teacher Catherine was found, but I thought it too late to recruit her to the
study. Refer to Table 4.4 for profiles of the six participant teachers.

<table>
<thead>
<tr>
<th>Case</th>
<th>Sarah</th>
<th>Tamara</th>
<th>Alan</th>
<th>Luci</th>
<th>Helen</th>
<th>Bec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Female</td>
<td>Female</td>
</tr>
<tr>
<td>Age</td>
<td>Mid 40s</td>
<td>Mid 40s</td>
<td>Mid 40s</td>
<td>Late 40s</td>
<td>Early 50s</td>
<td>Late 30s</td>
</tr>
<tr>
<td>Subject streams</td>
<td>Mathematics Computing</td>
<td>Mathematics</td>
<td>Mathematics Double</td>
<td>Science Chemistry</td>
<td>Science Psychology Special Needs</td>
<td>Science Chemistry</td>
</tr>
<tr>
<td>Years teaching</td>
<td>12 years</td>
<td>16 years</td>
<td>17 years</td>
<td>22 years</td>
<td>17 years</td>
<td>6 years</td>
</tr>
<tr>
<td>Years at school</td>
<td>5 years</td>
<td>14 years</td>
<td>14 years</td>
<td>7 years</td>
<td>17 years</td>
<td>1st year</td>
</tr>
<tr>
<td>Years teaching subject</td>
<td>2nd year VCE</td>
<td>1st year VCE</td>
<td>17 years VCE</td>
<td>4 years Year 7</td>
<td>10 years Year 7</td>
<td>1st year Year 7</td>
</tr>
</tbody>
</table>

Feedback from the teachers suggested that their participation had not been onerous.
They agreed that the scrutiny of lessons and subsequent questioning had raised
awareness of their practices and the consideration of alternative more contemporary approaches.

4.2.2 Data collection process

The data collection process followed the plan outlined in Table 4.1. Each phase of the data collection process is now explained in more detail.

4.2.2.1 Introductory meeting

The introductory meeting was held with the four original participants. The final two participants were recruited directly, and I updated them with details of the study. The curriculum coordinator organised the signing of teacher permission forms and gained parental permission for incidental participation of students in observed, audio-recorded lessons.

4.2.2.2 Lesson intentions

Participants were asked to provide a statement of their lessons’ learning intentions to the researcher via email in advance of the observed lessons, with particular focus on intentions related to the use of digital technology and the purpose of its use.

I was aware that the request for intentions might raise teacher consciousness about intended actions and distort intended activities. However, as it turned out, teacher intentions were usually limited to a statement of content to be addressed in the lesson and acknowledgement that computational software and the interactive whiteboard were to be used. The purpose of digital technology use was essentially overlooked, and often, the digital technology to be used was overlooked. It seemed the teachers were not in the habit of articulating their lessons’ learning intentions, whether using digital technology or not.

In one example, a VCE teacher expressed her intentions as the sine and cosine graphs using exact values and no technology. She commenced the lesson with the division of the class into groups of three. She provided students with a printed description of the task and a list of questions to be answered. The teacher was ready for the lesson with a plan for a collaborative conceptual activity that investigated content guided by a scaffold of questions to be answered (Lesson TO4).
In general, lessons were well planned and executed, and much richer in both student learning outcomes and digital technology use than stated as intentions. Lessons ran smoothly from one activity to the next. Often the teacher outlined the lesson plan as the lesson progressed: “What I’m going to do is first I’ll solve them using Mathematica (Wolfram Research, Inc., Mathematica, version 11.3, 2014) then I’ll show you how to do them by hand” (Lesson SO2).

Then there were occasions when the teacher changed the plan, and that was usually noticeable because they said something like, “I’ve changed my mind” or “Actually, we might do the manual solution first then we’ll do Mathematica” (Lesson SO4). Of particular interest was why the plan was changed and what that might mean.

As such, intentions were collected as incidences of stated intentions, unstated intentions gleaned from the teacher’s actions and statements as the lesson progressed, and changed intentions in the form of actions or language that contradicted what had previously been intimated.

4.2.2.3 Observations

To gain insight into the underlying beliefs of participants and their use of digital technology in the classroom, they were observed in their teaching role. Five of the participants were observed teaching four lessons each. Luci, was observed teaching two lessons only. As her contribution to the Year 7 team teaching was significant, her data were processed and included for comparison.

Bec, a Year 7 teacher, was new to the school. Her mathematics teacher colleagues treated Bec as an apprentice to the profession, providing her with instructions, resources, and support. The team dictated most of Bec’s actions in the combined Year 7 mathematics lessons. Ultimately, the Year 7 team were considered a single case study of one teacher, Helen, the third of the Year 7 teacher participants, with influence from Luci and Bec.

Observed actions to be considered in the framework of habitus were found in the general run of lessons. Incidents of interest took the form of instructions and statements, actions, and inactions that revealed teacher beliefs about mathematics (e.g., “There is always more than one way to do a problem”), how mathematics should be taught and learnt (e.g., “We’ll work on this problem together and then you can do some
practice examples”), and how digital technology might fit into the lesson (e.g., “First we’ll do it by hand and then you can use Mathematica”).

Uncertainty data were derived from incidents of digital technology use in the lesson. The teacher assigned the technology to particular tasks, for example, attendance recording, presentations, and computations. Incidents of interest took the form of teacher intentions, actions, and statements, the allocated digital technology task, and teacher or student usage, problems, fixes, and outcomes. Refer to Appendix 4 for the Lesson Observation Checklist used by the researcher as a guidance to observations.

I wrote field notes of lessons as they were observed and earmarked incidents of interest. Actions and researcher interpretations of the actions were noted. Field notes provided data and acted as a prompt during post-observation interviews. An example of field notes is found at Appendix 5. The classroom observations were also audio recorded. Audio recordings of lessons were fully transcribed, and these transcriptions were a significant source of data.

4.2.2.4 Observation interviews

Four post-observation interviews and a story interview between the researcher and each participant were planned. While lesson observations provided the context, interviews provided the opportunity for teacher explanations and interpretations of their decision-making and actions observed.

The study’s interviews were semistructured, with a certain number of interview questions prepared but not necessarily asked, with particular wording or strict order. Some structure allowed for reiteration of questions over the study period. With the continuous nature of the process, it was expected over time that questions would be redesigned as a result of analysis, and this did occur. Additional questions were asked of a particular participant prompted by previous actions, responses, and reflections of the participant or the researcher. The protocol for post-observation semistructured interviews can be found at Appendix 6.

Interview questions were framed around perceived changes of plans and uncertainty. Questions were focused on risk-taking beliefs—self-efficacy, control, outcome expectations, success/failure, support, and problems/solutions—as they related to the digital technology tasks just witnessed. For example, prior to an
observation, Alan was setting up to display a YouTube clip and asked me how to make the sound go into the projector. I helped with a solution. Alan said, “Talk about taking risks with technology”! I noted this as an incident of interest in my field notes along with further references to the clip that were made in this lesson and in the next lesson observation. I questioned the background and outcomes of this incident at subsequent interviews.

Not all interviews were recorded, and this was by agreement between the participant and me. At times, we were constrained by personal and professional commitments, and data collection did not proceed as smoothly as planned. The teachers did not necessarily have time to sit down for a recorded interview after a lesson observation. I conducted the interview as we walked along the corridor and saved up more thoughtful questions for a subsequent meeting. I noted these unrecorded interviews in the field notes.

Sarah worked part-time with tightly scheduled lessons and needed to leave school as soon as her lessons ended. Her interviews were mainly conducted via email. She very kindly took the time to answer questions in writing. My questions and her responses gave the impression of being more considered and more complete than the interviews conducted on the run, immediately after the lessons.

As I gained greater understanding of the methodology and emerging patterns, further questions for each participant arose. All the participants including Luci agreed to a final interview to verify ideas that had emerged. Sample interview data are found at Appendix 7.

4.2.2.5 Story interview

Participants were asked to relate their personal story on becoming a mathematics teacher. The purpose of the story interview lay in identifying early experiences with mathematics, mathematics education, and digital technology, perhaps linking experiences with current practice (Belland, 2009). It was expected that experiences would contribute to the participants’ confidence and competence in using technology, to the valuing of a mathematics task, or evaluating success. Early experiences pointed to current beliefs and added weight to observed actions (Bourdieu, 1977).
Of particular interest was a participant’s exposure to digital technology and to mathematics in their schooling, tertiary education, their teaching careers, and their personal lives. An example of influential experience was found in Sarah’s sophisticated approach to implementing Padlet in one lesson. It turned out that she had majored in computing as well as mathematics at university and had acquired a thorough understanding of digital implementation.

4.2.2.6 From audio recordings to verbatim transcripts

Audio recordings of lessons were captured using digital audio workstation software (Apple Inc. GarageBand, version 6.2.5, 2002-2012) and internal microphones on one or two laptops set up at strategic locations in the classroom. The focus of audio recordings was the participant teacher, with each proving to be effective in the projection of voice for lesson delivery. The teachers were usually positioned at the front of the class while addressing the whole class or projected their voices more strongly when addressing the class from elsewhere in the room. As such, most of the teachers’ communications were captured on a single computer, although communications between the teacher and individual students may have been missed. I listened to each audio recording many times and endeavoured to fully transcribe everything I heard.

4.2.3 Data analysis

4.2.3.1 Qualitative data analysis

Collected data in the form of mathematics teachers’ intentions, actions, sayings, and experiences were the units of analysis for this study. The data were analysed to form a matrix of participant beliefs about mathematics, mathematics pedagogy, and using digital technology in lessons.

The framework of Bourdieu’s (1977) field theory focused attention on the pedagogical environment, teacher beliefs, habits, and influences about mathematics philosophy, mathematics teaching and learning, and digital technology uses. The concept of uncertainty was related to how well digital technology uses were established in the lessons’ routines. Self-efficacy and control, purpose, expectation outcomes, and notions of success indicated levels of uncertainty about digital
technology use. Some uses for digital technology had been in place for several years and were not uncertain for the teacher.

4.2.3.2 Pedagogical style

Ultimately, I extended Table 3.1 to provide a more consistent approach to analysis of the collected data in terms of teacher pedagogical beliefs. Table 4.5 is based on Table 3.1 with added explanation and provides a guide for interpreting teacher pedagogical beliefs and beliefs about mathematics.

Levin and Wadmany (2006) included absolutist or relativist beliefs about mathematics within the teaching model. The authors associated absolutism with instructional techniques, and relativism with inquiry and constructive techniques.

4.2.3.3 Digital technology uses

Digital technology usage has been characterised by developed descriptive metaphors, entitled master, servant, partner, and extension of self, to theorise the varying degrees of sophistication with which teachers and students work with technology (Goo et al. (2003) These metaphors and descriptors are listed in Table 4.3.
Table 4.5  Categories for Interpreting Teachers’ Pedagogical Beliefs

<table>
<thead>
<tr>
<th>Teaching Model</th>
<th>Concept of Teaching</th>
<th>Concept of Learning</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct instruction</strong></td>
<td>Passing information; content driven;</td>
<td>Behaviourism</td>
<td>Teacher-centred; student dependence; instruction;</td>
</tr>
<tr>
<td>Instructional method; high scripted</td>
<td>assessment concern</td>
<td>Knowledge acquired exclusively through the senses; teacher conveys universal characteristics of reality to students</td>
<td>student-teacher interactions; watch, listen, copy, chant, memorise</td>
</tr>
<tr>
<td>in structure; drilling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Collaborative learning</strong></td>
<td>Transmitting information; concern for student understanding</td>
<td>Cognitive constructivism</td>
<td>Teacher-centred; student dependence; discussion; small groups working on designated activities</td>
</tr>
<tr>
<td>Instructional method; students work in small groups to achieve a common goal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cognitive apprenticeship</strong></td>
<td>Facilitation of learning to meet students’ needs</td>
<td>Social constructivism</td>
<td>Student-centred; student independence; scaffold; reflection; investigation; self-paced learning</td>
</tr>
<tr>
<td>Model, coach, articulate, reflect, and explore</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Discovery learning</strong></td>
<td>Facilitating independent learning for growth in understanding</td>
<td>Radical constructivism</td>
<td>Student-driven; independent; personal, internal, constructivist-based learning environment</td>
</tr>
<tr>
<td>Inquiry-based learning model for problem-solving situations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


4.2.3.4 Uncertainty about digital technology use

The characteristics of uncertainty, self-efficacy, control and outcome expectations have been explored in research literature (refer to Section 2.5.2). I prepared Table 4.6 as a guide to interpreting uncertainty about the use of digital technology in the
classroom based on these characteristics. Self-efficacy refers to competence, confidence and self-belief in performing a task.

Table 4.6  
**Interpreting Digital Technology Uncertainty**

<table>
<thead>
<tr>
<th>Belief</th>
<th>Intentions</th>
<th>Statements</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competent</td>
<td>To be faultless</td>
<td>I’m going to . . .</td>
<td>Able</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Self-assurance</td>
</tr>
<tr>
<td>Not competent</td>
<td>To muddle through</td>
<td>How do you . . .</td>
<td>Avoidance</td>
</tr>
<tr>
<td></td>
<td>To ask for help</td>
<td>Oops, that’s not right!</td>
<td>Mistakes</td>
</tr>
<tr>
<td>Confident</td>
<td>To be efficient and effective</td>
<td>I’m confident. I know what I’m doing.</td>
<td>Relaxed, smooth</td>
</tr>
<tr>
<td>Lacking confidence</td>
<td>Asking for help if needed</td>
<td>I don’t have a licence to drive this thing.</td>
<td>Hesitant, confused</td>
</tr>
<tr>
<td>Self-belief Assurance</td>
<td>I told you I could do this.</td>
<td>Thanks for pointing that out. Talk about taking risks.</td>
<td>Satisfaction</td>
</tr>
<tr>
<td>Lacking self-belief Doubts</td>
<td></td>
<td></td>
<td>Faltering composure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mounting stress</td>
</tr>
<tr>
<td>Control</td>
<td>In charge</td>
<td>The plan is . . .</td>
<td>Seamless use</td>
</tr>
<tr>
<td>Lacking control</td>
<td>Seek help</td>
<td>I’ve changed my mind.</td>
<td>Preparation</td>
</tr>
<tr>
<td></td>
<td>Change task</td>
<td>Now what do we do?</td>
<td>Unable to continue</td>
</tr>
<tr>
<td>Purposeful Efficient and/or effective</td>
<td>I’ve found that it’s good for manipulating.</td>
<td>Relevant, timely, quick, easy, accurate, clear, engaging</td>
<td></td>
</tr>
<tr>
<td>Goal directed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental or random</td>
<td>Little idea of purpose or benefit</td>
<td>I try anything new. Sarah said to use it.</td>
<td>Finding purpose and benefit</td>
</tr>
<tr>
<td>Success</td>
<td>Personal or student learning gains</td>
<td>That went well.</td>
<td>Contented, smiling teachers and students</td>
</tr>
<tr>
<td>Failure</td>
<td>Little idea of success</td>
<td>That was a failure.</td>
<td>Frustration, distraction, lack of progress</td>
</tr>
<tr>
<td></td>
<td>Lack of reflection</td>
<td>It’s not what I wanted.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other teachers said . .</td>
<td></td>
</tr>
</tbody>
</table>

Teacher self-efficacy in digital technology use encompasses confidence and competence and a self-belief in achieving successful application to a particular task. Control is a belief that the digital technology will perform as expected, or if not, problems can be fixed by the teacher or by someone else nearby. Outcome expectations in terms of digital purpose and benefit play a significant part in
overcoming uncertainty about self-efficacy and control—it’s worth having a go!
Experiencing success in using the technology increases self-efficacy and control. These
gains decrease uncertainty, and the teacher is more likely to use the digital technology
again. I had no formula for identifying these beliefs as such.

The incident of Alan showing a YouTube clip in Lesson AO3 provided an example
of analysing uncertainty. Alan’s intention for the digital technology use was interpreted
from what he said to me—“When you are observing I feel the need to use more
technology”—meaning, I suggest, that he wished to contribute to my study. In
addition, Alan commented to students in the lesson about showing the clip, “to be seen
as a modern teacher”.

He acquired the clip from colleagues, which was an indicator of collegial
cooperation. Alan confirmed that showing a YouTube clip in a lesson was an
innovation that he had not attempted before. He was confident enough to do so, but not
sufficiently competent to plug the board’s sound cable into his laptop. He asked me for
help, an indicator of external control close at hand. If it had not been me, he would
have asked the students, as seen on other occasions.

Showing the clip provided Alan the opportunity to practise, with the benefit of
taking control of a second clip presentation in a subsequent lesson. Alan was not sure
about the benefit of either clip. At the final interview, Alan said that he was unsure
about the success of the first clip, except that it was relevant to the topic and quirky.
Alan was unaware that he had back-referenced the first clip three times during
subsequent observed lessons and noted in field notes. Alan said the second clip was
successful because “it animated his class”, it was relevant to students, and they would
remember the concept of limits. He also said that he would be showing the video clips
and other clips in his lessons in future, thus planning to reiterate innovation with a
greater sense of certainty.

4.2.3.5 Innovation Uncertainty Model

In conjunction with the identification of uncertainty beliefs, the Innovation
Uncertainty Model (IUM; revamped in Figure 4.1) was designed to allow beliefs to
be considered at significant milestones in a repetitious cycle of innovation use that was
overall either a eustressful positive experience or a distressful negative experience. The model’s beliefs consideration points have been labelled as follows:

**IUM-A.** Beginning: perceived uncertainty in self-efficacy, control, purpose, benefits

**IUM-B.** Success

**IUM-C.** Success due to self: increased certainty in self-efficacy

**IUM-D.** Success due to external factors: increased certainty in external control

**IUM-E.** External influence on achievement: changed certainty in self-efficacy, benefit

**IUM-F.** Failure

**IUM-G.** Failure due to self: decreased certainty in self-efficacy

**IUM-H.** Failure due to external factors: decreased certainty in external control

**IUM-I.** External influence on achievement: changed certainty in self-efficacy, benefit

**IUM-J.** Success or failure of the digital technology innovation controlled by student learning external factors, leading to re-evaluation of use

The study threw up a multiplicity of examples that reflected many variations of the IUM. This included one digital activity that led the teacher, after several iterations, to a complete re-evaluation of her approach to teaching mathematics (IUM-J).
4.2.4 Analysis process

4.2.4.1 Coding of text data

The data documents from emails of intention, field notes, lesson transcripts, and interviews were chronologically ordered starting with the participant story, followed by the observed lessons and interview transcripts as they occurred. The documentation was digitised in a two-column table with transcript data on the left and my thoughts, interpretations, and questions on the right. For each lesson observation, statements of intention preceded the lesson documentation, field notes were inserted into lesson transcripts as they occurred, and the post-lesson interview data were inserted after the lesson documentation. In the initial analysis step, the data was coded and memos were written on incidents of interest in an unstructured and creative way.
The primary focus was on incidents of digital technology use. A list of 32 digital codes, D1 to D32, emerged with an additional number of sub-categories, such as digital storage D6: in the Intranet Learning Area D6A, and in the Network File Space D6B. Secondary digital technologies that underpinned the digital use incidents were also identified and coded. Refer to Appendix 10 for digital technology uses, purposes and codes.

The initial identification of digital technology use was followed with the identification of associated uncertainty beliefs: self-efficacy, control, purpose, and benefit. A high level of self-efficacy and control initiated a question about how long the teacher had been using the digital application. I found identifying and confirming self-efficacy and control relatively straightforward in observation lessons. I needed to ask more questions to extract the same information about digital use that was mentioned but not observed.

The example found in Table 4.7 gave me little indication of Tamara’s self-efficacy and control in making concept videos. In the final interview I asked Tamara to self-assess concept video creation. I also had background knowledge that Tamara had known about making videos using ActivInspire for about 4 years, since I had arranged the original professional development activity for the mathematics teachers. This information was needed to interpret Tamara’s uncertainty beliefs.

In addition, the agency of the digital application in terms of the teacher-assigned task and role was identified. The influences on digital use were also noted. The Victorian Curriculum and Assessment Authority (VCAA) had validated the use of the CAS application Mathematica for VCE Units 1–2 Mathematics Methods (VCAA, 2010-2015), while the school’s principal had influenced the school’s participation in a VCAA Mathematica trial, for example.

In Table 4.7 the teacher-assigned role was Partner to both teaching and learning using a teaching model of direct instruction, T&L1, with student learning by using senses. Tamara was self-motivated to make concept videos, as was Sarah. Their shared interest would perhaps have provided a positive influence on the activity.
### Table 4.7  Example Analysis Coding Stage 1

<table>
<thead>
<tr>
<th>Incident Details</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher identifier / memo number</td>
<td>FAB42</td>
</tr>
<tr>
<td>Post-observation interview for Tamara lesson observation 4</td>
<td>FABPIO4</td>
</tr>
<tr>
<td><strong>R:</strong> You said you would email the students who were missing from class. What's in the email? I’ll prepare a little video of the graphing of sine and cos as we did today. <strong>R:</strong> What software will you use? I’ll use Activ Inspire. I’ve done it before and so does Sarah. I might use one of hers. <strong>R:</strong> Do you always make videos? If I have time. <strong>R:</strong> What about videoing in class? I have videoed lessons in class but there’s a problem when a student asks a question. You can’t hear it properly. There’s a massive time gap when you don’t know what’s happening. It’s boring for the students to get through. It’s easier to do after class. I email it with any notes etc. Sometimes the notes are specifically for the students who are absent, rather than students who are in class. <strong>R:</strong> Why are students always missing from your class? It’s the Year 10s. They have lots of activities so they are always catching up. But they do different things. One does Outdoor Ed. And their days don’t coincide with Year 11 days. There’s Work Experience for example. That’s why I do the videos. <strong>R:</strong> Are the videos and notes accessible for other students? Yes, in the Learning Area.</td>
<td><strong>D3</strong> Email teacher-student  <strong>D18</strong> Internet for email  <strong>D21</strong> Teacher video capture and editing  <strong>D27</strong> Activ Inspire  <strong>TL3</strong> Teacher/teacher collaboration  Barrier: time  <strong>IU</strong> unsuccessful innovation  <strong>D10</strong> Teacher notes  Purpose  <strong>D6A</strong> Digital storage</td>
</tr>
<tr>
<td><strong>Final interview</strong></td>
<td><strong>FABFI</strong></td>
</tr>
<tr>
<td><strong>R:</strong> How would you rate your video creation and editing? Developing.</td>
<td><strong>D</strong> Developing</td>
</tr>
</tbody>
</table>

Memo 42: This post-lesson videoing for absent students is important to the teacher evidenced by the teacher willingness to do it. After all, she could just reference the students to the text book or classmates for notes. Because Year 10s were regularly missing from the lessons there was a need for catch-up videos. The videos took the role of partner in the T&L process. The lesson itself was collaborative with students working in groups and minimal teacher direction-T&L3. The videos were instructional T&L1. The teacher might use a colleague’s video and/or may not have time to make a video. Videos were stored for future reference.

**Self-efficacy**
**Control**
**Purpose:** Resourcing absent students
**Personal gain**

**Success**
**Habit**

Partner  T&L1 Direct instruction  Student learning through senses.  CA Concept Activity  COT Teacher collaboration  D3, D6, D10, D18, D21, D27 digital technology  M maybe  M Y yes  M no, loss of time; yes, teacher duty  Y N
Incidents in the lesson that indicated the teacher’s beliefs about mathematics and mathematics education were also coded. Examples included placing students in small groups to investigate a new concept or leading students through a discovery process.

These were important in identifying teacher beliefs about mathematics and how mathematics was best taught and learnt, but also in perhaps identifying tasks for which the teacher did not use digital technology.

4.2.4.2 Coding like-data

In the second stage of analysis, stage 1 memos and evidential data were systematically keyed with the participant’s identity code, and memo identity into an Excel worksheet, one worksheet for each participant. Similar actions and interactions were encoded under emergent themes. Themes included influence authority, intentions, lesson format, student engagement, digital tasks, and activities, for example. Some of these themes were ultimately discarded.

Excel provided the opportunity to readily sort and resort the data according to themes. Sorting strengthened connections between ideas. New ideas that emerged were also memoed and coded. Refer to Appendix 8 for a list of codes and themes and sample of analysis phase 2.

These steps resulted in a matrix of beliefs and data evidence that represented participant uncertainty beliefs about using digital technology in the mathematics classroom and their beliefs on mathematics and mathematics pedagogy.

4.2.4.3 Interpretation of meanings from encoded data

A third analysis stage involved writing up theory related to sorted memos. The theory addressed how the memo ideas related to each individual participant and answered the core research questions. The emerging themes and patterns for each participant informed the analysis for the other participants, particularly in the sense of identifying consistencies and contradictions between participants.

Each use of digital technology by participants was compared to the IUM. Some digital usage was found to be certain for the teacher in some situations. If the task had been performed many times, if confidence and competence were high, and the purpose
of the task was taken for granted, then the digital task was considered established into classroom pedagogy.

An example of an established digital task was recording attendance. Five of the six participants had been performing this task in every lesson for at least four years. The five teachers discretely checked attendance accessing the intranet on personal laptops in their observed lessons. The sixth participant Bec who was new, was loud, fussy, and deliberate in her attendance recording. Her newness to the activity with its uncertain behaviour provided contradictory evidence that validated the certainty of the task for the other participants.

4.2.5 Analysis disruption

The analysis results moved into an area that challenged a basic assumption that the behaviour of teachers was driven by their beliefs. I returned to recent literature to further my understanding of goals and habits. I gained a broader perspective of the drivers behind goal-directed behaviour and habitual behaviour and the role of uncertainty in moderating behaviour. I reviewed incidents of interest that had previously been puzzling me and came up with an hypothesis for why some teachers used digital technology in lessons and others did not (refer to Chapter 10).

4.3 Data Validity and Reliability

Every effort was made to ensure that the data collected through both observation and interpretation were valid and reliable. The four case studies provided a variety of personal and professional approaches to classroom mathematics teaching and learning. There was no intention to identify a single theory about digital technology use but rather to identify the cultural perspectives that the participant teachers brought into the classroom and the individual beliefs that facilitated or obstructed digital technology use.

Observations of teacher practice were conducted over three terms of a single school year to capture a variety of topics and approaches for each participant. Three VCE teachers were observed teaching four lessons each. Three Year 7 teachers were observed in five lessons overall, either as an individual teacher or working as part of a team.
At first, I was invited by the participants to observe a particular lesson, but that did not last very long. Full-time employment restricted my attendance options, and the participants had commitments that could not be ignored. Instead, lesson observations were arranged for mutually agreeable times. As such, the observation lessons were selected somewhat randomly and without much notice. The teachers had little time to prepare deviations from their usual lessons. This contributed to the validity of observations of “normal” lessons.

Each lesson lasted from 60 to 75 minutes. In other words, five participants were observed in practice for at least four hours. All lessons were audio recorded. The recordings were reliable in capturing the teacher’s general interactions in the classroom and many, but not all, interactions with individual students. All participant quotations from this study came from thorough transcriptions of audio recordings and can be verified. The audio recordings took care of themselves, while I concentrated on observing the lessons and noting incidents of interest as the lessons unfolded. The resultant field notes were cross-referenced with the audio recordings to validate the facts of incidents that had been identified. The lesson transcripts and recordings were revisited as analysis proceeded to check and recheck details and nuances that may not have been captured in the transcription process.

The participants were interviewed after the observed lesson to provide validation and depth to incidents of interest. The interview questions were semistructured, allowing basic questions to be posed but also flexibility to address particular incidents or interpretations. Questions were also reserved for a later date when time or location of the interview was inconvenient. All participants agreed to a final interview for additional verification of some data.

Sometimes I emailed a specific question to a participant. Early on in the data collection process, the VCE teacher participants told me not to come to lessons because they were studying probability and were using only scientific calculators. It was perhaps a mistake on my part to agree to stay away. However, as a matter of interest, I emailed questions to these teachers about using calculators for the subject in general, and their answers provided additional data. Whether walking the corridor or emailing a question, I made it clear to the participants that I was collecting data.
Extracting written intentions from participants was difficult. If the teacher did not respond to the request for intentions via email, I asked for intentions verbally just prior to the lesson, and the responses were brief. Otherwise, intentions were interpreted from the lesson as it unfolded.

An experienced mathematics teacher educator provided further validation of beliefs interpretation from collected data. My colleague and I worked together on a sample of data to clarify my approach. I then gave her a copy of a first-step data document compiled for one participant. The document contained the transcripts of lesson observations, interview questions and answers, field notes, and interpretations to review. After reviewing the data, my colleague provided feedback for further consideration, and she wrote that she agreed with all the claims that I had made.

4.4 Knowing Participants

I was concerned that the validity and reliability of data would be compromised because I knew and had worked with five of the participant teachers at the school. After consideration, I believe that knowing the participants led to the collection of richer data.

During six years of teaching at the school, I only taught one or two mathematics subjects a year, and usually it was a single-class subject such as Essential Mathematics Year 10. My need to collaborate closely with mathematics colleagues was limited at the time. As such, I was friendly with the teachers, went to mathematics meetings and social events, but was not particularly close to any of them. I was seen primarily as a computer teacher who filled in as a mathematics teacher.

I had held leadership roles, such as technology domain leader and e-learning coordinator, at the school. I had facilitated IT professional development sessions for the five known teachers, including a session on how to capture video using ActivInspire flipchart (Promethean, 2009) that had become the source of concept videos for the VCE teachers. I was creative and friendly about sharing digital ideas, but not demanding. Luci said, “She thinks outside the box” when she introduced me to Bec whom I had not met before. Mostly, in the spirit of collaboration, when sharing a subject, I taught mathematics as I thought my colleagues taught.
I thought the participant teachers might use more digital technology than usual for the sake of the study. The trial of Maths Pathway was perhaps seen as an example of opportunistically implementing an idea just in time. However, the arrangements for trialling Maths Pathway were already in place well before I turned up for observations. As it turned out, the Year 7 teachers could not keep up a belief in Maths Pathway for more than a few weeks. That failure led to in-depth discussions about their inclinations for trialling new ideas.

I considered Sarah’s efforts in implementing digital innovation as normal behaviour for her. I had known her as being the most receptive of the mathematics teachers to digital applications. I thought of Sarah as a digital change agent, always ready to give a new idea a go. During the year, Sarah extended her digital innovations to other classes and did not limited them to just the lessons I had observed.

To summarise, I had an existing but independent relationship with each of the known participants. I was familiar with the school, its history, infrastructure, and the way the school worked. In interviews, I quickly passed over questions where I could predict answers and instead concentrated on the participants’ perspectives that were unknown to me. The interviews were personal to the participant and more like conversations.

Of particular value were the teachers’ stories about becoming mathematics teachers. The stories were interesting and varied, and they contained cultural similarities that I had not expected. The teachers enjoyed relating the stories, and I enjoyed hearing them. The activity contributed to a sense of trust, with the participants gaining confidence in sharing their thoughts about teaching mathematics and using digital technology.

4.5 Limitations of the Study

“The purpose of the case study is not to represent the world, but to represent the case” (Stake, 2000, p. 244). The primary limitation of case study research is that the findings are specific to the case and cannot be generalised. As a result, the aims of this study were refined to further understand teacher beliefs that facilitated or obstructed digital technology use in lessons, to suggest remediating strategies to obstruction where these were identifiable, or to suggest areas for future research.
McTavish and Loether (2002) outlined a problem with using observation as a research strategy: “What humans see is conditioned by who they are and what they have learnt” (p. 12). My observations were influenced by my age, experience, and the identities I had formed—female, baby boomer, mathematician, computer analyst, teacher, table tennis player—to name a few. To someone else, my perspectives may seem normal, limited, or “outside the box”. I have been sufficiently reassured to put forward these claims, knowing that I have strived to be structured and consistent, and to approach the study with a logical methodology and supporting evidence to clarify what I mean.

The study was also limited by my experience as a researcher. I felt incompetent at the beginning. I needed to learn how to conduct observations and interviews, analyse pedagogical data, and report results. I discovered my interviewing techniques were inadequate. I adjusted my approach and interview data improved, but even so I became aware of opportunities lost. The analysis stage was lengthy and shifted focus from teacher beliefs to teacher behaviour. All the while, questions arose to which I had no answers and no valid recourse to reinterview participants.

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I began to think about the relationship between teaching table tennis and teaching mathematics. The most common table tennis training strategy used by my coach was based on Chinese tradition. Repeating a shot 10,000 times apparently created an automatic response in the brain. Was this the same as chanting times tables in a mathematics lesson? Did we really do those 10,000 times to make mental multiplications stick in our heads and slick in delivery?
CHAPTER 5
CASE SARAH DATA COLLECTION

My experiment with table tennis performance began. Over time, the mindfulness strategies began to take effect during my matches. I stretched my fingers between points. When it was my turn to serve, I chose the next two serves I was to deliver, as I stretched my fingers, instead of agonising over choosing the best option for every serve. I halved the thought processes and time devoted to selecting serves in a match. I counted backwards when the pressure was on. Very mindful thinking was needed to make mindfulness happen.

5.1 Introduction

As mentioned in Chapter 4, data in the form of teacher intentions, statements, and actions were collected from the observation and review of participants’ mathematics lessons and their personal stories. This chapter and the following three chapters are devoted to presenting data collected from the practices of the six teacher participants.

Data collection was driven by the rationale that digital technology use in the mathematics classroom is a situation of change from traditional mathematics teaching. All digital technologies used or mentioned in observed lessons or during post-observation interviews were in focus. Not all the uses of digital technology were related to mathematics pedagogy specifically. Some digital technology uses were normalised, some were innovative, with the teacher in a state of uncertainty about use, and some were in between. Some digital technology use posed a risk for the teacher with the potential for a loss of confidence, control, status, or even identity.

In addition, the characteristic behaviours of teachers as they related to mathematics and mathematics education, and residual behaviours derived from teacher life stories, were in focus in terms of whether the beliefs behind these behaviours facilitated or obstructed digital technology use.
The data presented here were selected from the collected data on the basis of being considered reflective of normal teacher practice, innovative teacher practice in which a new idea had been recently implemented, or disrupted teacher practice, where the teacher was confronted with an interruption that initiated a problem. This chapter reports on data collected from Sarah’s story of becoming a mathematics teacher and her observed and/or discussed teaching practices.

5.2 Sarah’s Story

Sarah qualified as a secondary school teacher of mathematics and computing in 1992. She worked as a payroll clerk for two years and then as a teacher until her career was interrupted by motherhood. She returned to teaching after raising her family. At the time of this study, Sarah had taught mathematics for 13 to 14 years altogether and very little computing in that time.

Sarah stated that she became a mathematics teacher because she enjoyed the challenge of mathematics and she liked helping students. She talked about natural mathematics aptitude but considered that her own ability was not so brilliant. Instead, to succeed at mathematics, she relied on hard work. She said that her parents instilled values of “work hard, do your best, find your own thing, and make yourself proud”. Sarah had developed a strong sense of self: “I believe encouragement had a big role to play in success but mostly it is self-belief and motivation”.

Sarah’s first exposure to digital technology was at university, where Sarah chose to study mathematics bundled with computing for a degree in applied science. She learnt how to use Microsoft Office applications, web-publishing software Dreamweaver, and programming languages Turbo Pascal, C+, and HTML.

No particular teacher influenced her mathematics teaching style but rather, she said, “I liked mathematics and so was happy just having the teacher teach me something and then complete exercises. That never bored me”. The main influence was the way she was taught at school. Sarah also told me that, at the start of her teaching career, she was very much driven by the textbook, and she still was: “The textbook gives you confidence that you are meeting the Australian Curriculum requirements”.

When asked what she wanted for mathematics education Sarah said,

I want mathematics to be more driven by real applications and less driven by content. I want more time for students to work on really good, rich projects that are real problems that are experienced in life and in the work force. I want students to be able to work for extended periods of time on large projects where they have to work together as teams and yet also be responsible as individuals. I want allocated time where students are involved in planning their course and searching for resources for their course. (Sarah Story)

The research observations took place in 2015 during Sarah’s sixth year of teaching at the participant school. It was her second year of teaching senior mathematics, having previously taught only middle years mathematics.

5.3 Sarah’s Classroom Fields

Bourdieu’s (1977) construct “field” provided the context of social interaction and comprised the environment itself, the inhabitants being the teacher and students, the rules, and the powers of influence, for example. Sarah was observed teaching two classes for two lessons each. The classroom fields are described below.

5.3.1 Students

5.3.1.1 VCE students

The first two observations were of Sarah’s VCE Unit 1–2 Mathematical Methods (CAS) class. Sarah described the class of 25 Year 11 students as challenging. She explained that six weaker students had been advised not to study the subject. Ten students failed the first assessment task, and two of these students chose to switch out of the class after the first observation lesson. Only one of the remaining 23 students failed the second assessment task. Sarah said she was proud of her efforts (Post SO2).

5.3.1.2 Year 10 students

Sarah invited me to observe the digital technology strategies she was using in her Year 10 Enhanced Mathematics class. By contrast to the VCE subject, these 27 students were advanced in their mathematics studies and expected to do well in VCE mathematics in the following years.
5.3.2 Classrooms

The two classrooms were set in an original 1960s school building with typical features such as a raised platform at the front and venetian blinds on the windows. More modern facilities included an interactive whiteboard facility (the board) centred on the front wall. The walls were coated in brightly coloured write-on wall paint. The students sat on chairs at rectangular tables for two, facing the board.

In each classroom, the teacher and students used personal laptops. Wi-fi provided connection to the school’s network and beyond. The internet, the school’s intranet, and commonly used applications such as email and Microsoft Office 365 (Microsoft Corporation, 2011) were accessible in the classroom. Online textbooks were referenced using the internet. The school’s intranet stored subject resources and links to student data such as attendance records and contact details.

Sarah’s VCE board was run by ActivInspire software on an Apple agent computer. ActivInspire flipchart, a presentation application, was available on the board and teacher and student laptops. In the Year 10 classroom, the board was an intelligent pen/projector combination, an ActivInspire facility upgrade. In this case, the Apple agent computer was projected onto a calibrated area of front wall and manipulated using an intelligent pen.

5.3.3 Curricula

5.3.3.1 VCE Unit 1–2 Mathematical Methods (CAS)

The Mathematics VCE Study Design 2010 (VCAA, 2010) informs the VCE Mathematical Methods subject curriculum. The aims of the VCE Study Design are for all students to apply mathematical knowledge and skills; model, investigate, and solve problems; and use technology. A learning outcome involves the use of a CAS. Demonstration of achievement for this outcome: “must be based on the student’s performance on a selection of tasks . . . which incorporate the effective and appropriate use of computer algebra system technology in contexts related to the content of the areas of study” (p. 72).

The VCAA provided strict guidelines for school-assessed coursework (SAC) tasks. Part A comprised assessment of technology-free skills, knowledge, and understanding.
Part B comprised assessment of technology-enabled problem-solving tasks to fulfil Outcome 3. Assessment took the form of teacher-developed topic tests, projects, and semester examinations.

The selected CAS application at the school was Mathematica. Mathematica was first introduced at Year 10 level in preparation for the two years of VCE to follow. Sarah and her Year 11 students were in the second year of using Mathematica at the time of this study.

5.3.3.2 Year 10 Enhanced Mathematics

The IB MYP (IB, 2014) informed the Year 10 Enhanced Mathematics subject. IB MYP curriculum was based on a philosophy of “learning how to learn” through the systematic development of learning skills in communication, collaboration, organisation, self-management, reflection, research, information literacy, media literacy, creative and critical thinking, and transfer of learning in a context of local curriculum requirements. Year 10 Enhanced Mathematics was assessed in the areas of knowing and understanding, investigating patterns, mathematical communication, and solving mathematical problems in real-life contexts. The local curriculum content was derived from the Australian Curriculum (ACARA, 2015).

5.3.4 Other influences in the classroom

The school’s Teacher Code of Behaviour informed various routines and standards in the classroom, some of which required the use of digital technology. One such example was recording attendance in every lesson.

The subject team of Alan, Tamara, and Sarah had developed the VCE subject’s curriculum delivery. The team had agreed on content, pace, and assessment tasks. The effect of collegial influences was also in focus for this study.

5.4 Sarah’s Professional Practice

5.4.1 Lesson intentions

5.4.1.1 Learning intentions

Sarah’s learning intentions were expressed in terms of curriculum content only. Sarah’s Lesson SO1 (meaning Sarah’s Lesson Observation 1) learning intentions were
expressed as “Hybrid Functions and Inverse Functions”. Sarah said that covering two concepts in the one lesson was unusual, but they needed to catch up with the others. The learning intentions for her other observed lessons were graphing cubic functions (Lesson SO2), “When and how to use the quadratic formula to determine the x-intercepts of a quadratic equation” (Lesson SO3), and generating quadratic equations (Lesson SO4).

Sarah followed a consistent lesson plan. Lessons began with a short introduction followed by a concept activity of notes and worked examples, an application of concept activity comprising practice exercises taken from the online textbook, and skills exercises were set for homework.

Variations to the lesson plan were observed in Lessons SO1 and SO3. SO1 featured a longer start routine with an introduction to the digital application Padlet, concept routines on two different topics in a row, and no practice exercises: “But I wanted to do that so we are on par with where the rest of the classes are at” (Lesson SO1). Lesson SO3 had two concept routines on the same topic and no practice exercises.

5.4.1.2 Digital intentions

Sarah provided detailed digital intentions, purposes, and actions. Prior to lesson SO1, Sarah wrote about experimenting with Padlet, an online bulletin board, and expressed her intentions as follows:

> I am going to try using Padlet in my classroom so that girls can post questions and answers related to our classwork. I want it to be a collaborative working space. I'm thinking it could be something that I have up on my laptop screen whilst I am teaching at the board and students may be able to discreetly ask questions but I'm hoping it will be utilised to help each other with exercises.

(Lesson SO1)

Sarah’s detailed digital intentions for Lesson SO2 indicated a switch of software from flipcharts to Slideshow to display her lesson notes: “I had recently discovered that Mathematica has a Slideshow module” (Lesson SO2). She suggested that using Slideshow would expose students to Mathematica more: “You can use manipulate/plot commands so that the students can explore the effects of different variables in equations” (Lesson SO2). In addition, Sarah expected to save preparation time by
typing notes, equations, and graphs directly into Slideshow without having to use other software.

Sarah was happy with her digital technology innovations in the VCE lessons and intended to share Padlet, Slideshows, and a new idea of using flowcharts to represent mathematical processes with her Year 10 class. Sarah invited me to next observe her digital innovations transferred to Year 10 Enhanced Mathematics class for Lesson SO3.

Sarah’s enthusiasm for innovation was waning by Lesson SO4. She wrote that she intended to use the board, Mathematica for calculations and graphing, Slideshow, laptops, and a SimpleMind image. She was continuing with digital ideas that had succeeded (Intentions SO4).

5.4.2 Lesson bookend routines

5.4.2.1 Start routine

Sarah’s lesson introductions were mainly short and to the point, “Has everyone got the Mathematica file? Can I ask everyone to go to lesson 7? Is it slide 25? Yes, that’s fine. Everyone has to be on 25. Slide 25, are we on it?” (Lesson SO3). Sarah recorded attendance.

Similarly, the introduction in Lesson SO4 was “Down to business. Today we are up to slide 13. OK can I get everyone ready to write, books open, pens out?” (Lesson SO4).

Sarah introduced Padlet bulletin board to students at the beginning of Lesson SO1. She explained to the class that the idea had come from a preservice teacher under Sarah’s supervision at the school, during a discussion about how to encourage reluctant students to ask questions in lessons. Sarah said that it would also help solve the growing problem of student emails asking for help outside class time. Sarah told the students that Padlet was a fairer solution in which everyone could participate (Lesson SO1).

Before the lesson, Sarah had initiated and tested the bulletin board online. She had recruited two students to trial the site, at home and at school. During the lesson, Sarah provided time for students to “play” with Padlet. The students immediately became
involved. They posted fun comments and bombarded the teacher with questions. The following dialogue was noticeable in that Sarah did not give out instructions to the students:

Student: Are the postings anonymous?
Sarah: How about if you would like to trial it? So if you have the link in your email handy you can try it.
Student: I posted hello.
Sarah: Does it show your name?
Student: No. What if you want to be identified?
Sarah: I’m not sure. (Lesson SO1)

Sarah’s comments indicated that students had played with the software, “So, if you’ve put a little fun comment up there, it’s your responsibility to delete it today. It’s OK to have a bit of a play. Then I want everyone to close the laptop and listen for a little while. So, delete your comment” (Lesson SO1).

In bringing the introduction to a close for the start of a concept activity, Sarah encountered a problem. The students wanted to know how they would ask discreet questions without their laptops. Sarah had not considered this complication but gave permission for students to leave their laptops open.

5.4.2.2 End routine

Sarah consistently ended each lesson with the same instruction to students to “finish the exercises for homework”.

5.4.3 Concept activities

5.4.3.1 Concept understanding

In the lessons observed, Sarah did not engage in any activity directed towards enriched concept understanding. Her concept introductions lasted a minute or so with a question-and-answer recall of previous learning. On one occasion only, Sarah linked the term “hybrid” to a relevant practical example: “Now did anyone in this class do the RACV Energy Breakthrough Challenge? OK, what’s a hybrid car?” (Lesson SO1). An aspect of the RACV challenge was for participants to understand the mathematics of fuel consumption. Sarah had missed the opportunity to use readily available “real” hybrid equations to illustrate the topic of hybrid functions.
5.4.3.2 Notes

Sarah had comprehensive flipcharts for every topic, and one of her characteristic teaching strategies was to share these with students. The flipcharts included theory, terminology, definitions, and incomplete examples. Sarah’s flipcharts also contained references to practice exercises in the online textbook and links to tutorials, concept videos, past assessment tasks, activities, and games. “I spend a lot more time these days, preparing electronic notes, tests and searching online for ideas” (Story Sarah).

Sarah emailed copies of the topic flipcharts to students prior to the start of a new topic and also projected slides onto the board: “So what I have done for you is make a list of this summary of what you need to know for inverse functions. What I’ll get you to do is copy this down first” (Lesson SO1). Students copied notes by hand to notebooks. Sarah said that the purpose of teacher notes was to support students to work ahead during class or to catch up if they missed a lesson (Post SO1).

Students were allowed to take their notebooks and digital notes into a Part B assessment task known as “tech-active” SAC but neither sets of notes were to be taken into a Part A assessment task known as “tech-free” SAC (Lesson SO1).

Sarah chatted to a student about using notes in assessment tasks and mentioned memorising: “I think in order to support you well in exams you really have to have it in your memory anyway” (Lesson SO2).

5.4.3.3 Worked examples

In the lessons observed, Sarah’s preferred approach to concept understanding was by way of worked examples. Sarah demonstrated the mathematical processes needed to answer typical topic questions. Ideally, Sarah liked to demonstrate one of each type of example found in the list of practice exercises. Sarah worked four examples on the board in Lesson SO3. Sometimes she ran out of time: “I still have two examples to go through” (Lesson SO1).

Sarah worked each example in detail:

Sarah: When we sketch new graphs, like the old graphs, we use the same concepts. What sort of things do we need to show?
Student: Where the graph crosses the axes.
Sarah: Yes, where the graph crosses the axes. So our x-intercept and our y-intercept, what is the easiest way to find the x-intercept and the y-intercept?

Students: $y = 0$ and $x = 0$

Sarah: How do we find the y-intercept?

Students: $x = 0$

Sarah: So, when I let $x = 0$ in that equation what do we get for $y =$ ?

What will $y =$ ?

Student: Zero ten

Sarah: So, if I’m writing the coordinates of my y-intercept what would be the coordinates?

Student: Open brackets 0 comma 10 close brackets . . . (Lesson SO2)

Sarah’s actions were indicative of an emphasis on instructions and process, rather than logic and understanding, as the following extract on inverse functions demonstrates.

Student: So what are you saying if you have $y = 2x$? Do you mean $2x = y$ or something else?

Sarah: I change the y to an x. I change the x to a y.

Student: $x = 2y$?

Sarah: Yes, that is pretty much the process of finding an inverse. Swap the y to an x and the x to a y.

The last thing is to sketch the graph of both the original function and the inverse. When you sketch the original function, put the line $y = x$ in. And then we will sketch the inverse on top. (Lesson SO1)

Sarah used the same detailed approaches in her Year 10 lessons. The student responses were slightly more enhanced:

Sarah: If I give you this equation $2(x + 5)^2 = 7$ would I be able to use the quadratic formula to solve this?

Student 1: No.

Sarah: Why not?

Student 1: The first part is not like something $x^2$ plus something plus something.

Student 2: You have to expand it out.

Sarah: You could expand it out, because you would get that format. As it stands at the moment it is not in the correct format. It
needs to be in this format to use the formula. If we expanded it out what would we get?

Student 1:  \( x^2 + 10x + 10x + 25 \)

Sarah: What are your like terms?

Student 2: 10x

Sarah: Is this right now? (Lesson SO3)

Sarah suggested memorising during worked examples in general and three times for the quadratic formula:

We are doing quadratic formula today. The first thing I want you to do is go to the formula and copy down the formula. That is something I want you to memorise.

All right. Now what’s the best way you can try to memorise the formula. Yep, keep writing it down so when you are doing questions in class today and for homework later on I want you to write the formula down every time you answer a questions.

Painful it may be. It will come automatically to you just by repetition. (Lesson SO3)

5.4.3.4 Linking concept to assessment

In the example above, Sarah mentioned examination technique as she worked the example. When Sarah unpacked solutions on the board, assessment techniques often emerged as the following examples demonstrate.

Sarah: Now in the Year 12 exam, if you are asked to find the inverse, and you leave your answer just like that. This is correct but you get penalised for writing that. You should write \( y^{-1} \). Inverse is shown as the power of a negative number. So, you write:

\[
y^{-1} = x^2 \quad \text{(Lesson SO1)}
\]

Sarah: If this was a tech-active exam and you use Mathematica to find the equation would this be the final answer?

Student: No.

Sarah: What do I do to write for the final answer? What can I do here?

Student: Plain text.

Sarah: Yeah plain text. In plain text write the answer. (Lesson SO4)
Sarah: The first thing I do when I solve this question is that I write down: a=, b=, c=. If you are being marked for communication, that is good communication. (Lesson SO3)

This last example is the only reference Sarah made to the IB MYP requirements for addressing mathematics communication in two observed Year 10 lessons and the post-observation interviews.

5.4.3.5 Working ahead of the teacher

Several students in the class kept pace with the teacher, but others proceeded through the worked examples and then the practice exercises listed in the notes file ahead of the class. At times, these students interrupted Sarah with a question that was out of sync with her demonstration. These events generated moments of confusion, and it appeared that Sarah did not react well to interruption. The first example demonstrates digital confusion, while the second example demonstrates mathematical confusion.

Student: What about finding the inverse using Mathematica?
Sarah: Good point. So, while I think of it on that Padlet I put some points about Mathematica help as well. But I answered one of the questions I asked in class without thinking. (Lesson SO1)

Student: Can you use the quadratic formula to find the factors in a quadratic function?
Sarah: Actually, the quadratic formula helps get the x-intercepts rather than factorising for you. (Lesson SO3)

5.4.4 Concept application activities

5.4.4.1 Practice exercises

After worked examples were completed, and if there was sufficient time, the lessons progressed to applying the demonstrated processes to practice exercises. While the students were relatively attentive during worked examples, the noise level rose noticeably during practice activity. The topics of conversation captured on audio recordings were not necessarily related to mathematics. Occasionally, Sarah looked around and shushed the class: “I hope everyone is working” (Lessons SO2, SO4).

During one practice activity, Sarah sat with a student for about 20 minutes discussing SAC results (Lesson SO2). In another, Sarah introduced Mathematica to a
new student (Lesson SO4). I observed that up to half the students did not look at or touch their laptops, workbooks, or pens during this time except perhaps when Sarah occasionally glanced around the room (Field Notes SO2, SO4).

5.4.5 Generic digital technology use

5.4.5.1 Padlet

Sarah introduced Padlet at the beginning of Lesson SO1 for a number of reasons (outlined in Section 5.4.2.1). Sarah then worked her way through an example of hybrid functions using manual methods. Her presentation was interrupted by a question from a student via Padlet. Sarah did not notice the question, and a second student prompted her to look:

Padlet: Why didn’t you cancel both sides?
Sarah: I did. Who wrote that message? (Lesson, SO1)

At the post-observation interview, Sarah said,

I think my intention to use it [Padlet] for question asking whilst I am explaining at the board will not work well for me as it is difficult to remember to check my computer screen. I also feel the verbal questions are much more valuable to the class and promote a more collaborative learning environment. That being said however, students can still post a question whilst I am explaining and I can respond to it later. (Post SO1)

Sarah had changed her mind about the purpose of Padlet during the lesson.

Sarah expressed delight at the success of Padlet after a fortnight of use. A survey had revealed that half the class had posted to Padlet. Sarah’s only hurdle had been reminding a couple of students to post and not email (Post SO2).

Sarah was again asked how Padlet was going, and her answer revealed yet another Padlet purpose, residual uncertainty, and some confusion in her reasoning:

Padlet is still being used a lot in my Year 11 class but it still hasn't taken off in my other classes. I think the unique thing with this Year 11 class is that there are a lot of students who are struggling. They want the help and they like being anonymous. (Post SO3)
5.4.5.2 Flowcharting

With innovation in mind, Sarah had made flowcharts of mathematical processes for her note files using a licensed application, SimpleMind. She thought that flowcharting would be good for student learning and planned a classroom activity in which students were to create a flowchart on the quadratic formula processes (Intentions SO3).

Sarah asked students to download the free version of SimpleMind in Lesson SO3. The free version application could not cope with mathematics nomenclature or images such as a photo of mathematics nomenclature. The quadratic formula proved to be an impossible flowcharting challenge for the free SimpleMind (Lesson SO3).

The teacher persisted with SimpleMind instructions during the lesson while the students went ahead using Inspiration, a similar mind-mapping application that they all had on their laptops. Inspiration could handle both images and mathematic symbolism, and the students were experienced users of the application. The students ignored Sarah’s instructions and successfully completed the activity using Inspiration (Lesson SO3). Sarah’s implementation of SimpleMind was quite different from her implementation of Padlet.

5.4.6 Mathematica

5.4.6.1 Using Mathematica

In her second year of using Mathematica, Sarah was well versed in Mathematic and exhibited confidence, competence, and control when demonstrating Mathematica commands. Sarah had created a glossary of commands, accessible online to staff and students alike. Sarah told me the students did not use the glossary (Field Notes, SO1).

Sarah demonstrated a new Mathematica feature, plotting hybrid functions, on the board in Lesson SO1. The following extract shows her detailed approach to laying out command syntax interspersed with student interaction.

Sarah: Start with the PLOT command. What do you think I should click on next? What is going to come in here?
Student 1: EXPR1
Sarah: What do you think the EXPR1 stands for?
Student 1: Equation 1
Sarah: Yes, equation number 1, then the conditions for equation 1. See that word. That means when I type my equations it goes there, then I’ll follow along with typing notes. Then tap key or type 1 then \( x \geq 1 \). How do I get the \( \geq \) sign on my keyboard?

Student 2: Hold \( >= \)
Sarah: The hold option then \( >= \). What comes next?
Student 2: Closed square bracket enter
Sarah: Closed square bracket, enter. That worked. (Lesson SO1)

When Sarah had finished the first example using both manual and digital methods, she wrote up a second example for students to complete. A student asked about using Mathematica:

Sarah: Jackie do you have a question?
Jackie: Do we use Mathematica?
Sarah: This one you are doing by hand. (Lesson SO1)

As the students worked away on the second example manually, Sarah told me she needed a third quadratic equation to use as a worked example: “Let me try this one \((-2x^2 + 7x + )\) on Mathematica and if it doesn’t work, I’ll think of another one”. She typed it into Mathematica on her laptop and it worked. Sadly, Sarah had lost an opportunity to model to the students an experimental approach made effective using digital technology (Lesson SO1).

5.4.6.2 Choosing Mathematica

In general, Sarah favoured working examples without digital help. She recommended Mathematica be used to check answers. “Once you have solved it by hand please type it into Mathematica to see if you can get a match. It’s always a nice moment when your manual answer equals your Mathematica answer” (Lesson SO3).

On two separate occasions, Sarah announced she would demonstrate the Mathematica process first and changed her mind:

Sarah: What I’m going to do is first I’ll solve them using Mathematica then I’ll show you how to do them by hand. You might like to write down the question first and draw the graph and then we’ll do the solutions.
Student: Are we drawing each one by hand or Mathematica?
Sarah: Both. Write it down. Draw the graph. Then we’ll do it on Mathematica. So, my first step ah. Actually, we might do the manual solution first then we’ll do Mathematica. (Lesson SO4)

In the following example, Sarah showed the students how to do a simultaneous equation set-up manually and then the set-up and solution using Mathematica.

Sarah: You’re not required to do it manually so we will use Mathematica. First, we have to set up the equation for each point. So, I am going to show you how to solve it partially manually first. (Lesson SO4)

The following extract further demonstrates Sarah’s mixed message about when to use Mathematica.

Sarah: OK we wanted to sketch the graph. It is very time-consuming at the moment isn’t it?
Student: Yeah.
Sarah: If you had the choice of using Mathematica to find the x-intercepts and sketch the graph would you do it?
Student: No.
Sarah: You wouldn’t, you’d do it by hand still?
Students: Yes.
Sarah: In exam conditions, if it’s a tech-active exam and you have to do this question and you are conscious of time are you going to do it by hand?
Students: No.
Sarah: No, you wouldn’t want to do it by hand. It’s going to affect the rest of your exam. You don’t want to spend time doing stuff that can be done quickly with Mathematica. (Lesson SO2)

One student commented about a returned SAC:

Student: Why am I so bad at Mathematica?
Sarah: Why are you so bad at Mathematica? You need to practise it more. That comes automatically to me.

[Aside to me]
Sarah: I told you the students lack confidence. (Lesson SO1)
5.4.6.3 Slideshow

At about the time of her first observation, Sarah became aware of a Mathematica presentation module called Slideshow. Slideshow featured a plain text mode and importantly a manipulate/plot mode to run Mathematica commands directly. Sarah thought notes in Slideshow would increase her students’ exposure to Mathematica (Intentions SO2). Sarah began the switch from flipcharts to Slideshows as her note-presentation platform. She had emailed students a Slideshow file of notes before Lesson SO2.

During the lesson, I asked Sarah how the conversion was going. She said that she was happy so far. She had successfully transferred text from the flipchart to the Slideshow file but was still to learn about inserting images and hyperlinks. The text was very basic as there were few formatting features available in Slideshow. Sarah said, “The Year 11 students don’t care!” (Field Notes SO2). However, Sarah cared.

By Lesson SO3 Sarah had introduced Slideshow notes to her Year 10 class with improved features. Sarah projected the Slideshow on the board and, while students were copying notes, she showed me the improvements she had made. She had added a hyperlinked table of contents, a selection button to skip slides, links to the intranet and the internet for resources, and the list of practice exercises hyperlinked to the online textbook. Finally, she had inserted coloured text images created using flipchart software for headings and emphasis.

I asked how making Slideshow slides compared to making flipcharts using ActivInspire and Microsoft Office “equation editor”:

Sarah: With flipcharts I found I got really carried away with colours and looks. With this it feels as though I am focusing on the work.
R: So, you think this is more productive?
Sarah: I feel like it is, I think for me. And even if it was similar in time in making flipcharts, although I think the flipcharts took longer. The positive response I got from the Year 11s made me want to continue.
R: Is it helping normalise the use of Mathematica?
Sarah: I think I am. I am now using Mathematica every lesson whereas before I wasn’t. I want to keep doing that. (Lesson SO3)
Sarah’s actions indicated she was new to using Slideshow. At first, she asked a student to demonstrate on the board how to change between plain text and manipulate/plot modes. This was the only time in the four observation lessons that Sarah asked a student to work on the board (Lesson SO3).

Returning to the board, Sarah encountered a problem scrolling down in Slideshow: “Am I going the right way or wrong way?” (Lesson SO3). A student answered that it was the wrong way, and Sarah reversed her scrolling action.

Sarah worked a second example on the board and ran into trouble changing modes:

Sarah: It’s very annoying when Mathematica does this.
Student: Why did it do that?
Sarah: When you are working in the orange shady thing, it chucks a wobbly. (Lesson SO3)

The “orange shady thing” was manipulate/plot mode. Students called out instructions to change back to plain text mode (Lesson SO3).

5.4.6.4 Calculators

The topic of calculators came up in an email about probability theory. Sarah was asked what she thought of using calculators in class:

I would like to limit the use of calculators in Years 7–9 so that they are only used within certain topics. They rely too heavily on their calculators to perform operations with fractions and decimals and many students lose the ability to recall times tables and do basic number operations in their head.
(Post SO2)

5.5 Withdrawal

After Lesson O4, Sarah said that she had had enough of participating in the study. The commitment was not affecting her workload, but she felt she should stop doing anything extra. She did agree that at the end of the year there might be a final interview if anything needed clarifying.

Sarah did have a short final interview at the end of the teaching year. In it, she volunteered that she had felt the need to change. She had realised she was spending too much time on the Slideshow notes files, and she had asked herself why. It was not a matter of time spent with converting flipcharts notes to Slideshow files. It was a
question of why she was giving them notes. She said, “I’m not teaching the way that I want to and I have to rethink what I am doing. Why am I spoon-feeding them?” (Sarah Final Interview).

5.6 Conclusion

The collected data included in this chapter were selected as examples of Sarah’s practice that were regular, such as her lessons plans; contradictory, such as being motivated by students’ feedback on Slideshows that first said they did not care (Lesson SO1) and then said they did care (Lesson SO3) about formatting in notes; disruptive, such as using free SimpleMind; and changing her mind, particularly about when to use Mathematica. Most importantly, Sarah was seen as being innovative with digital technology, with some success and some unexpected outcomes.

Over the course of the study, Sarah was brought to a point of re-evaluating her practice. She was committed to the curriculum content requirements but conflicted about how to best achieve learning outcomes. Awareness and re-evaluation towards the end of the year provided Sarah the opportunity to change.

While it seemed a daunting prospect for Sarah, a way forward was close at hand and rested with her two VCE teacher colleagues, Alan and Tamara. Perhaps unbeknownst to each other, each VCE teacher possessed a teaching strength. Sarah had by far the greatest interest and variety of digital technology use in her mathematics lessons. In addition to the examples of flowcharting and collaborating via a bulletin board, students made videos in Sarah’s lessons. She collected links to online tutorials, games, and other resources. She shared YouTube clips with her colleagues. Her resources and imaginative use of digital technology in lessons were assets from which all three teachers could benefit.

The next chapter unpacks Tamara’s professional approaches and uncovers collaborative strategies for the teaching and learning of mathematics in the contemporary classroom that she could share with her colleagues. Chapter 9 provides an analysis of Sarah’s data in terms of beliefs and how these might relate to this study’s research questions.
Trialling mindfulness in my table tennis games resulted in an immediate improvement in my serving, but otherwise time and practice were needed for the automation of mindfulness strategies and the subsequent effect of empty-minded approaches in match play. I slowly became more confident. The forehand drive began to appear more often, unconsciously out of nowhere, and to great success. The audience cheered wildly, a response that reinforced my growing confidence.
CHAPTER 6

CASE TAMARA DATA COLLECTION

The effectiveness of my new strategies was reflected in an elevated table tennis ranking. My opponents responded to the newfound composure with different tactics, the first being to avoid my forehand altogether. I scurried back to my coach for backhand practice. Further coaching and practice were needed to counteract the complexities that began to emerge in my table tennis matches.

6.1 Introduction

This chapter provides data collected from observation and discussion of Tamara’s actions in the classroom for the subject VCE Unit 1–2 Mathematical Methods (CAS). Selected data focuses on Tamara’s regular pedagogical approaches, use of digital technology, and the associated influences, purposes, expectations, and outcomes of digital use. Data, in the form of intentions, actions, and statements in classroom lessons, subsequent discussions, and Tamara’s story, were collected in order to identify teacher beliefs about mathematics, mathematics education, and digital technology use.

Tamara liaised with her colleagues on the subject’s topics, pace, and assessment but not on teaching strategies. Unlike her colleagues, Tamara favoured a collaborative learning environment for her students.

6.2 Tamara’s Background

Tamara remembered being raised in a supportive family environment. Her father, an architect, influenced her interest in mathematics. He encouraged her studies and expected her to do well. Tamara said that she had worked hard at mathematics and did do well. The seed for a career in mathematics education was sown in Year 10 when she found she was good at explaining mathematical solutions to her friends.

Tamara recalled that her Year 12 mathematics teacher was the main influence on her teaching style:
I think he had a similar style to me, knew the students, had a discussion with them, made them work hard, and encouraged them. He was a model for my teaching style. . . You don’t have to know everything, you just have to work it out, discuss it. (Tamara Story)

Tamara went on to major in physiology and mathematics at university. She qualified as a teacher of science, mathematics, and religious education in 1992, the same year as Sarah. Tamara experienced difficulty in acquiring a teaching position and instead worked in a bank. She said her bank-loans manager role as being about problem-solving, negotiating loans, and good communication with customers. In 1999, after the birth of her second child, she reconsidered her options and commenced a career in education as a casual replacement teacher. After one day, she was offered a six-week temporary replacement role. Before long, she was fully employed as an ongoing teacher of mathematics at the participant school.

Tamara has held several different leadership roles at the school, including the position of faculty head mathematics. As she explained it, “teachers were pretty much doing their own thing with the curriculum” (Tamara Story) at that time. Tamara achieved curriculum agreement between teachers on topics, timing, and assessment tasks. She put strategies and processes in place so that subject teams shared resources for equitable, fair, and accountable subject delivery. “I think of myself as a problem-solver. I think logically and that helps develop good mathematics skills and also be a problem-solver” (Tamara Story).

Tamara’s first exposure to computers occurred at a university in the late 1980s where she studied computer programming and word processing. She was introduced to database applications at the bank. Eventually, she taught herself Excel to use in her mathematics classes. More recently, she has acquired computing knowledge and skills from opportunities at school. The principal had prioritised IT professional development for all teachers.

In answer to the question about change in mathematics education, Tamara thought she would look for more activities that had a nontraditional approach to steer away from standing up in front of the class and talking: “There have been occasions that are quite powerful when I give the students activities where they have to explore the topic” (Tamara Story). Tamara also mentioned staff collaboration and continuing professional
development: “Things change all the time. Same old, same old is really boring” (Tamara Story).

6.3 Tamara’s Classroom Field

6.3.1 Students

There were 12 students in Tamara’s VCE class: eight from Year 11, and four from Year 10. The Year 10 students had previously studied at an enhanced level and skipped a year of mathematics to study the VCE subject earlier than usual. The students were assigned to the class according to subject preferences and school constraints (Post TO1).

At the first observation lesson, all the students were present. At subsequent observations, several students were missing due to extra curricula or year-level activities, and these were usually the Year 10s. Quite regularly, Tamara needed to provide catch-up material for absent students (Lesson TO3).

Tamara was observed teaching this class for 270 minutes. Refer to Appendix 9 for a breakdown of the time taken on particular lesson tasks. The observations were made during Tamara’s first year of teaching the subject, although she had taught similar subjects in prior years.

6.3.2 Classroom

Tamara’s observed lessons were set in an old-style classroom renovated to accommodate contemporary approaches to teaching and learning. The colourful environment comprised brightly painted walls, chairs, and tables. The tables were modular in shape and arranged so that students sat around them in circles in groups of six or fewer. The walls were covered in write-on paint. In Lesson TO4, students worked in groups of three and wrote their outcomes on the walls with marker pens.

6.3.3 Digital tools

The classroom digital technology set-up was similar to Sarah’s and included personal laptops for teacher and students, and access to wi-fi, the internet, and the school’s intranet. The internet provided an online textbook for the lesson while the intranet provided modules such as student data, digital document storage, and assessment tracking.
The interactive whiteboard facility was an intelligent pen/projector combination. Projection from the agent computer was onto a calibrated area of front wall called the ‘the board’. The intelligent pen communicated with the agent computer running the pen software, ActivInspire. Tamara was familiar with this technology having used different versions of it for more than five years.

Tamara and her Year 10 students were using Mathematica as the prescribed CAS for the first time in 2015. The Year 11 students had used Mathematica the year before when they studied Year 10 mathematics.

6.4 Tamara’s Professional Practice

6.4.1 Intentions

Tamara expressed learning intentions for each observation lesson in terms of curriculum content. These were cubic and quartic functions, Chapter 7 (Lesson TO1), gradient at a point (Lesson O2), absolute maximum and minimum (Lesson TO3), and graphing sine and cosine functions (Lesson TO4).

Tamara’s stated digital intentions were to use the board and Mathematica. She acknowledged that the purpose of the board was to facilitate communication in class using visual projections. Prior to Lesson TO4, Tamara said, “Sorry no technology” but used at least five different digital applications in the lesson. Much of Tamara’s sense of digital technology use had slipped into a subconscious level.

Altogether, the digital technology not mentioned in Tamara’s lesson intentions, but used or discussed in lessons, included teacher-to-student and teacher-to-teacher email; the online textbook; the intranet’s LMS for recording attendance, assessment tracking, and resource storage; online assessment; Slideshow; calculators; YouTube clips; Wolfram ProjectDemonstration; and homemade concept videos.

Tamara’s lesson plans emerged as the lessons unfolded. The lessons followed a consistent pattern that began with a short start and quickly moved into a concept activity. The concept activity may have included student note taking and demonstrations of worked examples. Concept application activity in the form of practice exercises or problem-solving followed. The lesson finished with a brief end
routine. One disruption to this plan occurred when IT technicians came into the classroom to update student computers.

6.4.2 Lesson bookend routines

6.4.2.1 Start routine

Each lesson commenced with a preamble while Tamara recorded attendance: “Did you get the Mathematica file I sent you? Remind me to show you a revision tool the other class has access to as well” (Lesson TO1).

Tamara gave out cupcakes at the beginning of the lesson TO1: “It’s part of building a relationship with the students. It is the first time I have had this subject. It’s a small group but I’m still nervous of the responsibility” (Post TO1).

For the first 10 minutes of Lesson TO3, Tamara prepared students for the presence of IT technicians in the classroom “to upload a new application on your laptops”. Otherwise, Tamara’s start routines were brief and centred on recording attendance without comment.

6.4.2.2 End routine

Tamara ended lessons with discussions about the next lesson and homework choices. Tamara did not set homework but rather suggested homework activities based on upcoming topics or impending assessments. In the following example, an assessment SAC based on Chapter 6 of the textbook was looming: “We’ll go through 7B tomorrow but I am also going to go through key things you need to know, things on 6 that might be a bit blurry. So, come ready with your questions” (Lesson TO1).

Another example was “Next lesson, I hope you will have finished all the worded problems. There’s exam revision stuff on the intranet as well if you want to look things up” (Lesson TO3). Tamara did not follow up homework in her four observation lessons.

6.4.3 Concept activities

6.4.3.1 Concept understanding

Tamara’s concept understanding strategies comprised student investigations, note taking, and demonstrated worked examples. Each observed lesson was characterised
by Tamara’s efforts to facilitate collaborative and student-centred learning. About
collaborative learning, Tamara said, “If I could think of something and I had enough
time I would include that type of activity” (Post TO1). She found that the demands of
the curriculum and keeping up with Sarah and Alan sometimes constrained her
ambitions (Post TO1).

Tamara introduced students to cubic and quartic general transformations by way of
a collaborative investigation and presentation in Lesson TO1. The students, divided
into groups, were asked to present transformations of their given function. Tamara
scaffolded the transformation activity with a list of questions to be answered in the
presentation: “I think you can answer these questions, without me giving you lots of
information, based on what we have covered in chapters 4, 5 and 6” (Lesson TO1).

During the preparation time, Tamara instructed individual Year 10 students on
using Mathematica to transform functions. During the presentations, Tamara
questioned the student presenters:

Student: So, it’s basically a parabola with a flat bottom.
Tamara: Yes. So, is it symmetrical?
Student: It looks like it.
Tamara: Around what point?
Student: Here. This is a point of inflection. Is it a point of inflection or a
turning point?
Tamara: I’m actually not going to answer that.
Student: It’s a turning point!
Student: Is it such a straight line or is it really a curve?
Tamara: OK it is just the way it is drawn. If you zoom in closer and you
can see the shape of the curve. Mathematica is good because you
can manipulate it. (Lesson TO1)

Tamara interrupted the Year 10s mid presentation to teach them how to insert a
label, but at the same time acknowledging Year 11’s previous learning: “That is my tip
on Mathematica today. If you have got a graph it is quite easy to write these points in.
You may have known that” (Lesson TO1).

Tamara initiated another well-defined collaboration task in the form of an
investigation of trigonometric functions graphs using exact values. Tamara assigned
students to groups of three. “What I want for you to come up with at the end of this is a
sine graph and a cosine graph . . . but I want you to do it from exact values.” (Lesson TO4). Once started, Tamara refrained from helping students and instead monitored student progress and asked an occasional question. Tamara admitted that it took self-discipline to leave it to the students: “The hardest thing about doing something like this is to not go and help too much. And it’s OK for it to take some time” (Lesson TO4).

During the activity, the student-to-student discussions were intense:

Student 1: As it moves here. So, you’ve got a tangent line like this so. If you move that forward and it gets greater and greater and greater.
Student 2: Yes.
Student 1: What happens when you get here?
Student 2: When you’re here?
Student 1: Yeah what happens there? What’s the tangent line through that?
Student 2: Oh, it’s parallel so it’s . . .
Student 3: It’s parallel.
Student 2: Undefined.
Student 1: Undefined. Yeah?
Student 3: Yeah. Why is it undefined?
Student 1: It’s undefined because you can’t have a tangent line there because x is 0.
Student 3: So, this line is parallel? Nice, cool thanks for that.
Student 2: Nice. (Lesson TO4)

The students enjoyed the learning:

Student 2: This is really good. It’s like true mathematics, working out stuff.
Student 3: I feel very accomplished right now, like I have achieved something.
(Lesson TO4)

Tamara spoke further about collaboration at the post-observation interview:

Sometimes when you are constrained by time, I wouldn’t give them as much time to unpack it. But this is critical to everything else that comes. If you spend the time getting it now, when it comes to doing things like amplitude and translating, they get it because they have the basics. (Post TO4)

After 40 minutes of investigation, Tamara instructed students to graph the functions using Mathematica. Tamara introduced ideas about the period and amplitude of the circular functions and demonstrated transformations, sketching on the wall with a marker pen (Lesson TO4).
6.4.3.2 Notes

Student note taking, in various forms, was a feature of Tamara’s mathematics lessons. Sometimes Tamara provided catch-up notes for absent students and revision purposes, but said that she preferred note taking to take place in class with teacher explanations if needed (Post TO1).

Following the presentations in Lesson TO1, students were instructed to write their own notes. In Lesson TO3, Tamara projected notes in a Slideshow file on the board:

This is on the Mathematica file I sent you. What we are looking at is applications of maximum, minimum and rate of change problems. So, it’s really those in the text type of questions. And the definitions there, girls, are straight out of your textbook as well. (Lesson TO3)

In Lesson TO4, the students photographed the work they had written on the walls to copy into their notebooks. Then Tamara handed out sheets of notes “that we will stick in our books over the next couple of lessons” (Lesson TO4). She asked students to copy notes on terminology. Students spent the rest of the lesson cutting and pasting notes into their notebooks.

6.4.3.3 Worked examples

Tamara worked very few process examples on the board. One exception occurred in Lesson TO2 when Tamara had instructed students to begin working on a practice exercise but found some students could not cope. With a change of plan, Tamara altered the exercise to be slightly easier and worked a detailed demonstration of the process on the board. She also demonstrated a worked example in Lesson TO3, while the IT technicians were in the room.

Tamara’s demonstrations were interspersed with student interaction with the teacher and each other.

The students asked many questions:

Student 1: What does the h with the arrow mean?
Student 2: Do you just let h approach 0? (Lesson TO2)
argued with each other:

Student 1: 2x^2
Student 2: No.
Student 1: Yeah.
Student 2: No, undefined.
Student 1: Undefined?
Student 2: That’s an h after the x.
Student 1: You can’t do it. (Lesson TO2)

and provided direction for the teacher:

Tamara: If you are looking at this point here which is x = 1 and what is the y-value?
Student 1: One.
Tamara: If you drew the tangent line in at this point, what is the gradient of that line?
Student 1: One.
Tamara: One?
Student 1: Three, sorry, it’s three.
Student 2: If x is two?
Tamara: If x is two, it’s up here. Is the gradient line going to be deeper or less deep?
Student 2: Deeper.
Tamara: Ok so you would expect this to be?
Student 2: Greater. Would it be 12? (Lesson TO3)

On two occasions, Tamara asked Michaela to demonstrate an example on the board. Tamara used questioning to lead the student through to a solution:

Tamara: Basic graph, what are we looking at?
Michaela: Cubic.
Tamara: What does the plus 2 do?
Michaela: Move it up 2.
Tamara: Ok, good. What are the key things we need to know when graphing it? (Lesson TO3)
6.4.4 Application activities

6.4.4.1 Practice exercises

Much of Tamara’s observed lessons were devoted to practice exercises or problem-solving tasks. A student commented, “This is great, having time to do chapter work in class” (Lesson TO2), which raised a doubt about the regularity of this activity.

The students sat in circles at tables, helping each other. Students also sought help from their peers at other tables. Meanwhile, the teacher circled the room and assisted individuals or groups when students requested or when prompted. At times during practice exercises, Tamara questioned the class as a whole:

Tamara: What would be the key values that I want you to write on the graphs?
Students: Intercepts, turning points, translations.
Tamara: I am not even going to go through that with you because that is really revision. (Lesson TO1)

On another occasion,

Tamara: Did anyone use the shortcut rules I showed you in Term 2? If you need to revise let me know.
Student 1: I used two of them and not the third one.
Tamara: Did anyone use a different strategy?
Student 2: I used expanding two of them and then did the third one. (Lesson TO2)

Tamara did not answer all student questions:

Student: But is the gradient positive?
Tamara: I’m not going to answer. I’m going to let you work it out and then you can tell me next lesson, if that’s OK? Because remember I don’t always give you all the answers, because I want you to think about it. (Lesson TO2)

Practice exercises were characterised by student distraction. The room became very noisy with conversations about mathematics but also about other topics. The audio recording for lesson TO1 captured three students, including Michaela, in a 20-minute conversation about the local shopping centre. At one point, Tamara came to the table but none of the students sought help. Michaela diverted Tamara’s attention with a
question about the next SAC. When Tamara had left, the shopping conversation resumed. Finally, Michaela stopped the conversation and asked her classmates at the table, “Has anyone done question 1a?” (Lesson TO1).

The teacher was unaware of the shopping conversation and said that it was the first time those particular students had sat together, and some social bonding was happening (Post TO1). In future observation lessons, Tamara was vigilant in keeping Michaela, a Year 10 student, on task. One strategy was to ask her to demonstrate examples on the board as previously mentioned (Section 6.4.3.3).

Conversations picked up by the audio recording in Lesson TO2 during practice exercises were about the zodiac, personal relationships, chemistry, and “Have you heard the latest goss?” In this case, Tamara overheard: “Goss, I don’t want to know the gossip!” (Lesson TO2).

During practice exercises in Lesson TO4, most students spent their time sticking paper-based notes into their workbooks as they chatted. Tamara resorted to shushing: “Shhh, you have an exam in a couple of weeks” (Lesson TO4).

6.4.4.2 Problem-solving activity

Lesson TO3 was an exception to student distraction. When the two technicians were in the room for about 20 minutes, the students were quiet and attentive to Tamara who was working at the board. After the technicians had left, the students remained quiet and focused on completing a problem-solving task taken from the online text (Lesson TO3).

6.4.5 Assessment focus

Tamara’s observation lessons were interspersed with conversations about assessment. The race activity in Lesson TO1 was followed by a discussion about SAC marks. Tamara promised to reveal marks at the end of the lesson, after she had checked with the other teachers. She sent an email to Sarah and Alan during the lesson (Lesson TO1).
Students asked SAC-related questions:

Student: So, on the SAC where you are not allowed to use any technology, would we have to do a quartic of a number?
Tamara: You mean like 2 to the power of 4?
Student: Yeah, like that. (Lesson TO2)

Towards the end of the lesson, the students mentioned SAC results again. Tamara responded by recording results and SAC solutions in the intranet assessment-tracking module. Tamara encouraged her students about their SAC results: “When I give you back the SAC, that’s the powerful thing. You’ll know what things you know and you’ll know what things to revise” (Lesson TO2).

As she worked through example demonstrations on the board in Lesson TO3, Tamara referred to tech-free and tech-active assessment requirements of the VCE curriculum. Her statements were detailed and specific:

Tamara: Obviously, if you were not going to do a tech-active SAC, I wouldn’t ask you to graph it. But I might ask you what is the absolute maximum of the function?

. . . If it’s a tech-active question, you can graph it using Mathematica. So, definition wise you need to have absolute maximum and absolute minimum written down. But obviously you can graph it and then you can quickly substitute in the maximum and minimum, as well as using Mathematica.

. . . So obviously, if this was a tech-active question you have this as your function but then you do the derivative of it on Mathematica.

Student: Do they do derivatives on tech-free exams? (Lesson TO3)

Tamara returned online assessment SACs to students: “You have your SAC. I have just emailed it back to you. I have also sent you a worked solution as well” (Lesson TO4).

She explained her marking to one student: “Yes. When you changed it from hours to minutes but not minutes to seconds. I did not deduct a mark for that”. Tamara said that she thought the mistake was due to an online scrolling error and gave the student the benefit of the doubt (Lesson TO4).
6.5 Digital Technology Use

6.5.1 Generic digital technologies

6.5.1.1 Assessment-tracking module

With a change of plan in Lesson TO2, Tamara used the intranet’s assessment-tracking module to return SAC results to students: “SAC results. Do you know what I might do? I am going to put them in the intranet” (Lesson TO2). Tamara was efficient and effective in using the application, but a lack of confidence was evident when she said to me, as an aside, “I just have to create a new assessment. As you can see, I haven’t used it much. I have used it once or twice before, just this term. If I can get the intranet to work!” (Lesson TO2). Tamara took less than two minutes to create the assessment space, add the marks, and message students.

Tamara used the application again during Lesson TO4. She commented on the assessment tracking and the duplication of effort in entering marks into yet another application: “It’s still double handling. I would wait so that this thing goes straight into their reports. I want somebody to do that for me. That’s the ideal” (Field Notes TO4).

6.5.2 Mathematics-specific digital technologies

6.5.2.1 Mathematica

Tamara was new to Mathematica but came across as competent and confident on the few occasions she used it (Field Notes TO2). She had found Sarah’s glossary of Mathematica commands to be indispensable (Post TO2). Tamara said her confidence with Mathematica in general was still developing, and that she relied on the Year 11 students for help with Mathematica in the classroom (Post TO1).

Tamara continually referred to when students were to use Mathematica or not:

- We won’t be using much technology and then we’ll be using Mathematica to find the gradient. (Lesson TO2)

- We know \( F(x) = x^3 \) what is \( F(x+h) \), without using Mathematica? (Lesson TO2)

- We’ll do notes and I’ll get you to use Mathematica. (Lesson TO3)
If it’s a tech-active question, you can graph it using Mathematica. (Lesson TO3)

It might be good while you are starting if you can do that on Mathematica as well. (Lesson TO3)

Sometimes the students wished to know:

Tamara: Could I get you to sketch this graph?
Student: Using Mathematica or by hand?
Tamara: By hand, and then we’ll talk about it. And we’ll talk about it in terms of using Mathematica to solve it as well. (Lesson TO3)

Tamara expressed thoughts about Mathematica in observed lessons, including benefits and nonbenefits:

Mathematica is good for graphing. (Lesson TO1)

Ladies once you have got an answer you can check it using Mathematica. It is important that you can do it by hand and on Mathematica as well. (Lesson TO2)

If you want to cheat, check with Mathematica, if you are really worried. Come and draw it, take a risk! (Lesson TO2)

Most of your computers are back and you can start playing with Mathematica. (Lesson TO3)

When asked to comment on the value of Mathematica, Tamara said,

Its value is in helping to solve problems. It’s a more efficient and effective way. I would have used it more frequently if there was more time. Ideally, I would have gone through modelling it a little more. You have to think on your feet and I’m relearning the maths as I go and dealing with the technology. (Post TO3)

When asked how Mathematica compared to the CAS calculator, Tamara replied, “I think that Mathematica is a much more useful teaching and learning tool than a CAS calculator. As a teacher the misconceptions a student has made are much easier to see as the file shows all the calculations” (Post TO3).
6.5.2.2 Slideshow

Tamara was also new to the concept of Slideshow files. She said she had liaised with a colleague, Alan, about using his Slideshow files but adapted them to “her own style and priorities” (Post TO1). Alan’s topic-based Slideshow files contained relevant Mathematica commands and practice exercises to be completed. Tamara added notes and definitions (Post TO1).

Tamara was confident and competent in using Slideshow files in observed lessons (Field Notes TO1). She said that she could do everything required to use Slideshow with a bit of practice beforehand. She regarded her files as most valuable for absentee students and for revision purposes. By the end of the year, Tamara said her use of Slideshows was well developed but not yet established in her lessons (Post TO3).

6.5.2.3 Calculators

The VCE teachers did not want me to observe classes on the topic of Probability and Statistics because they would only be using calculators (Intentions AO3). This led to a question for all the teachers about the value of calculators. Tamara gave a formal reply by email, “In the modern maths classroom calculators have an integral role to assist in calculations and in relation to VCE there is a specific outcome related to the effective use of technology” (Post TO1).

Tamara was the only participant teacher seen using a scientific calculator in a lesson. When she asked students to graph circular functions, she gave specific instructions: “Plot the trig functions using exact values and don’t use any digital technology” (Lesson TO4). Tamara ended up using a calculator on two occasions on behalf of the students. She calculated the approximate value of $\frac{\sqrt{3}}{2}$ and converted degrees to radians when requested (Field Notes TO4).

6.5.2.4 YouTube clips

Tamara mentioned the *Mean Girls* video clip in Lesson TO2:

Tamara: Has anyone seen *Mean Girls*?
Student: Yeah. Are we going to watch it?
Tamara: We’ll get to that in a couple of lessons time. I’m very excited about it. (Lesson TO2)
A few minutes later, when describing the slant on the tangent at a point, Tamara back-referenced the *I Will Derive* clip that had been seen earlier: “. . . or the gradient of the tangent as we saw in that video” (Lesson TO2). In commenting on YouTube clips, Tamara thought that the clips would be “something for the girls to relate to and they will remember about limits” (Post TO2).

6.5.2.5 *Wolfram Demonstration Project*

Towards the end of Lesson TO3, Tamara featured a Wolfram Demonstration Project (Wolfram, 2015), *Spinning Out Sine and Cosine*, to demonstrate the relationship between the unit circle and the sine and cosine graphs. Tamara started out saying, “I will send you a copy of the file in a minute and you can play around with it”. Then she was distracted and had an in-the-moment change of mind: “I’m going to show you the demo file and I will send it to you as well” (Lesson TO3).

Tamara projected the file onto the board and showed the students its features. The demonstration by the teacher covered every angle while the students watched on. The students were not observed playing with the application in class time (Lesson O3).

6.5.2.6 *Concept videos*

When asked about supporting her absent students, Tamara said that she made short videos of the concept activity and/or worked examples, using flipcharts to give to students: “I’ve done it before and so does Sarah. I might use one of hers. Then I email it with the notes. Sometimes the notes are specifically for the students who are absent, not for the students in class” (Lesson TO4).

The videos were stored in the intranet’s LMS and accessible to students. Tamara’s guiding questions for making a video were “Are students missing?” “Is there a video on the topic already?” “Do I have time?” (Post TO4).

6.5.3 *VCCA Mathematica trial of online assessment*

The impending experiment of online assessment for VCE Unit 1–2 Mathematical Methods (CAS) students caused great consternation for the VCE teachers, judging from their huddled discussions in the staff room.

The school had participated in an official VCAA Mathematica trial of online assessment (VCAA, 2010) for the Year 12 subject VCE Units 3–4 Mathematical
Methods (CAS) Part B examinations. A Slideshow presentation file was used as the online examination platform. Even though the official trial had ended, and there had been little progress on implementation of online examination for a wider audience, with the support of the VCAA, the school had continued online testing at Year 12 level. Alan, Tamara, and Sarah had decided during Semester 1 that, for the first time, Years 10 and 11 mathematics students would sit online assessment tasks (tests, SACs, and examinations) for the VCE Unit 1–2 Mathematical Methods subject. As Tamara said, “We felt that the drive for online examinations would not go away” (Post TO3).

The school technicians were given the task of finding a solution to running transparent, accountable assessment tasks on the students’ personal laptops. Their solution emerged towards the end of the year (Post TO3). After much investigation, the technicians had developed a boot script that restricted access to the internet and all software applications on the laptop. The boot script was to be provided on a USB key with copies of the Mathematica application and of the examination questions in a Slideshow file. In Lesson TO3, the technicians had come into the class to change students’ laptop settings to enable the individual laptops to boot from a USB key.

In the lesson, Tamara explained the process to the students:

OK, so what will happen is you’ll have to bring your computer to the class for the SAC and you will have a USB key which you will plug into it. The reason behind it is that you save your document to your USB key, in that SAC and then I’ll mark it, OK . . . my aim is to get all of you used to it . . . The other thing is you will answer questions in a [Slideshow] file, which has to be on the USB key but we’ll go through that. (Lesson TO3)

The students asked questions. The first was about taking digital notes into the examination on a USB key. Tamara replied, “Do you have two USB ports?” Some students had not brought their laptops to class or to school and complained. Tamara said, “No I made the decision to do it in class so that I would know all the computers had been done and we were ready for the SAC”. The next question was about how students might get their laptops updated. “Leave it with me” was Tamara’s reply (Lesson TO3).

When the technicians arrived in TO3, Tamara went into a flurry. She spoke quickly, loudly, and repeated herself:
So just for a sec, if you have your computer here, close the file, shut down your computer. Write your name on a sticky note I have provided here and take it up the back. Save any work, shut down and write your name on a sticky note. Save your work, put the computer up the back. (Lesson TO3)

Tamara spoke with the technicians about USB keys and arranging for absent students and absent laptops to be updated (Field Notes TO3).

At a later date Tamara was asked about the success of the online SACs:

The SACs on Mathematica were successful due to the support from IT. Having individual USB keys solved the possible issue of sharing resources. The students had some problem with scrolling and losing the question, so it was good to have printed copies of the SAC to read. (Post TO4)

6.6 Conclusion

The data in this chapter represent some of Tamara’s intentions, actions, and sayings collected before, during, or after four observation lessons. In Chapter 9, the results of data analysis in the form of Tamara’s beliefs related to mathematics, mathematics education, and the use of digital technology are described.

The next chapter presents data from the third VCE teacher. Alan was more experienced than Sarah and Tamara. He had been using Mathematica software for more than five years, and it was interesting to observe the way he used it in his lessons. Alan said that he loved Mathematica, and he used it often.

I discovered a latent backhand loop left over from my youth as well. It just needed jiggling into action. This was enough to continue beating some opponents, while others changed tactics again—to heavy backspin, no spin, long and short shots, across court angles and down the line of play.
CHAPTER 7

CASE ALAN DATA COLLECTION

With each new challenge, I went back to my coach for expert advice. He taught me techniques to force the opposition to play my game, not theirs. I learnt to put sidespin on the ball so that the returned ball would automatically carry into the path of my forehand. Now I was playing routines with multiple purposes: sidespin to force the forehand, stinging drive to win the point. I became quite skilled.

7.1 Introduction

Sarah and Tamara shared the VCE Unit 1–2 Mathematical Methods (CAS) subject with a third participant teacher, Alan, who had taught variations of this subject for 17 years. Alan differed from his colleagues in favouring inquiry and discovery learning techniques. Chapter 7 comprises data collected from observations of Alan’s lesson delivery and digital technology use in the classroom, discussed at post-lesson interviews and from his story of becoming a mathematics teacher.

Alan taught in only three of his four observation lessons. During Lesson AO1, he mentored Giulia, a student teacher on a preservice teaching round at the school. The lesson was marred by an overnight power failure, and Alan’s reaction to the problem proved a valuable source of data for the study. Alan also provided a copy of his comments on Giulia’s teaching and these, in turn, revealed much about his approach to teaching and learning.

The data described in this chapter were chosen as indicative of Alan’s pedagogical approaches, the uncertainty he faced with digital technology use, and his personal experiences with mathematics education.

7.2 Alan’s Story

Alan related that he had learned to love mathematics at primary school where, after an “ordinary start”, he became very good. His parents were supportive and happy that
he could excel at something—not sport, not music, not anything else. By high school, he was in the advanced mathematics stream. Alan said he liked his mathematics teachers but none were particularly influential. He found he could identify key elements, understand them, and readily explain them to his classmates. From Year 9 onwards, his peers were paying him to help them with their mathematics.

At university, Alan said he tried engineering for a year but only liked the mathematics. He transferred and completed a Bachelor of Science degree with honours in statistics. He spent the next four years number crunching in trade and financial administration. He was not particularly happy. Education beckoned.

Acting on his mother’s advice, he enrolled in a Diploma in Education. His impression: “University doesn’t prepare you for teaching!” (Alan Story). He said that he did not relate to pedagogical theory, just the practice, and he longed to be let loose in the classroom. During his first preservice teaching round, the mathematics teacher was absent and he took over the classes with great success; apparently, the absent teacher was so boring. Alan began his teaching profession in 1998 and since then has taught at three different all-girl schools. At the time of this study, he had been at the participant school for 14 years. He was the senior mathematics teacher and had responsibility for the school’s timetable.

Alan was passionate about teaching mathematics and especially about teaching mathematics to girls. He had found that female students lacked confidence, and very few students expected to do well. He wanted the students to learn to love mathematics, to be challenged in their thinking, and to choose to be in his class. He wanted them to acquire a greater depth of understanding and to experience more success.

In commenting on the curriculum and its impact on his teaching, Alan said that over the years, there had been different advancements, and that it was important to keep up. The VCE Study Design provided dot points of the content you had to get through. He thought in general that there was “too much emphasis on getting results and not enough on learning mathematics” (Alan Story).

Growing up, Alan’s exposure to digital technology had been more extensive than that of his female colleagues. In Grade 4, his father gave him a musical digital watch that made him very popular at school. Alan was able to reel off a detailed list of digital
games and toys that followed. At high school, there was a computer laboratory of Apple 2E computers, and he remembered learning programming, word processing, Minitab, and Excel.

As part of his Diploma in Education, he was exposed to the internet and email, webpages, the graphing calculator TI-83, and Geometer Sketchpad, which he still enjoyed using in the classroom. In the past 10 years, there had been huge digital technology advancements at the participant school. To Alan, as he related, the technology was so commonplace, he found it hard to recall a time when it was not around.

7.3 Alan’s Classroom Field

7.3.1 Students

Alan had 12 Year 11 students in his observation class. These students had chosen traditional hard-science subjects, such as physics, chemistry, and specialist mathematics, and would be considered serious about their scientific and mathematical studies.

Alan was a quiet, calm, and patient teacher who used strategies to “care” for his female students (Alan Story). He was observed being sensitive about questioning individual students in class who were not keen to answer publicly, giving one-on-one support to each student in class following the return of an assessment task and making time for students outside of class: “Give me a ring if you have any problems” (Lesson AO3).

Alan’s students were extremely quiet while he was in charge. The audio recordings of Alan’s observed lessons picked up lengthy silences broken occasionally by muted whisperings of the teacher or students.

7.3.2 Classroom

Alan’s students sat at tables arranged in a U-shape around the sides and back of the room, facing an interactive whiteboard (“the board”) and a separate whiteboard. This was Alan’s preferred arrangement for all his lessons. Alan mainly stood in the middle of the room facing the students, occasionally at the board, or walking around the U monitoring student progress (Field Notes AO1).
7.3.3 Digital tools

Alan’s classroom had access to generic digital technologies such as wi-fi, school networks, the school’s intranet and the internet for the online textbook and email. The board at the front of the classroom was connected to an Apple agent. Alan was the only teacher in the school using a Windows-based personal computer (PC). The laptop held ActivInspire software to run the board, and in every lesson, Alan unhooked the Apple agent and hooked his PC to the board. Alan had not converted to the school’s standard Apple platform when it had been introduced six years before because as part of his professional role he used a legacy application to generate the school’s timetable that only ran on the Microsoft Windows operating system. Alan’s students used Apple notebooks.

7.4 Professional Practice

7.4.1 Intentions

Alan did not provide learning or digital intentions for any of his lessons, and insight into lesson intentions and planning were revealed as the lesson unfolded. Alan’s content learning intentions were remainder theory, logarithmic functions, gradient of a curve at a point, and rates of change for Observation Lessons AO1 to AO4.

Alan’s lesson delivery incorporated many of the same elements as Tamara and Sarah’s, but there was no discernible routine. It seemed that each lesson proceeded from where the previous lesson had left finished. His final observed lesson was distinctive for being a last-minute change of plan comprising a second treatment of the kinemetric concept that had been introduced in the lesson before (Lesson AO4).

The digital technology used in Alan’s observed lessons included his laptop, the board, Mathematica and Slideshow, attendance recording, student laptops, flipchart used by Giulia in AO1, YouTube clips, email, and an online textbook. Despite saying, “No technology today” (Lesson AO4), digital technology was used in every one of Alan’s lessons.
7.4.2 Lesson bookend routines

7.4.2.1 Start routine

The introduction to Lesson AO1 was unusual. Alan was to oversee a preservice teacher, Giulia, teaching her first lesson. Giulia was unfamiliar with the board’s Apple operating system and the plan had been to download the ActivInspire software to Giulia’s Windows PC prior to the lesson. However, overnight there had been a power failure, and there was no time before the lesson to download the software.

When the lesson began, the power and digital network facilities had been fully restored, but the board was down. Neither Alan nor Giulia knew how to use the Apple agent to start the board. Eventually, a student stepped forward and solved the problem for the teachers. However, Giulia struggled with the Apple technology for the entire lesson. Alan’s PC had the necessary software, and he could have swapped PCs with Giulia, using her PC to write his notes about her teaching: “I didn’t think of that!” he said when asked (Post AO1).

Alan began the second observation lesson by taking attendance and starting up the board using his PC. He reminded students that an assessment task was looming. He mentioned that he had emailed revision questions for the SAC and a Slideshow file for the new topic on logarithms. He said he was holding back on the revision solution so that students “could have a go at them” (Lesson AO2).

Alan decided to show a YouTube clip, I Will Derive, at the beginning of Lesson AO3. When I walked into the classroom, he said, “How do you get the sound? Here is the perfect example of taking a risk with technology” (Intentions AO3). I helped out, while the gathering students watched on in silence. When the clip was playing, he recorded attendance using a dual monitor function on his PC. At the end of the clip, there was no reference to the clip and Alan started the lesson with

Alan: So, how’s your deriving going, “hey hey”? [quoting the clip]
Student: I worry about how you spend your spare time.
Alan: I want to be a modern teacher. (Lesson AO3)

Before Lesson AO4, Alan had spoken to students at recess and, acting on their confusion about the previous lesson, had determined that he would tackle the concept
again in a different way. At the beginning of the lesson, after explaining himself, he launched straight into a concept understanding activity.

7.4.2.2  Homework

Alan’s approach to homework was evidently flexible. In Lesson AO2 when the bell rang, Alan set homework: “On those exercises keep going” (Lesson AO2). Alan set a flipped classroom concept activity for homework in Lesson AO4. He emailed students the details in class: “There is a link to watch. There are some questions. That is the focus of your homework” (Lesson AO4). This task was set a week before the class was to begin the topic of circular functions. Homework in Lesson AO3 was SAC revision. Alan reviewed homework activities in Lesson AO2.

7.4.2.3  Concept activities

Alan’s primary focus in observed lessons was on concept activities (Appendix 9). Alan introduced logarithmic functions by way of graphing them in Lesson AO2. The details are outlined here as evidence of the variety of learning techniques he used in a concept activity. “I want to look at some graphing today, and we have done graphing of the exponentials, so I want to look at graphing log functions” (Lesson AO2).

Step 1 was a general question-and-answer type recall of the different functions and features that the class had recently graphed. Then a direct question to Madison was posed:

Alan: Madison, what form could the log function take?
Madison: \( y = \log_2 x \)
Alan: Good job, \( y = \log_2 (x) \).
Student 2: How does she know that?
Alan: She reads ahead. (Lesson AO2)

Alan used his knowledge of Madison to his advantage. He had his function pinned down by an enthusiastic student. He had volunteered nothing at this point except perhaps the hint of speaking about exponentials and logarithms in the same sentence.

Step 2 was an instruction for students to think and talk to their neighbours about what the log function graph might look like “without using Mathematica, without looking at the textbook, without asking the teacher” (Lesson AO2). During this time, he circled the room, monitoring student participation and progress.
Step 3 was unpacking the graph’s features. He directed questions to students:

Alan: Laura, tell me something.
Laura: Would it be the inverse of \(2^x\)?
Alan: Interesting, hold that thought. (Lesson AO2)

He reinforced the use of logic:

Student: An asymptote?
Alan: Why would you say that?
Student: It’s related to \(2^x\) and \(2^x\) has an asymptote.
Alan: If it’s related to this, this has an asymptote and if it’s related to that, then that should have an asymptote as well. Sounds logical. (Lesson AO2)

He reinforced the use of correct mathematical language:

Alan: Asymptote, when you say “on x”?
Student: \(x = \text{something}\)? (Lesson AO2)

Alan used Mathematica to generate \(y\)-values of the log function using particular \(x\)-values. He prompted the class for the Mathematica command and then values of \(x\) to try. He asked individuals to predict the answers:

Alan: For \(x = 16\) that is \(\log_2(16)\), Alexia what do you think?
Alexia: 4
Alan: 4 great, say why.
Alexia: 2 raised to the power of 4 = 16. (Lesson AO2)

A discussion followed to unravel function features:

Alan: It has to be positive but it is not allowed to be 0 and it’s not allowed to be negative. Yep, does that tell you something about the asymptote?
Student: 0
Alan: Zero right. (Lesson AO2)

He followed up on students’ prior comments:

Alan: What were you saying before about inverses?
Laura: That \(\log_2(x)\) is the inverse of \(2^x\)
Alan: Your instinct was correct. Everyone get their finger in the air or on the page and draw the shape of \(y = 2^x\). Draw the shape with your finger of \(y = 2^x\). You want the inverse of that shape. (Lesson AO2)
A discussion followed on the characteristics of graphing inverse functions, as he wrote a comparison of the features of \( y = 2^x \) and \( y = \log_2(x) \) on the board. He had reached his concluding idea:

Alan: They are the three important points I was after. Swap \( x \) and \( y \), swap domain/range, reflect the graph on the line \( y = x \). (Lesson AO2)

Step 4 of the process was to unravel the logarithmic function transformations using Mathematica. He challenged Ashley:

Alan: Here’s a transformation: \( y = \log_2(x + 1) \). Ashley can you describe the transformation?

Ashley: The graph moves up by 1.

Alan: Moves up by 1?

Ashley: It moves left by 1.

Alan: Pardon?

Ashley: Left, \( x \) plus 1. It would move left by 1.

Alan: I’m glad you are thinking. I deliberately wanted you to. (Lesson AO2)

Only then did he write the function on the board with brackets carefully located. A discussion about brackets ensued.

Alan used Mathematica profusely. These occasions included expanding the \( x \)-scale to \( x = 50,000 \) when looking at a horizontal asymptote, plotting a function and its inverse on a single set of axes, experimental computations with multiple variable values, and demonstrating multiple graphical transformations.

The concept activity in Lesson AO3 was an analysis of a generic cubic function graph that Alan had drawn on the whiteboard. Critical points were labelled a, b, c, d, and e: “I want you to explore this graph. Where is the function and its derivative equal to zero, greater than zero, and less than zero? I would encourage you to use set notation where appropriate” (Lesson AO3).

After the students had spent 10 minutes sorting out the six parts of the question, the class deconstructed the graph together, with Alan writing down the answers in the form of a table, which was the learning goal for the lesson (Lesson AO3).

Alan then gave students an example and asked students to graph the function’s derivative: “Get a pencil and sketch”. He generated a graph of the example function using Mathematica and back-referenced the clip from the beginning of the lesson: “I’ll
get my orange pen out. Where is the gradient = 0? Follow the line just like on the video, follow the orange pen on the black line” (Lesson AO3).

In Lesson AO4, Alan addressed rates of change for a second time in response to students’ expressed concerns. Using nondigital technology of a toy resistance car and a biro, numerous car zooms in a variety of directions and pen tosses were graphed on the whiteboard: displacement, velocity, and acceleration. The students became very excited and noisy, thinking up variations on direction and speed and how they should be graphed. All the while Alan was tossing, zooming, and sketching according to their instructions.

At one stage, during the demonstration, a student asked a question about determining the positive direction in rates of change problems:

Student: I am struggling to understand how to apply that into an equation because we’re making the gravity go in any direction it wants to go. So, in the equation how do we know the direction it wants to go?
Alan: Good question. So if we have a displacement equation. We would need to find the second derivative to look at the function for acceleration. It’s as simple as that.
Student: OK. (Lesson AO4)

Not okay, as it seemed the student did not understand the answer the first time and she asked again 20 minutes later:

Student: How can you know which direction is positive?
Alan: So, in the question it has to be defined, which direction is positive and which direction is negative. If I say something is thrown up into the air, I need to tell you if up is positive or negative.
Student: If it doesn’t?
Alan: It will, exactly. Sometimes in exercises it doesn’t do that.
Student: It doesn’t.
Alan: So, we have to let you know to the right is positive, up is positive, to the left is negative. (Lesson AO4)

Alan has related these two questions first to the speedy process of finding the second derivative and second to the assessment conditions, rather than just answering the questions. The student’s questions challenged Alan’s usual reasoning, and in the moment, he was unable to call to mind the mathematical context and reverted to
answering the question in terms of what needed to be known for the assessment context.

When asked at interview about a second challenging question, Alan replied, “I never studied physics” (Post AO4). Alan agreed that his teaching techniques were “pretty much” inquiry-based and discovery learning techniques (Post AO1).

7.4.2.4 Notes

Alan’s approach to notes was summarised in his comments for Giulia when she explained the remainder theory by working her way through an example:

There was a golden moment lost when deriving the remainder theorem. Don’t lose sight of the main goal of the lesson, which in this case is the theorem. It needs to be explicitly stated, written on the board and highlighted. (Alan’s Comments AO1)

Alan did not say “copy this down” to his students when his summary was written on the board in any of the observed lessons. But he did say, “These are the three important things I was after” (Lesson AO2), which was enough to have the students making notes or at least checking their work against the summary.

7.4.3 Concept application activities

7.4.3.1 Practice exercises

Giulia set practice exercises in Lesson AO1. During this time, she became engaged helping an individual student and the class became very noisy and distracted. Alan commented,

When teaching you need to have eyes everywhere, particularly if you have some naughty kids in the class. When explaining to Tamsyn you were positioned well—facing the rest of the class—but did you keep an eye on the others to see if they are engaged? You are spending way too much time with her—“See how you go and I’ll come back to you later”. (Alan’s Comments AO1)

This comment is mentioned because the class was not noisy or distracted or naughty when Alan was teaching. When the students worked on practice exercises in Lesson AO2, they did so in silence. When asked about the silence and whether the
students were intimidated by him, Alan said, “No, it’s just this cohort. There’s only one lively one that gets my humour” (Lesson AO2).

At the request of students, Alan worked through problematic homework exercises in Lesson AO3. He worked the first exercise on the whiteboard. He did not just read out the problem and do it, he analysed it aloud and asked the students to translate his thinking into maths:

Alan:

Sketch the graph of \( f(x) = \frac{1}{x^2} \) which is our beloved truncers.

Looking at that. “Let P be the point F(1) and Q be the point F(1+h)”. What does that mean? What can I do with that? What can I do with anything?

Student: Make a division to a multiplication by that [pointing].

Alan: Can you tell me the end result without doing it mathematically? By doing it visually?

Student: No.

Alan: That’s the theory we did the other day. They put it in an application like this one. (Lesson AO2)

Alan demonstrated manual computations but did not repeat the same process a second time. Instead, he used Mathematica. The same function as above, in a different format, was found in a second question:

Alan: Anything else came up?

Student 1: Number 5.

Alan: Find the coordinates of the points on the curve of the equation \( F(x) = x^2 \), it’s the same function, same function, with the gradient 16 and gradient -16. What is my command for Mathematica to solve that?

Student 2: \( F' = \)

Student 3: Solve. (Lesson AO3)

Having explained where the solution to a homework problem would come from, Alan asked Alison for the appropriate Mathematica command to continue. Using the student’s suggestion resulted in three answers—one real and two imaginaries:

Alan: What does that mean? Sometimes Mathematica throws up things like this. What would you do at this point Alison?

Alison: Take the Reals only. (Lesson AO3)
7.4.3.2 Problem-solving activities

The final 30 minutes of Lesson AO4 was spent on the Ant Problem a problem-solving activity. The students worked individually in silence, except for an occasional cough or tiny murmur from student–teacher interactions. Eventually, at the request of students, Alan demonstrated Part F on the board using Mathematica for graphing. As he went, Alan unpacked the reasoning behind formulating the answer:

Part F. The question was, what value of \( t \) is acceleration negative? Probably the easiest way to do that is to graph acceleration to see what it looks like. And the acceleration is positive, at \( t = 3 \) it is briefly 0, then it’s negative. Now we have a domain restriction for this problem. We have a domain of \( t \) from 0 to 6. And at \( t = 3 \) it’s 0. (Lesson AO4)

7.4.4 Assessment focus

Alan was very concerned about concept understanding and relatively unconcerned about assessment tasks. At the most, Alan reminded the students about upcoming SACs and promised to send revision material: “I’m also going to email you last year’s SAC” (Lesson AO2, AO4).

7.4.5 Digital technology use

7.4.5.1 Attendance recording

Alan recorded attendance in every lesson without fuss.

7.4.5.2 The board

Giulia’s lesson was disrupted by an anxious start and ongoing difficulties using the flipcharts and Mathematica, both of which were new to her. “Need to sort the flipchart problem in order to keep the lesson moving” (Alan’s Comments AO1). When Mathematica was needed, Giulia asked a student to do it: “Good idea to ask Ashley to do the Mathematica entry” (Alan’s Comments AO1).

Alan actively promoted digital technology use four times in his comments to Giulia such as, “You are writing out the next example on the board, Mathematica would’ve also worked well” and “A flipchart would’ve helped here—enabling you to stay at the back of the class” (Alan’s Comments AO1).
I was surprised by the contradiction between Alan’s helplessness with solving the PC issue and his promotion of Mathematica and flipcharts to Giulia in his comments. Alan was fully at ease in the regular set-up of his PC running the board, and he used Mathematica on the board in every lesson observed (Field Notes).

7.4.5.3 Email

Alan used email in and out of lessons to send resources and Slideshow files to his students. The second half of Lesson AO4 was devoted to a worded problem: “I am going to send you a single problem, the Ant Problem. Having a few email issues.” (Lesson AO4). He became flustered, but there was no real problem.

7.4.5.4 Mathematica

With more than five years’ experience, Alan’s use of Mathematica was skilful, confident, and controlled. Alan said he thought Mathematica was great. In reference to the need to sit both tech-free and tech-active assessments, he said, “I don’t know why they [VCAA] just don’t use it [Mathematica] all the time and use the processes learnt to solve more complex problems” (Post AO1).

Alan used Mathematica and manual computations and plots almost equally and without comment. However, when launching the students into solving the Ant Problem, he said, “We are going to use Mathematica” (Lesson AO4). The VCE Study Design had indicated the use of the CAS application specifically for problem-solving.

Alan relied on the students when his memory of commands drew a blank. After distorting the scale, he could not remember the command to make the $x$- and $y$-axes equal again:

Alan: The scale is different. Do you remember the commands to make the scales the same? I actually don’t remember so I’m asking you.

Student: Aspect ratio. (Lesson AO2)

7.4.5.5 Mathematica Slideshow

The school’s principal was influential in the choice of Mathematica as the school’s CAS technology. In general, she had challenged the teachers to find savings to justify the additional cost of student laptops. The mathematics teachers discovered the VCAA
Mathematica Trial of Online Examination in 2009, which included a site licence for Mathematica. Mathematica ran on laptops and saved parents the expense of an individual handheld CAS calculator (Post AO1).

Alan had been part of the implementation of Mathematica and the trial since its inception at the school. The trial had targeted the VCE Unit 3–4 Mathematical Methods (CAS) subject with the VCAA providing external online examinations on the presentation platform, Mathematica Slideshow. The Slideshow module provided the facility of two modes, plain text for questions and manipulate/plot modes for online computations and plots. The official trial ceased after three years, but the VCAA continued to provide external online examinations to the school. Alan said the school continued to use Mathematica and online examination because online examination was the way of the future (Post AO1).

When asked about using Slideshow for students’ notes, Alan acknowledged that students used their handwritten notes as the major source of information to take into Part B assessment tasks. The students had found it was too tedious to type mathematical symbolism into Slideshow. He gave Slideshow files to his students as a secondary source of information for assessment tasks with a particular purpose in mind: “Slideshow files are used generally to ensure students have the correct syntax for the Mathematica commands” (Post AO3).

7.4.5.6 YouTube clips

Alan said that he had never shown a YouTube clip prior to Lesson AO3: “When you are coming, I feel the need to use more technology” (Intentions AO3). He also said that he was somewhat confident in showing the clip “provided that the technology works” (Post AO3).

After showing the I Will Derive clip, Alan back-referenced it three times in Lessons AO3 and AO4. He danced an orange pen along the plot line of a function graph to show the tangent at a point on the line in the same way as in the clip. Alan had shown a second YouTube clip, Mean Girls, to the class in a subsequent lesson that was not observed. When asked about the importance of the clips to learning he said that the I Will Derive clip was not important but Mean Girls was:
Mean Girls was very effective as it made a connection between something familiar to the students and what is a fairly dull, abstract mathematical concept. I do think that YouTube clips were very engaging for the students. They animated my class. (Post AO4)

Alan said that he would use the two clips in future. He had considered using a YouTube clip for Lesson AO4 but could not find a suitable one in the short time he had had to look for it. Sarah had a video on quadratic kinemetric, but it was not quite right for Alan’s purpose of demonstrating linear examples. By way of explanation, Alan said,

The main thing is that when I prepare to teach, all that I do is in my head. I don’t use notes. You may have noticed. So, to add additional technology, I would have to think I needed it and then find it. (Post AO4)

7.5 Conclusion

The data described in this chapter represent a selection of Alan’s intentions, actions, and statements collected before, during, or after observation lessons. The analysis of this data for Alan’s underlying beliefs about mathematics pedagogy and use of digital technology is found in Chapter 9.

Chapter 8 looks at the data acquired from Year 7 lesson observations. The three Year 7 teacher participants were blocked on to teach at the same time, and they were able to combine their classes for team teaching and a collaborative learning environment. They also experimented with a software application, Maths Pathway, to assist in skills and knowledge learning in the combined class environment. Neither the collaborative learning environment nor Maths Pathway experiment went exactly as planned. Chapter 8 addresses the struggles that the teachers encountered with both and identifies the team’s preferred teaching approaches.

I had learnt how table tennis shots became connected into a routine and automated with practice. I applied the learning to the connection of mathematical skills to make a mathematical procedure such as the one needed to solve simultaneous equations. The mathematics process was memorised through repetitious application.
CHAPTER 8
CASE Y7 TEAM DATA COLLECTION

For something different, I watched a YouTube clip of Re-Design My Brain (2013), which I had previously seen on television. In the clip, former Australian Olympic representative table tennis players, William Henzell and Trevor Brown, used table tennis to increase Todd Samson’s visual processing speed. The players demonstrated the unconscious selection of visual cues to anticipate the speed, direction, and spin on the ball to stimulate the most effective return. A new awareness of cueing led to a greater ability to read my opponents’ serves and shots. I also noticed that the opposition were reading my cues for their own benefit.

8.1 Introduction

The Year 7 observation data were somewhat different from the VCE teachers’ data. In the year of the data collection, 2015, the Year 7 teachers were challenged with several changes. The Year 7 learning space had been renovated to become a collaborative open plan learning space. The expectation of the school’s leadership was that the Year 7 mathematics teachers would team teach, promoting differentiated levels of study and collaborative learning experiences for the students. In addition, Year 7 students were assigned an Apple iPad instead of the laptop that had been the standard digital device for the previous six years.

Leadership had allocated the Year 7 mathematics team, Luci, Bec, and Helen, an open classroom area and common time slots for their lessons. “We were told that we had to do it” (Helen, Final Interview).

The collective data for the Year 7 team, under pressure to change in a number of ways, proved to be most enlightening, although fewer data were collected for individual participants. At times, Helen removed her class from the combined group, and I needed to split observation time between two separated areas. Then Luci was
unable to continue her participation and was replaced by Catherine, who was not a participant in the study. Overall, I observed five Year 7 mathematics lessons to make up for the reduced individual observation time. I concluded that the Year 7 teachers had agreed to teach in a singular way: same curriculum, delivery, timing, resources, homework, assessment tasks, and teaching style. The teachers met each fortnight to discuss issues and coordinate the next cycle of lessons (Bec, Post Y7O2).

The team had decided to trial an online application, Maths Pathway, “to help us with the open plan and the differentiated learning” (Helen, Final Interview). Luci suggested that the observation of their combined lessons featuring Maths Pathway would provide interesting data for this study. Luci was the leader of the Year 7 mathematics teacher team and the driving force behind the adoption of Maths Pathway.

Bec was new to the school that year and had much to learn about the digital technology infrastructure, the leadership initiative, the school, teaching mathematics, MYP assessment, and Maths Pathway. She was nurtured by team members and given the curriculum flipcharts and worksheets at the fortnightly meetings, assistance with digital issues, and cross-marking sessions for assessments (Final Interview).

When Luci departed, Helen took over as the Year 7 mathematics team leader. Ultimately, Helen became the focus of my attention, and most of the data collected related to her practice. The case study was renamed “Helen”. I have included brief data from Bec and Luci as a means of rounding out the context in which Helen was teaching.

The format of this chapter is different to the previous data collection chapters. The data have been grouped under the headings Classroom Field and Pedagogical Strategies. Subheadings of the latter are Collaborative Team and Year 7 Observation Lessons 1 to 5. Digital use has been included in the observed lesson or interview in which the technology was used or discussed rather than in a separate section. The format change has been made to make it clearer which of the trio of teachers was doing what, and when.
8.2 Classroom Field

8.2.1 Teachers

8.2.1.1 Luci’s background

Luci was born and raised overseas. Both her parents were mathematics teachers and encouraged Luci in her studies, but her mother provided most of the guidance with mathematics homework. In her schooldays, classes were large and lessons were teacher centred. The teacher demanded respect: “You came to class, you sat quietly, you paid attention, you followed instructions, you went home, you did your part, and you came back. There wasn’t much fun participation” (Luci Story).

Luci said she excelled at mathematics in a very competitive environment. However, she did not study mathematics at university, instead completing a science degree with honours. Luci qualified as a science teacher and had been teaching science and mathematics since 1993 in Dubai and in the United States. Migrating to Australia in 2008, she was employed to teach mathematics and science at the participant school. In Australia, she would be considered an out-of-field mathematics teacher, having studied secondary school mathematics only.

8.2.1.2 Helen’s background

Helen was also an experienced mathematics teacher with a science background. When asked about family influences, she replied that when she was growing up, she liked playing school and as teacher inflicted schoolwork onto her younger brother and sister.

Helen described her mathematics lessons at school as traditional: “I can picture the maths teacher we had in Year 10—the gown, the black shoes, the hair in a little bun. We were all in rows, you know that sort of thing” (Helen Story). Helen said she was good at mathematics but not passionate. She had a passion for science, majoring in psychology and biology at university and ultimately completing a Master of Neuropsychology.

When she graduated, jobs were scarce. A year later, she completed a Diploma in Education with a qualification to teach biology and general science at secondary school level. She taught for more than two years at the participant school before taking 14
years’ maternity leave. When considering a return to work, Helen studied special education and was employed as an integration aide but soon realised that “the job [teaching] hadn’t changed”. Helen returned to the participant school and worked for about 11 years teaching psychology and mathematics. She explained her special education course had qualified Helen to teach mathematics up to Year 9 level (Helen Story).

At one stage in her career, Helen spent two years overseas teaching mathematics at an IB secondary college. At the time of this study, Helen was the mathematics domain leader.

8.2.1.3 Bec’s background

Bec had been teaching for five years and was much younger than her colleagues. She mentioned her father, a secondary school mathematics teacher, as the primary influence on her mathematics learning. She was good at mathematics. “A lot of the time I was an independent student, as were my three sisters. We all wanted to do well”.

At school, Bec was unimpressed with her unapproachable mathematics teachers. This had a reverse influence on her teaching style: “That is making sure that the girls are really comfortable with asking for help and I think that they are. I am always going to check what they are doing, what they are up to”.

On leaving school, Bec studied a Bachelor of Agricultural Science (Viticulture and Winemaking). On graduating, she worked in the wine industry for a year and was not happy. She then completed a teaching qualification in chemistry and science. Bec was also an out-of-field mathematics teacher: “I have come in as a science teacher but I have taught Year 7 and 8 mathematics every year” (Bec Story).

8.2.1.4 Catherine

Catherine replaced Luci in the Year 7 mathematics team, but she was not recruited as a participant in the study. She was present in the classroom field for several observation lessons, and her name cropped up in data.

8.2.2 Open space

The Year 7 mathematics classes were held in a dedicated area where four classrooms were adjacent to a large central space. The classrooms assigned to Luci and
Bec were opened up to each other and the central space with their connecting walls retracted. A third enclosed classroom, assigned to Helen, had a door opening onto the central space, while the fourth enclosed classroom remained empty.

In the various spaces and rooms, brightly coloured geometrically shaped tables were arranged in a number of different configurations, surrounded by colourful chairs. Beanbags, cubes, and oblongs were also available for students to lounge or sit. Oblong furniture was arranged in a tiered configuration of steps in front of Luci’s board. At the beginning of combined lessons, students congregated on the steps or at tables in the background.

Some of the walls of the open area were covered in write-on wall paint. Students and teachers wrote on walls with whiteboard markers.

### 8.2.3 Students

There were about 70 Year 7 students in the combined class; all students were new to the school at the start of the year. The students had been streamed according to the results of a mathematics test derived and administered by the Year 7 mathematics teachers and taken by prospective Year 6 students at the end of the year before. Helen had responsibility for the streaming process. When asked if any other indicators such as national test results or primary school references contributed to the streaming choices, Helen replied, “No, not usually” (Final Interview).

Each teacher was allotted about 20 students. Luci had the most advanced students, Bec the middle group, and Helen the least advanced students. In other words, the combined group was a large, mixed-ability one.

### 8.2.4 Rules

The curriculum for Years 7 to 10 was based on the principles and practices of the IB MYP (IB, 2014). The school adopted this program in 2007 and was authorised as an IB World School in 2012. To achieve the accreditation, all middle school mathematics teachers underwent extensive IB professional development. Luci and Helen had participated in MYP mathematics teacher training, leadership and implementation training. Bec, being very new to the school, had not yet been IB trained and was mentored by her colleagues when confronted with IB MYP matters (Post Y7O2).
The IB MYP had a rich pedagogical approach. Problem-solving was associated with “areas of interaction”, which included social issues such as the environment, health, social welfare, community service, human ingenuity, and subject-specific aspects of learning such as mathematical methods. The mathematics subject was assessed in areas of knowledge and understanding, pattern recognition, mathematics communication, and problem-solving.

IB expectations included teacher promotion of the IB “learner profile” (IB, 2013). The profile named the general student attributes of asking questions, seeking knowledge, thinking, communicating, principled action, open-mindedness, caring, risk-taking, balance, and reflection. The IB pedagogical philosophy was a version of social constructivism (Ernest, 1991).

The IB recognised the importance of local governance of curriculum content. The Year 7 mathematics teacher team referred to the Australian Curriculum (ACARA, 2015) for mathematics curriculum content.

8.2.5 Digital tools

Digital technology in the Year 7 open area included common school equipment such as an interactive whiteboard running on an agent Apple computer, teacher personal laptops, and students’ personal iPads, printer, and wi-fi connection to the school’s networks.

8.2.5.1 Maths Pathway

The first two observation lessons featured the use of Maths Pathway software. The trial came about after Luci and Helen had visited a neighbouring school with open mathematics lessons. They witnessed teacher instruction to a large group and individual student participation with a self-paced digital mathematics application. When a visiting preservice teacher suggested trialling Maths Pathway, they jumped at the opportunity. Luci said: “We were always keen to try something new” (Final Interview).

In 2015, Maths Pathway was in its second year on the market. Information gleaned from the company website revealed that the application is “a Learning and Teaching Model that supports students along an individual pathway to build a deep appreciation
and knowledge of mathematics” (Maths Pathway, 2015, para. 01). Further informal discussions with Maths Pathway personnel revealed that the teaching model of the software was instructional and directed to knowledge, skills, and processes. The program worked best in a school with an open curriculum and individuated progress.

Maths Pathway comprised diagnostic tests, documented worked examples, tutorial videos, worksheets with answers, and an embedded calculator. Students were tested and provided with practice worksheets generated according to diagnostic test results. The learning was self-paced. According to the Year 7 teachers, the program was to be used for about 70% of lesson time with testing every fortnight and 30% of the time devoted to problem-solving activities or “rich tasks” (Helen Lesson Y7O1).

The Maths Pathway tests were dynamic and individual. Each started from a point of student achievement but adapted to the student’s answers as they unfolded. If the student made a mistake on the test, the next question for that concept was simpler; if correct, the next question was more difficult (Luci Lesson Y7O1). The worksheets were generated according to the least successful level achieved on the diagnostic test. The Year 7 teachers were aware of these approaches: “Maths Pathway would argue that you can’t learn that until you learn the other. There is no point doing the fraction work until you have actually mastered the whole number work” (Helen Post Y7O2).

The worksheets were downloaded to student iPads and hand copied to student workbooks. With success, the program moved the students forward to the next diagnosed issue. The steps in the pathway of mathematical learning were individual to the student (Luci, Lesson Y7O1).

8.2.6 Year 7 observation lessons

There was much to be seen in the five Year 7 observation lessons. The first two lessons involved experimenting with Maths Pathway and open class teaching and learning for three combined classes. The third lesson was an individual class lesson taught by Helen, with a flipchart presentation, worked examples, and printed worksheets—a regular lesson for Year 7 mathematics. The fourth lesson was a rich task for the combined classes. The fifth observation was again a regular lesson for Bec and Catherine’s combined classes.
8.3 Pedagogical Strategies

8.3.1 Collaborative team

The data collected comprise the intentions, sayings, and actions of the teachers in the classroom as they related to mathematics, mathematics education, and the use of digital technology and from statements made in interviews. Of particular interest were intentions, statements, and actions consistent or contradictory or a change of mind for individual teachers, and those that matched or contradicted their colleagues. The data were grouped as lessons observed and derived from teacher intentions emailed or mentioned prior to the class, transcribed audio recordings of the lessons, researcher field notes, and recorded post-lesson interviews.

Year 7 mathematics had an established curriculum that had been in place for a number of years. I was familiar with the Year 7 mathematics lesson plan and accompanying flipcharts created by Helen and seen in observation lessons. I had used them myself when I had last taught Year 7 mathematics in 2011 at the school. The first two observation lessons featuring Maths Pathway were a deviation from this pattern.

8.3.2 Year 7 Observation 1

Learning intentions: Luci emailed intentions for the lesson “to provide students independent learning and the opportunity to take responsibility for their own learning” (Intentions Y7O1).

Digital intentions: Students to complete Maths Pathway worksheets using iPads.

Digital intentions not mentioned: Maths Pathway video clip of instructions displayed on the board run by an Apple agent computer; wi-fi access to Maths Pathway online; teacher laptops; intranet for recording attendance.

Lesson plan: The students had already been assessed using the first Maths Pathway diagnostic test and were to start on worksheets. The plan emerged as the lesson unfolded: start, Maths Pathway worksheets, end.
8.3.2.1 Start routine

The three classes were combined at the beginning of the lesson with all students located facing the board. Luci outlined the lesson and introduced the Maths Pathway worksheets.

Luci expressed her understanding and expectations to the students: “You all did a diagnostic test and clearly, based on your ability, that clearly reflects where you are at this point in this topic” (Luci Y7O1).

Luci instructed students about independent note taking, something they had not experienced previously:

What happens when you have a program like this? Are we teachers going to tell you what to write down in your notes? What are you meant to achieve in your notebook? That’s correct. Before things were teacher directed. The teacher says “put this in your notebook”. So, what do you think goes into your notebook now? All right. Things that are new to you, things that you notice as you are working through your program that you identify that you really need help. Something that you think, “oh, that’s interesting”. (Luci Y7O1)

Luci instructed students to be honest:

The worksheets are there and the more honest you are in doing them the better you will be in doing your test. Remember again, everyone gets a different set. All right. So, there is no benefit in looking across to your neighbours, I can’t do a question. Don’t look at the answers. It’s easy you have all the answers there. Do your work honestly. (Luci Y7O1)

Luci instructed students to be independent and use the program for support:

Really this is a program designed for independent learning. It is designed for responsible learning. Do you all understand what responsible is? You take ownership for your learning. It’s no longer the teachers saying, “What are you going to do first?” We should be almost your last resort. Really, not getting it? Watch the videos several times, look through the worked examples, and then if you have a problem. (Luci Y7O1)

During the introduction, Bec watched on in silence. Helen played a minor role by inserting clarifying comments into Luci’s spiel:
The other thing the notebook is good for. At the end of the two weeks you are asked to revise the work you have done. So obviously, if you’ve got any notes you can actually refer back to your notes and that would be a good way of revising for the actual test (Helen Y7O1).

A Maths Pathway video that followed outlined the Maths Pathway approach to worksheets: “Set up your exercise book properly; read the questions thoroughly; write down your answer carefully; always check your answers; and, get help when needed from the videos, a friend or the teacher” (Field Notes Y7O1).

Luci finished with a suggestion that students “return to their own pockets”. Helen removed her class to their allocated classroom. “I have the weakest group”, she said (Field Notes Y7O1).

The remaining students were scattered around their allocated classroom spaces. They set to work downloading worksheets. The teachers marked attendance for their individual classes, Luci without comment, while Bec was less sure—“I can’t get the program to work” (Bec Y7O1)—but actually she could without any help. Bec’s self-consciousness in performing the attendance task contrasted with the silent confidence of her colleagues.

8.3.2.2 Maths Pathway worksheets

Luci spent the next 10 minutes solving student technical problems. Some diagnostic tests had not been fully processed, and Luci told students to refresh or reload the answers. Luci expressed uncertainty about the reliability of Maths Pathway but seemed competent in dealing with the issues that she had encountered in lessons. She told me that her Maths Pathway liaison had provided her with solutions to potential technical problems (Field Notes Y7O1).

With technical issues sorted, Luci was observed pouring over diagnostic results on her laptop. She explained to me how Maths Pathway worked. On two occasions, she circled the open space checking on student progress. She commented to me about the open space, “This environment is uncomfortable, not conducive to this work. There is so much writing. This is a collaborative space and better for activity-based subjects. This program (Maths Pathway) is for individual progress in mathematics” (Lesson Y7O1).
Bec’s students lined up with worksheet generation problems. Bec conferred with Luci about what to do and then handled these technical problems. She then sat watching her class. She looked lost. At times, students approached her for help, and Bec replied, “What have you done to help yourself?” (Lesson Y7O1). Eventually, she walked around the space, asking students about their progress (Field Notes Y7O1).

I visited Helen in her classroom. By contrast to Luci and Bec, she was constantly interacting with her students. Helen expressed concern about the percentage time to be spent on Maths Pathway (Field Notes Y7O1).

Helen left her classroom and came into the open space twice. She immediately started helping students who called for her attention. The three teachers huddled to discuss the progress. They all agreed it was going well; “better than expected”, Helen said about student engagement (Field Notes Y7O1). The teachers thought that worksheets were too easy, and they expressed amazement some students had been given Years 3 or 4 standard questions. Helen commented, “They’re not that bad” (Field Notes Y7O1), meaning that she thought the students were at a higher mathematical standard than the worksheets indicated.

During the lesson, the students in both spaces were very chatty with each other and somewhat distracted with off-topic conversations. The distraction fluctuated with each teacher shushing them on at least one occasion. Towards the end of the lesson, students in the open space indicated to Luci that they had finished one or two worksheets. This rate was consistent with the Maths Pathway expectations related to me during an informal discussion I had with Maths Pathway personnel.

8.3.2.3 End

The lesson ended abruptly with a school announcement and everyone rushed off to recess.

8.3.2.4 Post-observation interviews

Luci provided the most comprehensive post-observation interview. Her verdict was that Maths Pathway was successful in engaging students: “All the students were engaged most of the time” (Luci Post Y7O1). She admitted to having concerns at the
beginning about technical issues and was pleased with her efforts. She said she was happy and confident about using Maths Pathway and glad that the students had all commenced on their individual path.

Luci also volunteered a comment on resisting answering student questions directly: “When they ask for help, you need to respond with open ended questions. Sometimes I forget. I forgot today and I answered a question” (Post Y7O1).

Luci acknowledged that the students had access to a calculator in the Maths Pathway application. Luci commented on using the board saying that the interactive whiteboard helped her to communicate more effectively with students (Post Y7O1).

Helen said that she was surprised her students had worked so well, but the work was very easy and they had enjoyed it. When asked why she had moved into the separate classroom, Helen said that she had the weakest mathematics students and the stronger ones intimidated them (Field Notes Y7O1).

By way of explanation, Helen related consulting with an experienced open plan teacher, Amelia prior to the Maths Pathway trial. Helen explained to Amelia that with a program like Maths Pathway, the lower level and higher level classes were going to end up at different spots on the pathway. Amelia advised the team to organise the groups and take the weaker group into a separate room (Helen Post Y7O1).

Bec gave limited feedback during this lesson

Bec: You do this for 75 per cent of the lessons!
R: What are you supposed to do?
Bec: Don’t know! (Lesson Y7O1)

8.3.3 Year 7 Observation 2

Between observations, students had completed the first cycle of Maths Pathway worksheets and a second diagnostic test. The students were ready to embark on the second set of worksheets.

Learning intentions: “Using Maths Pathway to provide students opportunity to hone their skills in order to reach a standard” (Luci Email).

Digital intentions: Maths Pathway worksheets.
Lesson plan: start routine, Maths Pathway worksheets, end routine.

8.3.3.1 Start routine

Luci and Bec had combined classes for Lesson Y7O2, while Helen’s class was located in the separate classroom for the entire lesson. Luci addressed the students, reiterating her ideas about Maths Pathway being for independent learning and an honest approach. She challenged the students to finish four worksheets in the lesson. She also added a new idea and a new strategy to achieve it:

Because remember our goal is to finish. We all have to finish at the same level. So, if you feel that it’s really easy and that you are repeating the work over and over again, [Bec] and I would be happy to push you along so that you are making the progress you need to make at this stage. (Luci Y7O2)

8.3.3.2 Maths Pathway worksheets

The second diagnostic test had generated repeated worksheets for many students, some back to the beginning. A line of students gathered around the teachers. Luci showed Bec how to skip worksheets, and the two teachers each spent half an hour progressing students to the next topic, Fractions. Other technical problems emerged. One student could not connect to the internet immediately and had to wait for the log-on surge to abate. Another student had a faulty iPad and was sent to the IT technicians for assistance (Field Notes Y7O2).

Once technical issues had been resolved, the teachers spent most of the time circulating the room checking progress and providing assistance to students. During this lesson, the students were observed spending more time on task and less time chatting than in Lesson Y7O1 (Field Notes Y7O2).

Halfway through the lesson, I moved my observation to Helen’s classroom. Helen was found to be completing a lesson on Fractions that she had commenced in the previous lesson. She wanted to finish her teaching before asking students to complete Maths Pathway worksheets. Helen said that, according to the diagnostic tests, “her students were lagging behind” (Field Notes Y7O2).

Helen instructed students to stick printed sheets of multiplication tables and practice exercises into their workbooks, saying to the researcher, “We have resorted to getting a worksheet out. That’s not what I would call a “rich task” but we have to do
some practice because the kids, my kids particularly, aren’t getting any practice or exposure to fractions on the pathways”. (Helen Y7O2)

An incident of interest occurred when Helen approached a student who was staring blankly at her workbook. Helen peered over the student’s shoulder. The student pointed to an expression that she had written down “6 x 8”:

Helen: You know that, six times eight.
Student: Oh! 48. (Field Notes Y7O2)

Helen urged individual students to finish the exercises. She then spent time skipping worksheets for several students: “I have done 20 overrides I think to try to get them into fractions” (Helen Y7O2). The students spent about 10 minutes on Maths Pathway worksheets towards the end of the lesson.

8.3.3.3 End routine

The students left when the bell rang.

8.3.3.4 Post-observation interviews

Luci and Helen made themselves available for a long post-observation interview to discuss Maths Pathway. Their comments have been separated for easier reading. Bec had an individual interview later.

Luci said that she was confident about using Maths Pathway. Her students loved the program now that it had become a little more challenging. She thought that Maths Pathway was successful in identifying key difficulties students had coming into secondary school, and added, “It is not getting them along because they keep doing the same thing. I am not sure how we can all achieve the same result to some level of the curriculum, at the end” (Luci Post Y7O2).

About overriding worksheets, Luci said, “Maths Pathway has zero tolerance for mistakes on worksheets”. Luci had skipped up to 20 worksheets to advance some student to Fractions. She went on to say, “We all want to do Fractions but if the kids are still adding and subtracting whole numbers and learning to write words, we have a bigger issue here” (Luci Post Y7O2). An incident of interest was that Helen and Luci had both “skipped up to 20 worksheets” for their student to reach Fractions.
Later, when asked whether Maths Pathway had enough depth, Luci replied, “Yes it does. It really moves them along. Like Jackie is getting good stuff. She is getting into percentage points, and Gabby” (Luci Post Y7O2). Luci had contradicted one of her previous answers. The question remained: Did Maths Pathway move students along the pathway, or not?

When questioned about students asking for help from classmates, Luci said,

Do you think they are not all on task? Yes, they are all on task. If they have a conversation about what they are doing, I say they are edging each other on. Of course, you hear those irrelevant conversations. You bring them back, “now have some quiet time” or “now stop the chat so that you can think about what you are doing before you have a conversation about what’s relevant”.

(Post Y7O2)

Luci was defensive about her students’ engagement and her reply contradicted her instructions to students about not seeking help from classmates.

At the post-lesson interview, Helen spoke about preparing for open plan learning and related a visit that she and Luci had made to a neighbouring school prior to using Maths Pathway. Helen was critical of this model as being inadequate, yet it was basically the model the teachers chose to follow when using Maths Pathway,

They also had breakaway rooms, which I think is what we are lacking. We have one giant open space. There, students do five minutes on an application they liked to do. Then the teachers would drag them all in. Then they would do very traditional teaching of adding fractions together, say. Some kids might write notes. And then they went back and started working with a [digital] program. (Post Y7O2)

Helen spoke about the Maths Pathway trial in a way that expressed doubts about the merits of the application, “We can use it, but I don’t whether we are using it effectively. The kids are working on something they need to learn, supposedly”. (Post Y7O2)

Helen mentioned problems with Maths Pathway diagnostic tests, first the 100% pass rate needed for progress, and “one question only on any particular type of question was not sufficient to test achievement levels accurately” (Post Y7O2).
Helen mentioned that Maths Pathway wasn’t helpful for the teachers. “It was supposed to be replacing the textbook but here we are printing practice worksheets for students”. (Helen Post Y7O2)

Helen moved the discussion into the disadvantages of the open plan space and advantage of streaming:

I’ve got the weak group. When you have that discussion as a big group the weak kids are never going to want to come to the board or put their hands up. It will always be the brighter ones for fear of being stupid. Whereas if you’ve got like kids together, then obviously they are happy to have a go. (Helen Post Y7O2)

Helen went on to say that there would be no need to stream if combined classes and open plan learning continued.

Bec’s post-Y7O2 interview was conducted after the teachers had met with a Maths Pathway representative, Luci was no longer teaching, and MP had been discarded. At the interview, Bec confirmed that she had contributed to changing the teacher role to proactively helping students in Lesson Y7O2 at the previous fortnightly meeting. Bec said that the teachers were aware of Maths Pathway’s recommendation to group students together according to their diagnostic test results for teacher-targeted assistance, but they had not really discussed it.

In terms of discarding Maths Pathway, Bec told me that the teachers had made a list of questions that they put to a Maths Pathway representative. The representative’s answers clarified the software benefits and challenged the teachers to provide targeted assistance to students. Bec questioned the logistics of such a move: “Where would you do it?” (Bec Post Y7O2). Since there were two available classrooms attached to the open area, I thought the answer was obvious. It seemed that teacher preparation and problem-solving for the Maths Pathway trial had been limited.

An assessment conflict was discussed with the Maths Pathway representative: “He was saying that you could catch up in the end. Obviously with our assessments that was never going to fit in” (Bec Post Y7O2).
8.3.3.5 Final interview comments on change initiatives

At the final interview, Luci revealed that during the Maths Pathway trial, the teachers remained loyal to the assessment requirements of the IB MYP curriculum. Topic tests based on IB MYP guidelines were structured to deliver a summative achievement level for each topic. By contrast, Maths Pathway provided formative assessment of students according to their ongoing achievement levels. Luci said,

> We have an open curriculum and yet we don’t. I don’t know if that makes sense. Because we still want students to have certain goals, certain levels of achievement . . . The assessment module of Maths Pathway didn’t match with ours, because we have a common assessment and theirs is based on assessment that is not common. So that was a big problem. I don’t think it was suiting the purpose for our school. (Final Interview)

Luci also suggested that Maths Pathway did not work because she was not there to see it through (Final Interview).

At her final interview, Helen agreed that Luci had been the driver behind the Maths Pathway experiment: “Without her driving force the experiment was shelved”. (Helen, Final Interview). Helen added that Maths Pathway was valuable in identifying the need to fill in gaps, “but for some kids the gaps were huge and they were never going to get to the next topic” (Final Interview).

Helen referred to the pressure for team-teaching and student collaborative learning, “We need to jump on-board and I thought we were doing really well. Why do we have to change every year” (Final Interview).

Bec’s final words on Maths Pathway were, “I found it too boring. We just stopped it. It didn’t work. We stopped it because we had issues with it. We agreed that we wouldn’t continue to work with it” (Final Interview).

8.3.4 Year 7 Observation 3

The Year 7 team participation in the study was disrupted by Luci’s departure and the arrival of the replacement teacher Catherine. The team disbanded the Maths Pathway trial. There were now two new teachers working to deliver Year 7 mathematics lessons according to the existing curriculum. Bec was a participant in the study, but Catherine was not.
I decided to concentrate on collecting data from Helen. She had been integral to
designing and developing the curriculum and was now leader of the team. Bec and
Catherine seemingly concentrated on adjusting to the existing arrangements. Helen
agreed to complete two more lesson observations. The third Year 7 lesson observation
was of Helen’s class only, held at the end of Term 3.

Helen did not provide learning and digital intentions, and these were derived as the
lesson unfolded. The class was held in her allocated classroom adjacent to the open
space.

*Learning intentions*: unit—Linear Relationships; topic—Cartesian Plane.

*Digital intentions*: teacher laptop, student iPads, tables app, attendance recording,
flipchart, interactive board.

*Lesson plan*: derived as the lesson unfolded and included a start routine of times tables
practice, concept understanding activity with worked examples and notes, practice
exercises, and homework instructions at the end.

8.3.4.1 *Start routine*

The lesson began with Helen instructing students that because of their performance
in the most recent topic test, they needed to use an iPad app to practise times tables:

> Often you have actually written the right things down. You have written
down times 5 or times 7 but then when you have actually done it [the
multiplication] the answer is incorrect. Choose a times table that you know is
not your favourite, is not your best and do some practice. (Lesson Y7O3)

Deafening silence ensued, causing the teacher to remark, “Wow, they have to
concentrate” (Lesson Y7O3). While they were doing so, Helen recorded attendance
and set up the board with a flipchart.

When asked, the students reported practising the multiplication tables of 5, 8, 11, 1,
10, and 2 quite successfully. The teacher steered them onto the 7 and 9 tables. In 10
minutes of tables, the noise level went from silence to crescendo, and the teacher asked
the students, “Put iPads away as I am ready to begin” (Lesson Y7O3).
8.3.4.2 Concept and examples

Concept understanding focused on the grid plane and coordinates to locate points and describe locations. The teacher addressed the concept, terminology, and grid rules using an interactive flipchart on the board. Helen’s techniques included recall of previous learning with questions addressed to the class as a whole or to individuals. The following excerpt from the lesson was an example:

Helen: If I said the butterfly is located at?
Student 1: You need a y-axis and an x-axis.
Helen: What do you mean by a y-axis and x-axis?
Student 1: Axis with numbers.
Student 2: With letters.
Helen: What is an axis? Are you saying a y-axis with letters and an x-axis has numbers? You were talking about “thing on an axis”? What is an axis?
Student 3: It’s like a guide to where everything is.
Helen: So, you are telling me you need a bit more information to locate the butterfly. We need to actually have the numbers and perhaps the letters. Yes Claudia?
Student 4: Like coordinates.
Helen: Like coordinates. What do you mean by coordinates?
Student 4: You have numbers and . . .
Student 3: You have where the lines cross.
Helen: Yes, we could do that, couldn’t we? If I do this, we put two lines in. (Lesson Y7O3)

During Helen’s presentation, students were watching, listening, and answering questions verbally or writing on the board at her request.

After an attentive start, the noise level rose, and most students became distracted. Within 10 minutes, iPads began to appear: “Brooke, if you are on your iPad, I am taking it away from you”. Hairdressing became popular: “Adriana, no it is not time to do your hair. It seems to be a bit of a theme happening”. Helen’s efforts to keep the class attentive became more and more pronounced: “Ok, shhhh. Who knows what this is called? What do we call it?” (Lesson Y7O3).

The dynamics of the class, at first the enthusiastic student responses to recall questions and then dwindling attention, inspired me to look up, on the spot, the year
level at which students were first introduced to the Cartesian plane. The answer from an Australian website was Year 4. This was perhaps the fourth time the Cartesian plane had been presented to the Year 7 students.

Worked examples based on locating and naming points on a grid at the board were interwoven into the presentation. Helen asked students to come to the board to name or locate points. Many students jumped at the opportunity, with the exception of Gabby:

Helen: Gabby can have a go.
Gabby: I don’t want a go. (Lesson Y7O3)

8.3.4.3 Flipcharts

Helen used the interactive whiteboard with confidence, competence, and control. The Year 7 mathematics flipcharts provided the pedagogical structure for curriculum topics in the form of concept understanding activities, notes, worked examples, and practice exercises. The flipcharts observed in Lessons Y7O3, Y7O4, and Y7O5 were Helen’s creations (Post Y7O3). The flipcharts provided an efficient means of communicating knowledge. They also contained interactive elements such as the Cartesian plane (Section 8.3.4.2) that enhanced mathematical understanding by providing visual representations, colour, and interest (Field Notes Y7O3).

8.3.4.4 Notes

After 20 minutes of presentation, Helen gave the students printed worksheets to annotate and stick in their notebooks as a means of creating notes about the Cartesian plane:

I am going to get you to take your notebooks out. I have a sheet of paper and I am going to get you to label the Cartesian plane and then see if you can fill in the blank spaces on the piece of paper. I apologise because it is quite small. Stick it in your notebooks. (Lesson Y7O3)

To save paper, Helen had photo-reduced the worksheets from A4 to A5 size and they were hard to read (Field Notes Y7O3). Helen verbally reviewed the answers and students pasted the sheets into their notebooks.
8.3.4.5 Exercises

Helen gave out two puzzle sheets also printed on A5 paper, with small print and squashy layout. One puzzle was “Join the coordinates to make a shape” in four parts 1(a) to 1(d), for example, 1(a): (1,2) (3,2) (3,4) (1,4). Helen also gave verbal instructions about completing the puzzle:

You need to plot the points, the pairs of coordinates, and then connect the points in each group. So, don’t put all the points on the Cartesian plane and then say which ones do I need to join up. You need to plot the points that are listed in question 1(a). And join those points up and you should find they make a shape all right. So do one question at a time. (Lesson Y7O3)

The students joined all the points listed in question 1(a) together and did not produce the shape outline as expected:

Helen: I haven’t seen a perfect one yet.
Student: Perfect what?
Helen: A perfect shape. What sort of shape is that? This one is wrong. This one is a 2. You need to join them, my dear. Join them together before you move onto the next one. Read the instructions. You have to read the instructions. (Lesson Y7O3)

Helen’s verbal instructions were different to the printed instructions, and both were ambiguous. The students struggled (Field Notes, Y7O3).

8.3.4.6 End

Helen finished the class with homework: “So I won’t see you again until Friday in maths. So that’s when you need to bring your Maths Mate sheet in”.

8.3.4.7 Post interview

Helen’s immediate comment on the lesson was

Helen: Well, that was a failure!
R: The technology went well.
Helen: Surprisingly, yes.
R: So, what happened?
Helen: I don’t know, not a single student, even the good ones, managed to complete the puzzles correctly. (Post Y7O3)
When asked, Helen could not provide an answer to why she felt the lesson was a failure (Post Y7O3). I also asked Helen about using the Tables app. Helen recognised the app as improving basic skills with the benefit of engaging students. The students still required guidance:

Helen: I just found that there are basic skills that they’re missing. And we don’t have a lot of time. That again is fraught with danger. In a sense some will get on with it. Some will choose 1 and 11. Some don’t get it.

R: There are a million skills apps that they could get into.
Helen: Yeah it funny cos it’s something that is sort of engaging. You know something that they want to do rather than something just being told. (Post Y7O3)

Further on was a discussion about worded questions and reading. Helen recognised that the teachers were pushing ahead with the curriculum and not responding to student learning needs:

Helen: There are kids I have noticed that have struggled with the worded questions. They’ve done hardly any and the only worded questions they have down, are when I’m standing at the board and saying “what do you need to do next?”

R: You are always driving it and they can’t do it on their own?
Helen: So, you put it back on them.
R: Yeah but are you teaching them to read? You are here as a maths teacher thinking that you need to teach them maths, but that may not be the problem.
Helen: That’s really evident when you require written answers. I sit there saying, “What is this person trying to say?”
R: The kids doing Cartesian planes were very verbal.
Helen: It was all coming out of their mouths but their writing doesn’t match their verbal skills. I think that we just keep ignoring it. We can see those things but we keep ignoring them because we push through it, we push ahead. (Post Y7O3)

Helen was asked at her final interview if she had had any further thoughts about the lesson but the answer was no, she could not say why the lesson had not worked (Final Interview).
In addition, I asked Helen at the final interview about using alternatives to Maths Pathway such as an application “Specific Mathematics Assessment that Reveals Thinking” (Price, B., Stacey, K., Steinle, V., Chick, H., Gvozdenko, E., [SMART], 2009). Helen said, “We use SMART tests for Year 7 and 8” (Post Y7O3), and related SMART’s adoption.

Several years before, school leadership had promoted a school-wide digital application for recording pre- and post-test results. This application relied on teachers creating the tests. Helen knew about SMART through Catholic Education Office professional development activities. The SMART suite included tests, a database for test results, the analysis of test results, and suggested strategies for rectifying student gaps and misconceptions. Helen said,

SMART have done all the research. They have put together questions that specifically target different concepts and they give some information about misconceptions and gaps. Then there’s information about what you can do to address those things (Final Interview).

Helen had encouraged her mathematics colleagues to use the tests: “Why don’t you do this? Why don’t you try that?” (Final Interview). She did not get support from colleagues. Helen quoted one teacher saying, “What’s the use of them? I’m not going to teach any differently, anyway”. Helen found that very discouraging and she rarely used pre- and post-testing strategies herself.

8.3.5 Year 7 Observation 4

Despite my best efforts to concentrate on Helen for data collection, she arranged for the fourth lesson observation to be a combined class rich task with Bec and Catherine’s classes.

Learning intentions: unit—Linear Relationships; topic—Patterns

Digital intentions: teacher laptop, attendance recording, flipchart, the board.

Lesson plan: derived by observation and included start routine, worked example, investigation. There was no end routine.
8.3.5.1 Start routine

Helen began the lesson in her classroom with attendance recording and homework checking. She took her students into the open area to join the other Year 7 students.

8.3.5.2 Worked example

The task was to investigate patterns made from a variety of manipulatives (e.g., matchsticks, tiles, discs) in order to identify a representative pattern of numbers and generate a relationship between number variables. Catherine introduced the task to the students by way of a simple worked example in a flipchart on the board. As she did so, Helen and Bec set up the patterns, manipulatives and instructions in multiple locations around the open space. At the completion of Catherine’s demonstration, the investigation began (Field Notes Y7O4).

8.3.5.3 Investigation

Printed instructions for each of eight problems included an image of a pattern of shapes, directions for developing the pattern, and a printed table with the numbers of one shape component (e.g., house, triangle) and blank cells for the number of the shape variable (e.g. matchsticks, tiles or discs). Students were instructed to build the next item in the pattern series and fill in the table until they were able to recognise an emerging number pattern. The students needed to represent the number pattern as a symbolic relationship and then use the relationship to predict answers to questions.

At the beginning of the investigation, chaos reigned. The students randomly congregated as pairs, groups, or individuals at the pattern locations. Many students seemed to have no idea how to start, and the patterns were much harder than the one demonstrated by Catherine on the board. All the teachers in the room (three classroom teachers, one preservice teacher, and me) became actively engaged in getting students going, reminding them about steps and moving them onto the next problem.

Helen helping a student was captured on the audio recording:

Helen: If you have 10 houses how many matches would you need?
Student: Add 5.
Helen: No, it’s not. So, how did you know what happened every time you add a house?
Student: Add 5.
Helen: Yes, but remember what [Catherine] said if you don’t know the previous number you can’t add. You need to find the connection between the house and the groups of matches. If I add five to that one plus 5 equals 6. Each time when you add a house you need to know the groups of matches. So, if you have 5 houses how many groups of five do you need?

Student: 25.

Helen: But we actually have 26.

Student: 25 + 1.

Helen: That’s correct so why do we have an extra one.

Student: So . . .

Helen: No, no, no. We’ve got five houses we need five matches for each house and then we add 1. Why?

Student: Because there’s 1 there.

Helen: Right so you actually need that one. This one is finished. (Lesson Y7O4)

I was listening to this conversation between Helen and the student as it unfolded. I was alarmed that the teacher’s logic was not sequential, and the teacher’s choice of using the example of five connected houses made up of groups of five matches, with an extra match to complete the wall, was confusing for the student. To me it seemed like the teacher knew the answer and was barrelling towards it, knocking obstacles out of the way, while the student was guessing answers to the teacher’s questions. The teacher bypassed the process suggested on the printed instruction sheets. This example demonstrated the teacher’s limited understanding of the problem-solving techniques that had been suggested.

Most students were very excited by the activity. They helped each other, they copied or resolutely did not copy from each other, or they worked on their own (Field Notes Y7O4). A number of students were distracted, making cheeky comments on the audio recording. A handful of students worked their way through more than four of the eight problem options. These students were then challenged by the teachers to make up a pattern, draw it on the wall, and generate the relationship. The students had great difficulty making up a consistent pattern and generating the linear relationship correctly, and no student succeeded in this task extension.
8.3.6  Year 7 Observation 5

I requested an additional Year 7 lesson observation of Bec’s practice. At this point, I had observed Bec in three lessons but had not seen her leading a lesson. Although I had decided to focus on Helen for data collection, I wanted to confirm that Bec was not teaching independently. I discovered that Bec and Catherine had been combining classes for every lesson. There were about 50 students in the lesson.

*Learning intentions:* unit—Linear Relationships; topic—using a linear rule to generate values and plot a graph.

*Digital intentions:* interactive board, flipchart.

*Lesson plan:* derived as it unfolded and included start, recall, examples, exercises, and end.

8.3.6.1  Start

Bec and Catherine recorded attendance for their classes. The students gathered in front of the board at Bec’s request: “You don’t need anything” (Lesson Y7O5). Students did not take notes on the presentation.

8.3.6.2  Recall

While Catherine watched on, Bec began with recall of the previous lesson about using $x$ and $y$ from a table of values to make a rule. Bec quizzed the class for the rules behind tables of values. The students were reluctant to engage at first but eventually sparked up. It took time for the large group of students to settle into the task of recalling the previous lesson. Bec used a technique of waiting until about half the class had raised their hands before selecting a student to answer a question.

Bec moved to a flipchart slide of an interactive algebra computer that generated OUTPUT values for given INPUT values for the class to identify the rule. Bec said, “Think about it and when you are confident of your answer, put your hand up”. The students were correct on every occasion. Bec flustered over a mistake in the algebra computer on one flipchart slide. She knew about the mistake, but it still disrupted her flow. I recognised the mistake in the slide from my own experience and could vouch for the fact that it had been there since the flipchart’s inception.
8.3.6.3  *Worked example*

The lesson’s new topic was using a linear rule to generate values and plot a graph. Bec introduced students to the topic by way of a worked example:

Before you go and do these on your own, let’s look at the first exercise. It’s really important. When we were doing this yesterday with the other class, people didn’t read instructions. So, before you start you have to read it.

(Lesson Y7O5)

Bec and Catherine had two sets of combined classes, and this was the second time they had taught this particular lesson. On the previous occasion, Bec had suggested that students read the exercise instructions on the worksheet and then do them. But that had not worked, so this time around she worked through the first exercise with the students (Post Y7O5).

As she worked through the exercise, Bec did not reference the instructions on the worksheet, for example, by reading them aloud and unpacking their meaning with the class. Her verbal instructions at the board did not exactly match the written instructions (Field Notes Y7O5).

Bec displayed the rule and a table with the x-value cells filled. Bec instructed the students to fill the table with y-values:

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**Bec:** You’ve got a table. You have your value x, and you are going to work out the y. You are told the rule. You are not working out the rule. You are given the rule. So, looking at the first one it tells you x is 1. So, this is your working out. What am I going to put in here? x is 1 so what do I put in here?

**Student:** $y = 1 - 1$

**Bec:** We want you to write in here what you have worked out. So $y = 1 - 1$ equals?

**Student:** 0

Bec finished with

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**Bec:** This part is important. If x is 17 use the rule to find the value of y. You’ve got your rule. You’re going to have to work out the value of y. So, you’ve got $y = $ what?

**Student:** $17 - 1 = 16$. 
Bec: So then use your graph to find out the value when \( x = 17 \). Go to the x line here. Here is the graph you are going to draw, very similar to this. So, count up by 2 and when you go back to this. So, when I think about it (1,0), (2,1). So, go with these values you are going to plot coordinates?

Students: Yes. (Lesson Y7O5)

Finally, Bec told the students to open up their workbooks, draw a table, fill it in, and draw a Cartesian plane. She also said to use the numbers 0 to 20 on the axes and to avoid squashing up their graphs: “Draw your graphs nice and clear” (Lesson Y7O5).

Bec’s presentation lasted 18 minutes. The student options during this time were to watch, listen, recall, and answer questions. The students did not ask any questions (Field Notes Y7O5).

### 8.3.6.4 Application

After the presentation, the students returned to their allocated classrooms and spent the rest of the lesson working on an online worksheet of exercises. The teachers quickly discovered that the students had not read coordinates from a table of values before. Catherine went to the board and explained the process.

Eventually, when helping struggling individuals, Bec’s instructions such as “You have to number each part” and “You can’t do more points than what you are asked for” did not exactly match either the exercise printed instructions or her verbal instructions at the board. Bec’s feedback to students amounted to “You haven’t followed instructions”. Bec was frustrated with her students (Field Notes Y7O5).

### 8.3.6.5 End routine

The end routine was an announcement about an assessment task for the next day:

> You know you have an assessment task tomorrow on this topic. It is not a test as such on knowledge and understanding. It’s an assessment task where you are given a situation and you’ve got to draw graphs and table of values and find a rule as you did today but under test conditions. (Bec Y7O5)

Bec went on to suggest that students bring suitable equipment including a calculator “that could be handy”. She added, “If you use a calculator on your iPad you won’t be using that” (Lesson Y7O5). This was the only reference made by a Year 7
mathematics teacher to the use of a calculator in the five observation lessons (Field Notes).

8.3.6.6 Post Y7O5 interview

The post-lesson Y7O5 interview and Bec’s final interview were combined. We reviewed the Maths Pathway trial and why it did not work, her use of other digital technology at the school, the problem of using the calculator on the iPad, collegial support, the established curriculum, and other digital technology that she used in her lessons in general.

I asked Bec if she had been trained in the IB MYP. She replied that she had not but IB MYP was really only about assessment: “It’s a matter of getting used to it and understand how it worked with those different levels of questions. The assessment and the number of assessments can be a little overwhelming” (Post Y7O5).

I was interested in her perspective, which was shaped by her colleagues and not by external training. Her answer indicated to me the Year 7 mathematics teachers’ approach to IB MYP. In the Year 7 mathematics domain, IB MYP was treated as an assessment concern only and barely mentioned in lessons. At the time, the mathematics teachers had achieved only a limited adaption to the IB MYP philosophy.

8.4 Conclusion

Data were collected from the observation of Year 7 mathematics lessons and subsequent interviews with teachers. Data from the first two observation lessons provided insight into the teachers’ experiments with the open plan classroom, team teaching, and Maths Pathway innovations. Data from the remaining observation lessons represented the established Year 7 mathematics lessons that had been in use for several years.

The data presented in Chapters 5 to 8 were chosen for being indicative of a variety of teacher beliefs, highlighting contradictions in sayings, intentions, and actions of the teachers, and providing incidents of interest. The incidents of interest, such as the discussion of SMART software, provoked a great deal of thought about the beliefs behind the teachers’ actions of selecting, implementing, and assessing digital technology uses in the classroom.
Chapter 9 is devoted to a discussion of my interpretations of the data in order to answer the research questions about the uses of digital technology and the teacher beliefs that facilitate and obstruct digital technology use.

The final piece of the puzzle was “cue misdirection” where the opponent disguised their stroke and I was fooled into making an inappropriate return. I was overwhelmed by disappointment when this happened, until I became more skilful at reading the misdirected cue. When I made a good return, I experienced irrational joy. I started using cue misdirection myself. My game improved, acquiring greater depth and breadth. At one stage over three exciting weeks, I beat nine people that I had never beaten before.

Knowledge of cues in table tennis raised the issue of cues in mathematics learning. After watching a student in an observation lesson falter on “6 x 8” until the teacher cued her with a verbal “6 times 8”, I suspected that the student was not attuned to the \(x\) symbol. Perhaps she could not differentiate between plus and times symbols. Perhaps she was dyslexic. Even so, I began to wonder about the care and attention devoted to identifying procedural cues in mathematics.
CHAPTER 9
ANALYSIS AND RESULTS

What had happened to my table tennis? I had learnt that the most effective shots in fast-paced table tennis were automated skills. An empty head facilitated automation. The skilled shots were designed to land on the table with attributes such as speed, spin, length, direction, and power, with the purpose of either making the ball difficult to return or allowing it to be returned in a way that suited an unfolding routine. Responses to cues provided the means for shifting from one automatic routine to another. Decision-making about strategies was relegated to breaks between points and games.

9.1 Introduction

Chapters 5 to 8 were devoted to the data collected from four case studies, of which three were focused on individual teachers Sarah, Tamara, and Alan who taught the VCE Unit 1–2 Mathematical Methods (CAS) subject. The fourth case study focused primarily on Helen, a member of a team of three Year 7 mathematics teachers. The premise that the teachers’ own beliefs and practices about the relevance of digital technology to student learning somehow obstructed or facilitated its use (Ertmer et al., 2012) provided incentive to continue the study.

The study’s theoretical framework provided a cultural view of teacher practice under pressure to use digital technology in the classroom (Chapter 3). The framework was based on constructs of Bourdieu’s (1977) field theory—field, habitus, and cultural capital—embedded with an instrument of analysis, the IUM, developed to reflect the uncertainty faced by teachers when confronted with digital innovation. The methodology outlined in Chapter 4 described the conditions for data collection and analysis using the principles of constructivist grounded theory (Grbich, 2007) within the theoretical framework.
The analysis of data was time consuming, complex and indicative of the complex framework being analysed. Results have been grouped together under specific headings as a means of understanding and comparing case results. This chapter presents analysis results for each case study organised under the headings Field Beliefs, Pedagogical Beliefs, Digital Technology Beliefs, Effect of Beliefs and Beliefs’ Results.

Field analysis identified regular and disrupted practices of teachers, including established digital technology use, and external and personal influences on changing teacher practices. Habitus analysis identified teacher beliefs about mathematics, mathematics pedagogy, and digital technology use for each case study. Disruptions to beliefs were also identified.

9.2 Field Beliefs

9.2.1 Regular classroom practices

One objective of the field analysis was to determine the teachers’ “regular” pedagogical practices in the classroom against which changed practices could be compared. Regularity was seen in field characteristics, external influences that acted on the dynamics of the field and established uses of digital technology, the influence of students, and the teachers’ regular pedagogical practices.

The primary external influences on the VCE and Year 7 subjects were the prescribed curriculums (ACARA, 2015; IB, 2013; VCCA, 2010–2015). Each authority defined the content to be covered and learning outcomes, such as the use of digital technology from the VCE Study Design and pattern recognition according to the IB MYP. The teachers developed their lessons accordingly.

Additional influences came from the teachers’ lifetime experiences with mathematics education, the school’s leadership priorities, and the influence of colleagues as individuals or as part of a team.

9.2.1.1 Case Sarah

Sarah’s VCE and Year 10 classes were similar sizes, and located in similar classrooms with consistent facilities. The VCE class was considered by Sarah to be “weak”, the Year 10 Enhanced Mathematics class to be “strong”. The lessons were
governed by different ideologies contained in the VCE curriculum and the Year 10 MYP curriculum (Section 5.4.3.3).

Sarah’s lesson format began with a short introduction, concept activity of notes and worked examples demonstrated by the teacher at the board, and practice exercises from the textbook with their completion for homework (Section 5.4.1). These actions were reflected in the sentiment of her story about learning mathematics: “I was happy just having the teacher teach me something and then complete exercises. That never bored me” (Section 5.2). Sarah acknowledged the possible boredom of some students and provided students with the lesson activities in comprehensive topic files. She encouraged students to move at their own pace through the activities (Section 5.4.3.2).

In Sarah’s lessons, the dominant, constant external influence of curriculum authorities was to cover the knowledge and skills requirements of curriculum content (Section 5.4.1.1). Sarah spoke about “meeting Australian Curriculum standards” (Section 5.2) in her story. Other learning outcomes were taken for granted in Sarah’s observed lessons.

A collegial influence came from the VCE teacher team and required keeping up with Alan’s pace of delivery. Sarah spoke about the need to keep up with the others (Section 5.4.1.1).

Sarah spent most of the lesson time at the board (Appendix 9) and rarely walked around her crowded classrooms. Her students remained seated for the lesson’s duration. The students were mostly attentive while Sarah was teaching, either copying board work or quietly working independently.

The students became disengaged when Sarah was not at the board. At these times, she sat with an individual student providing assistance (Section 5.4.4.1). Sarah did not seem particularly concerned about student distraction. I interpreted this as a tacit agreement between the teacher and students—do the practice exercises immediately in class or complete them at home. The effect of distraction during practice exercises was to devalue the activity for students and teacher.

Sarah’s regular field was indicated as a consistent teacher-centred lesson delivery of topic information, processes and skills, and practice exercises. She provided lists of
exercises and internet resources for students to work at their own pace in the classroom or at homes.

9.2.1.2 Case Tamara

Tamara adhered to the demands of the VCE curriculum but, being new to the subject and Mathematica, relied on the support of her colleagues and their previous experience. Tamara said the mathematics influences of her childhood included a supportive, knowledgeable father and an approachable Year 12 teacher who taught for understanding through discussion (Section 6.2). These ideas were reflected in the collaborative learning environment of Tamara’s classroom.

Tamara’s lesson format was similar to Sarah’s, but her regular lessons were a hive of activity—movement, discussion, and variation in tasks. Students sat around tables and shifted in their chairs to watch and participate in Tamara’s board presentations. Students also presented concepts and work examples at the board (Sections 6.4.3.3 and 6.5.2.5).

During practice activities, Tamara walked around the classroom providing assistance and so did the students seeking or providing help from each other (Section 6.4.4.1). Individuals or groups of students wrote on the walls (Section 6.3.2).

Amongst all the activity, some students remained resolutely disengaged, evidenced by lengthy off-task conversations captured in audio recordings (Section 6.4.4.1). There seemed to be the same tacit agreement between teacher and students as in Sarah’s lessons—do the work now, or do it at home.

Tamara’s regular practice was conducted in a field of student-centred collaboration by agreement between the teacher and the students.

9.2.1.3 Case Alan

Alan was an experienced teacher of the VCE subject and resolute in adhering and adapting to the demands of the mathematics VCE study design in its entirety. Alan had said in his story that he had not been influenced by anyone in particular in his schooldays of learning mathematics (Section 7.2). It seemed that he had developed his own unique style of teaching that had begun to develop early on when he had taught mathematics to his peers in Year 9 (Section 7.2).
Alan’s lessons contained similar elements to Sarah and Tamara’s, but these were not observed as consistent or regular. It seemed the lessons began where the previous lesson or homework had left off (Section 7.4.3.1). Alan engendered a sense of continuity from lesson to lesson, a reflection perhaps of his experience in teaching the VCE subject.

Alan’s classroom environment was a hybrid of traditional and contemporary teaching and learning activities. The room had an ordinary whiteboard and an interactive whiteboard for visual communications. The students remained seated behind a U-shape arrangement of tables facing the boards for the entire lesson. Alan’s overall board time was less than either Sarah or Tamara’s (Appendix 9).

Alan walked around the front of the U-shape constantly when he was not at the board, challenging, monitoring, encouraging, and assisting student progress. Teacher-to-student interactions were constant, while student-to-student interactions were minimal (Section 7.4.4.1). There was no visible or audio-captured student distraction in Alan’s classroom. His regular lessons were very quiet.

Alan’s regular classroom field was student centred, extremely quiet, and peculiar to Alan’s interpretation of mathematics teaching and learning.

9.2.1.4 Case Y7 Team

Helen was observed teaching regular lessons in a closed classroom using a similar format to Sarah and Tamara’s style. Helen’s students sat around tables and swivelled when Helen was at the board. The students were enthusiastic but easily distracted, and Helen worked hard to keep them engaged with continual interaction between teacher and individuals or the class as a whole (Section 8.3.4.2). Helen invited the students to work examples on the board (Section 8.3.4.2).

The Year 7 students had been streamed according to mathematics ability, and Helen’s class was considered by the Year 7 teachers to be the weakest (Section 8.2.3). Evidence collected during the Maths Pathway trial indicated that Helen’s class encountered similar progress problems to Luci’s class (Sections 8.4.3.5 and 8.4.3.6). This idea cast a shadow of doubt over the strength of Helen’s class when compared to Luci’s and hence the validity of the description “weakest” (Section 8.3.3).
Helen’s story revealed a traditional and not particularly engaging experience of learning mathematics at school. Helen excelled in science and discarded mathematics at university. She qualified to teach mathematics at middle school level as a special need’s teacher. Her personal story indicated perhaps a lack of self-belief about doing and teaching mathematics and a strong belief in helping the disadvantaged (Section 8.3.1.2). Helen was possibly influenced by a prevailing idea from her schooldays about girls and mathematics that had eroded her confidence, which she now sought to rectify for her students. This idea was not discussed or confirmed with Helen at the time.

Helen’s regular classroom field was noisy and teacher centred, with a class of enthusiastic but easily distracted students.

Bec and Luci, and then Bec and Catherine, combined their Year 7 mathematics classes for a different field dynamic. However, the lessons were very similar to Helen’s. Neither Helen’s closed classroom field nor Bec and Catherine’s open plan learning environment influenced curriculum delivery. The lessons were effectively the same.

The Year 7 teachers had an agreed approach to delivering a well-developed, resource-laden curriculum (Section 8.3.1). The influence of curriculum authority was evident with respect to covering content. Learning outcomes were not stated or discussed. The Year 7 mathematics teachers adhered to the assessment requirements of the IB MYP.

9.2.2 Regular digital technology use

Each of the classrooms observed was equipped with generic digital facilities. These included a network-cabled interactive whiteboard. Wi-fi capability provided personal device access to the school’s network and hence the school’s intranet and the internet. The digital infrastructure reflected the influence of the school’s leadership and Federal Government funding (Section 1.1). The teachers used personal laptops in lessons, as did the VCE students and Year 10 students (Section 5.3.2). Each Year 7 student had an iPad (Section 8.3.5).

The regular use of digital infrastructure for administrative tasks, accessing online resources, and communicating with students via the interactive whiteboard and email
caused very little concern for the four case study teachers under normal circumstances. Each had been using these facilities for more than five years.

The use of digital technology for the specific teaching and learning of mathematics varied considerably for teacher participants. Some mathematical digital uses were established and some innovative. New uses were considered a digital disruption to the regular classroom field and were analysed using the IUM on a case-by-case basis.

The following sections describe beliefs identified in teacher pedagogical practices and the use of digital technology.

9.3 Pedagogical Beliefs About Mathematics

9.3.1 Analysis of mathematics pedagogical beliefs

Habitus, the set of teacher dispositions including beliefs, guided the actions of the inhabitants in the field (Bourdieu, 1977). The beliefs guiding teacher delivery of mathematics pedagogy were interpreted from the statements, actions, and intentions of the teacher in the classroom (Reay, 2004). Analysis results were organised along beliefs themes about mathematics, lesson intentions, concept understanding, and concept application. Collected data were compared to instrumental comparison tables developed for this study using understandings of Levin and Wadmany (2006). Refer to Table 4.5.

9.3.2 Absolutism and relativism of mathematics

Levin and Wadmany (2006) intertwined beliefs about mathematics into their pedagogical categories. Teacher-led instructional activities, passing information, and concern for assessment are indicative of an absolutist viewpoint that mathematics exists independently of individual interpretation. Cognitive activities for learning indicate a teacher with a relativist view of mathematics in which mathematics is constructed in the mind and is relative to context and the individual. Ernest (1991) recognised that teachers could have an absolutist belief about mathematics and teach from a relativist perspective and vice versa (Section 4.1.4).

I noticed that each participant teacher taught a disconnected bubble of mathematics that was constructed around curriculum requirements. In 17 observed lessons, the mathematical links to external contexts were minimal, and historical references were
nonexistent. The VCE students studied the Ant Problem, where the ant only walked in a straight line (Section 7.4.4.1). The Year 7 students were asked to locate a butterfly that was stationary in the centre of a flipchart slide (Section 8.3.4.2). These actions were indicative of an absolutist perspective.

Sarah and Helen used instructional techniques related to an absolutist viewpoint. Tamara and Alan used inquiry-based and strong collaborative learning activities that indicated a leaning towards relativism. Participant teacher beliefs about mathematics are summarised in Table 9.1.

Table 9.1  Teacher Beliefs–Mathematics

<table>
<thead>
<tr>
<th>Case</th>
<th>Beliefs</th>
<th>Action Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarah</td>
<td>Absolutism</td>
<td>Curriculum driven concept of inverse: “When you sketch the original function, put the line ( y = x ) in” (Section 5.4.3.3)</td>
</tr>
<tr>
<td>Tamara</td>
<td>Absolutism with relativism techniques</td>
<td>Curriculum driven: “I don’t always give you all the answers, because I want you to think about it” (Section 6.4.4.1)</td>
</tr>
<tr>
<td>Alan</td>
<td>Absolutism with relativism techniques</td>
<td>Curriculum driven: “I’m glad you are thinking. I deliberately wanted you to” (Section 7.4.3.1)</td>
</tr>
<tr>
<td>Helen</td>
<td>Absolutism</td>
<td>Curriculum driven concept of axes: “If I do this, we put two lines in” (Section 8.3.4.2)</td>
</tr>
</tbody>
</table>

9.3.3  Mathematics pedagogical beliefs derived from learning intentions

The participant teachers struggled with the request to provide learning intentions prior to observed lessons. Sarah, Tamara, and Helen replied in terms of curriculum compliance with the lesson’s topic, such as gradient at a point (Section 6.4.1) or Cartesian plane (Section 8.3.4.2), and Alan not at all. Despite this, the lessons flowed smoothly and were clearly planned. The underlying lesson plan was inferred from observations as the lesson unfolded, while learning intentions were interpreted from the lesson plan. Refer to Table 9.2 for a comparison summary of teacher beliefs with action examples reflected in learning intentions.

Sarah, Tamara and Helen followed a traditional plan for each of their lessons, comprising notes, recall/concept, worked example demonstrations, skills practice and
problem-solving, and homework, although not every step appeared in every lesson (Sections 5.4.1.1, 6.4.1, 8.3.1).

Tamara spent more class time on collaborative interaction, skills practice activities, and problem-solving, with little time spent on worked examples (Appendix 9). While the two teachers had similar lesson plans, Sarah had a greater focus on teaching and demonstrating, and Tamara had greater focus on student interaction and practice.

The collaborative Year 7 teacher team had agreed on delivering consistent uniform mathematics lessons using the same plan (Section 8.3.1). Helen’s observed lessons were dominated by practice exercises (Appendix 9). Homework was set regularly each week. The “rich task” activity that was observed in Lesson Y7O4 followed the same lesson structure.

Case Sarah: Learning intentions were bound to curriculum content and otherwise unconscious. Lesson plans were formulaic. In observed lessons, Sarah focused mainly on worked examples. Concept learning was achieved through instruction and passing information, and teacher demonstrations of processes. Application learning was through repetitious practice exercises either at school or at home. Sarah’s learning intentions primarily indicated a learning belief in behaviourism.

Case Tamara: Learning intentions were bound to curriculum content and otherwise unconscious. Lesson plans were formulaic but focused as a priority on providing collaborative learning opportunities for students. Teacher and students participated in concept understanding development together, while practice applications included teacher–student and student–student interactions. Tamara’s learning intentions indicated traces of behaviourism and learning through cognitive and social constructivism. Tamara shifted from one style to another dictated by the need to keep up (Section 6.4.3.1).

Case Y7 Team: Learning intentions were bound to curriculum content and otherwise unconscious. Lesson plans were consistent and formulaic, with the same approaches used for concept understanding and concept application. Helen’s learning intentions were indicative of a belief in behaviourism.
The learning intentions of Alan’s lessons were curriculum driven with learning for understanding derived from small, goal-directed activities and the application of mathematical concepts in problem-solving activities (Section 7.4.3.1). Traditional elements were evident, but the variety in his four observed lessons disguised any underlying pattern. Skills practices, summary notes, and worked example demonstrations were intertwined when needed with concept understanding and application and were not specific to one section or the other (Section 7.4.4.1). Each of Alan’s lessons started from where the previous lesson had ended, that is, not always with a new concept.

Case Alan: Learning intentions were unspoken but evidently bound to curriculum content. Learning was enacted in a teacher-facilitated environment of goal-directed concept activities and application of concepts to semirealistic problems. Alan’s learning intentions indicated multiple facets but were best described as cognitive constructivism with a hint of social and radical constructivism indicated by the focus on individual cognition and the achievement of goals.

<table>
<thead>
<tr>
<th>Case</th>
<th>Beliefs</th>
<th>Action Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarah</td>
<td>Behaviourism; curriculum-driven, repetitious, and formulaic plan</td>
<td>Sarah followed a consistent lesson plan. Skills exercises were set for homework (Section 5.4.1.1).</td>
</tr>
<tr>
<td>Tamara</td>
<td>Cognitive and social constructivism; curriculum-driven, repetitious plan with collaborative tendencies</td>
<td>Collaborative concept activities took more time (Section 6.4.3.1)</td>
</tr>
<tr>
<td>Alan</td>
<td>Cognitive and social or radical constructivism; curriculum-driven, flexible plan featuring goal-directed activities</td>
<td>Adapted the lesson to suit students’ expressed concerns (Section 7.4.3.1)</td>
</tr>
<tr>
<td>Helen</td>
<td>Behaviourism; curriculum-driven,</td>
<td>Homework was always a Maths Mate worksheet (Section 8.3.4.6)</td>
</tr>
</tbody>
</table>
repetitious, and
formulaic plan

9.3.4 Mathematics pedagogical beliefs derived from student note taking

At VCE level, note taking is both a learning strategy and a potential assessment aid given the possibility of taking notes into Part B assessment tasks (Section 5.4.3.2). The VCE teachers approached student note taking in different ways.

Case Sarah: Sarah emailed information to the students including detailed digital files of notes (Section 5.4.3.2). In classes, students copied the notes from the files to handwritten notebooks. Sarah believed in providing the notes for students to copy, which is a teacher strategy of passing information.

Case Tamara: Tamara provided notes in lessons, wrote notes on the board to copy, adding verbal explanations as she proceeded (Section 6.4.3.2), or asked the students to write their own notes. The notes activities were conducted in a collaborative environment that allowed for student and teacher interactions and individual thinking. Tamara’s notes approach used listening, thinking, creating, writing, and copying notes. Tamara’s approach was indicative of knowledge construction and passing information.

Case Alan: Students acquired notes in Alan’s classes by working their way through various concept activities that required cognitive effort and individual student written responses (Section 7.4.3.2). At the end of the activity, Alan wrote a succinct summary on the board, allowing students to check their work or copy (Section 7.4.3.2). Alan’s strategies promoted thinking, problem-solving, asking and answering questions, writing, listening, watching, checking, and copying. Student learning was acquired through a co-construction of meaning by the class as a whole and individual progress in reaching a goal.

Case Y7 Team: Helen provided notes in one observed lesson. After a class discussion on the Cartesian plane, Helen provided a printed sheet of questions with blank spaces to fill in. Students were given time to complete the sheet, Helen reviewed the answers, and students pasted the sheet into their notebooks (Section 8.3.4.4). This note-taking technique included reading, writing, listening, recall, and checking. Her use of scaffolding added the possibility for student thinking and hence the construction
of knowledge. Helen’s approaches were indicative of teacher scaffolding, recall, and passing information for student learning.

The Year 7 teachers referred to notes during Maths Pathway sessions. Luci instructed students to write their own notes about things that were new, that they needed help with, or thought were interesting. Helen added “things that might be on a test” (Section 8.2.1). The teachers did not refer to note taking in any other observed Year 7 lesson. There was no evidence collected that the students had constructed notes from the two cycles of Maths Pathway. Refer to Table 9.3 for teacher beliefs about notes.

Table 9.3  *Mathematics Pedagogical Beliefs–Notes*

<table>
<thead>
<tr>
<th>Notes Strategies</th>
<th>Beliefs</th>
<th>Action Examples</th>
</tr>
</thead>
</table>
| Sarah            | Learning through the senses  
Passing information | “What I have done for you is make a list of this summary of what you need to know for inverse functions” (Section 5.4.3.2) |
| Tamara           | Learning through the senses  
Co-construction of meaning  
Knowledge construction | “The definitions there, girls, are straight out of your textbook as well” (Section 6.4.3.2) |
| Alan             | Learning through the senses  
Co-construction of meaning  
Individual progress | “The goal needs to be explicitly stated, written on the board and highlighted” (Section 7.4.3.2) |
| Helen            | Learning through the senses  
Scaffolding  
Passing information | Helen gave the students printed worksheets to annotate and stick in their notebooks as a means of creating notes about the Cartesian plane (Section 8.3.4.4) |
9.3.5 Mathematics pedagogical beliefs derived from concept understanding activities

9.3.5.1 Case Sarah

Sarah exhibited a consistent approach to concept teaching and learning in her regular lessons, with a minimal introduction to the concept followed by a demonstration of several worked examples taken from the textbook (Sections 5.4.3.3). Sarah invited student participation in demonstrations by drilling for answers with easy and repeated questions to the class as a whole. Generally, the class answered in chorus (Section 5.4.3.3).

While she was at the board, Sarah did not respond well to interruption (Section 5.4.3.5). She gave an impression that she was working from memory rather than connected reasoning. Sarah referred to the technique of memorising for students several times—memorising the quadratic formula (Section 5.4.3.3) and memorising for exams—rather than relying on the notes (Section 5.4.3.2). It seemed that memorising had been a characteristic of Sarah’s personal learning as well as a strategy that she promoted for students.

Sarah’s pace of lesson delivery was very detailed and slow. She provided the structure of lessons in the digital notes file and encouraged self-paced learning for speedier students (Section 5.4.3.2). These actions were identified as catering for student difference with the opportunity for attaining understanding within the teacher’s prepared structure. Sarah provided links to internet tutorials and games in the digital notes file, but there was no evidence in the four observation lessons that Sarah’s students used the additional internet links to further enhance their learning.

Sarah’s techniques for concept understanding comprised teacher instruction on new information and procedures for some students and, for other more independent students, self-paced learning of teacher-prepared tasks and the opportunity for extended learning. These actions indicated a teacher belief in direct instruction and a concern for individual student needs.
9.3.5.2 Case Tamara

Tamara’s concept activities were varied and engaged the class as a whole or in smaller groups. Observed lessons provided evidence of recall, instruction, exploration, and revision techniques used by Tamara. Board work was interactive and presented or guided by the teacher or the students (Section 6.4.3.1). At times, Tamara interrupted an activity to revisit a concept, to teach a new Mathematica command, or to change a problem to make it easier to understand (Sections 6.4.3.1 and 6.4.3.3). Tamara’s interruptions indicated a degree of flexibility in her teaching model and an ability to respond to what was happening in the moment.

Tamara initiated and scaffolded collaborative concept activities such as student concept presentations and students teaching students in groups (Sections 6.4.3.1 and 6.4.3.3). Despite leaving students to their own devices, Tamara remained an influential presence in the classroom, stepping in to assist when needed (Section 6.3.1).

Tamara’s techniques for concept understanding included scaffolding, coaching, instructing, training, modelling, recalling, revising, questioning, and teacher/student collaboration. These teaching characteristics were indicative of a belief in a co-construction of meaning in the social environment of a classroom lesson.

9.3.5.3 Case Alan

Concept understanding was achieved in Alan’s lessons through teacher-guided discovery activities or teacher-scaffolded investigations (Section 7.4.3.1). During concept activities, the class worked together with significant interaction between teacher and students but minimal interaction between students and students (Section 7.3.3.1). Student suggestions led the teacher through the car zooming/pen tossing activity in Lesson AO4 (Section 7.4.3.1).

Alan worked examples on the board when students requested help (Section 7.4.4.1). He provided reasoning for all the steps he initiated and expected the same of his students (Section 7.4.4.1). He challenged students to apply new understandings in reasonable ways. Alan’s questions to students required listening, thinking, and public speaking (Section 7.3.2.2) or private speaking for his three students who did not cope well with a public forum (Section 7.2). Alan’s noticeable restraint on student–student
interactions was interpreted as a teacher belief in individual student cognition mediated by the teacher.

Alan’s strategies for concept understanding promoted reasoning and connection to previous learning, adaptation to individual student needs, collaborative interactions mediated by the teacher, and individual student cognition and progress. These strategies were indicative of a belief that knowledge was acquired in an adaptive cognitive process.

9.3.5.4 Case Y7 Team

Helen’s lesson on the Cartesian plane in Lesson Y7O3 comprised a teacher-led recall of previous learning and worked examples on the board (Section 8.3.4.2). Student attention fluctuated during the activity, and Helen worked hard with individuals to keep them on task. One strategy was to invite students to work the examples on the board. This particular activity was interpreted as a recall of previous learning.

Lesson Y7O4 led by Catherine and Lesson Y7O5 led by Bec were sourced from Helen and followed a similar approach (Sections 8.3.4.4 and Section 8.3.4.5). In particular, the teachers emphasised the need for students to “follow instructions”. Concept understanding primarily relied on teacher instructions, memory, and repetition and less so on reasoning.

Helen’s strategies for concept understanding comprised teacher instructions, recall, and memorising. Helen’s actions indicated a belief in direct instruction and a concern for individual student needs.

Refer to Table 9.4 for a comparison of teachers’ beliefs about concept understanding.

9.3.6 Mathematics pedagogical beliefs about concept application strategies

Practice exercises and problem-solving tasks are agreed features of both the VCE curriculum and the Year 7 curriculum. Alan bundled worked examples, practice exercises, problem-solving, revision, and assessment into a single construct, which was seen as the application of the newly acquired concept (Section 7.4.4.1). By contrast,
Table 9.4  
*Mathematics Pedagogical Beliefs – Concept Understanding*

<table>
<thead>
<tr>
<th>Case</th>
<th>Beliefs</th>
<th>Action Examples</th>
</tr>
</thead>
</table>
| Sarah   | Passing information on new ideas and procedures  
          Student individual needs | Instructing, recalling, drilling, providing structure  
          “Where the graph crosses the axes. . . What is the easiest way to find the x-intercept and the y-intercept?” (Section 5.4.3.3) |
| Tamara  | Facilitating learning to meet student needs | Instructing, reasoning, exploring, modelling, coaching, collaborating  
          “I think you can answer these questions, without me giving you lots of information, based on what we have covered in chapters 4, 5 and 6” (Section 6.4.3.1) |
| Alan    | Accomplishment of goals  
          Reasoning  
          Co-construction of meaning  
          Transmission of knowledge  
          Individual student needs | “If it’s related to this, this has an asymptote and if it’s related to that, then that should have an asymptote as well. Sounds logical” (Section 7.4.3.1) |
| Helen   | Instruction  
          Recall  
          Repetition  
          Memory | “I have a sheet of paper and I am going to get you to label the Cartesian plane and then see if you can fill in the blank spaces on the piece of paper. I apologise because it is quite small. Stick it in your notebooks” (Section 8.3.4.4) |

Sarah, Tamara, and Helen spoke about practice exercises, problem-solving, and revision and assessment as separate identities (Sections 5.4.3.4 and 6.4.5).

9.3.6.1 Case Sarah

When worked examples had been completed, Sarah devoted any remaining lesson time to practice exercises. While students worked she assisted individual students (Section 5.4.4.1). Homework for each of Sarah’s lessons was to finish the exercises (Section 5.4.2.2). Sarah did not review homework in the observed lessons, an action that indicated perhaps that practice exercises were the responsibility of the students. However, Sarah provided VCE students online solutions to practice exercises on Padlet when students posted a request for help.
Sarah’s actions indicated a belief in student-driven repetition of application procedures for learning. The teacher showed little concern for completed exercises during lessons but provided exercise solutions online when requested.

9.3.6.2 Case Tamara

Tamara devoted the largest proportion of her observed lessons to practice exercises, but this may not have been typical (Section 6.4.4.1). The teacher and students interacted in a collaborative environment as students sought assistance from the teacher but also from each other. Tamara challenged her students to make their own decisions about homework (Section 6.4.2.2). Tamara’s concept application activities exhibited a degree of flexibility, student choice, and teacher concern for application understanding.

Tamara’s actions indicated a consistent belief in teacher-facilitated, collaborative student-centred learning for concept applications of practice exercises and problem-solving.

9.3.6.3 Case Alan

During application activities, Alan did not demonstrate worked examples in the first instance but instead left the students to discover if they could use their acquired knowledge to complete examples and exercises without his help. Alan continually monitored student progress and assisted individuals in short bursts of time only to ensure his attention did not stray from the class in general (Section 7.4.4.1).

Alan’s actions indicated an holistic approach to concept understanding and application. He continually monitored and facilitated student progress and achievement for concept application activities in class. His actions were indicative of a belief in inquiry-based learning and individual student progress.

9.3.6.4 Case Y7 Team

Helen’s approach to concept application in Lessons Y7O1 to Y7O4 featured practice exercises with individual student intervention when needed and continual teacher monitoring of student progress and their attention to set tasks. Regular homework was a Maths Mate worksheet corrected in class.

Helen’s students showed a dependency on the teacher for instructions, explanations, reminders, and assistance for application activities. Helen’s actions
indicated a belief in teacher instruction and teacher-facilitated repetition of application procedures. Refer to Table 9.5 for a comparison of teacher beliefs about concept application.

### Table 9.5  
*Mathematics Pedagogical Beliefs – Concept Application*

<table>
<thead>
<tr>
<th>Concept Application</th>
<th>Beliefs</th>
<th>Action Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarah</td>
<td>Learning through senses</td>
<td>“This is correct but you get penalised for writing that. So, you should write $y$ inverse. Inverse is shown as the power of a negative number” (Section 5.4.3.4)</td>
</tr>
<tr>
<td></td>
<td>Constructing knowledge with teacher assistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Independent student repetion of application procedures</td>
<td></td>
</tr>
<tr>
<td>Tamara</td>
<td>Learning through senses</td>
<td>“I am not even going to go through that with you because that is really revision”</td>
</tr>
<tr>
<td></td>
<td>Cognitive adaption</td>
<td>“Did anyone use the shortcut rules I showed you in term 2? If you need to revise let me know” (Section 6.4.4.1)</td>
</tr>
<tr>
<td></td>
<td>Constructing knowledge with teacher and peer collaboration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Student independence and choice</td>
<td></td>
</tr>
<tr>
<td>Alan</td>
<td>Learning through senses</td>
<td>“I want you to explore this graph. Where is the function and its derivative equal to zero, greater than zero, and less than zero?” (Section 7.4.3.1)</td>
</tr>
<tr>
<td></td>
<td>Cognitive adaption</td>
<td>“What can I do with that? What can I do with anything?” (Section 7.4.4.1)</td>
</tr>
<tr>
<td></td>
<td>Achieving a goal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Constructing knowledge in a whole-of-class collaboration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>facilitated by teacher</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individual student learning</td>
<td></td>
</tr>
<tr>
<td>Helen</td>
<td>Learning through senses</td>
<td>“The only worded questions they have down are when I’m standing at the board and saying, what do you need to do next?” (Section 8.3.4.7)</td>
</tr>
<tr>
<td></td>
<td>Constructing knowledge with teacher assistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dependence on teacher for concept application</td>
<td></td>
</tr>
</tbody>
</table>

#### 9.4 Digital Technology Pedagogical Beliefs

**9.4.1 Analysis of digital technology use and purpose**

Digital technology uses were analysed in terms of the IUM. Progress or regress on the IUM hinged on beliefs about self-efficacy, control, purpose and benefit, and success or failure sensed personally and perhaps reinforced positively or negatively by external influences (Table 4.6). These beliefs were interpreted from the intentions,
actions, and statements of the participants in observed lessons and post-lesson interviews.

In addition, digital purposes were compared to the digital technology roles defined by Goos et al. (2003) in order to identify how much responsibility or agency the teacher was prepared to assign to the digital technology (Table 4.3). Ultimately, the digital technology analysis was conducted to identify beliefs patterns that facilitated or obstructed digital technology use in the mathematics classroom.

The complete list of digital technology use, purpose, and benefit observed in lessons and/or discussed at interview can be found at Appendix 10. In general, the participant teachers did not disclose their intentions for digital technology, the purposes of use, or the benefits to learning. Most purposes/beliefs listed were inferred from my observation of classroom practices.

Alan and Tamara had both said to me that they were using no technology in lessons; however, they each used five or six different technologies (Sections 6.4.1 and 7.4.1). I assumed that taking digital technology for granted indicated teacher certainty about digital use. By contrast, Sarah did not take digital technology use for granted. Her intentions for Padlet and Slideshow suggested several purposes for the applications (Section 5.4.1.2). Year 7 teachers used little digital technology for pedagogical purposes in the classroom other than flipcharts.

An awareness of digital technology intentions, purposes, and benefits contributed to initiating the use of digital technology at the start of Innovation Uncertainty Model IUM-A and to the assessment of digital technology success at point IUM-B or failure at point IUM-F (Section 4.2.3.5).

The following analysis has been organised in terms of generic digital technology in lessons, Mathematica application in VCE lessons, Maths Pathway in Year 7 lessons, and finally, other digital technologies used for pedagogical purposes in observed lessons.
9.4.2 Pedagogical beliefs about generic classroom digital technologies

9.4.2.1 School’s digital infrastructure

The teachers and students’ laptops, internet, intranet, the interactive whiteboard, and wi-fi networks had been established for more than five years at the participant school. These digital technologies did not specifically relate to mathematics pedagogy but facilitated the learning of mathematics indirectly by supporting communication and organisation, and enabling the use of mathematics-specific applications, for example, Maths Pathway.

The digital infrastructure was taken for granted until it failed, for example, with an overnight power failure prior to Lesson AO1 (Section 7.4.2.1). The participant teachers believed the infrastructure to be vulnerable, evidenced, for example, when Helen replied, “That’s a surprise” when I commented that the technology had worked (Section 8.3.4.7).

9.4.2.2 Generic-use digital technologies in the classrooms

Sarah, Tamara, and Helen were all observed using generic technologies in lessons with confidence and competence. The benefits of these technologies were efficiency gains, with outcomes requiring less time, effort, or cost to the school, the students, or the teacher. These technologies were categorised as servants (Goos et al., 2003), fulfilling professional duties such as recording attendance, facilitating communications using the interactive whiteboard and email, and managing resources using digital document storage, for example. The digital actions in these well-defined tasks contributed indirectly to the more efficient teaching and learning of mathematics.

Alan was slightly less comfortable than his colleagues were with generic digital technologies, despite having been exposed to them for an equal length of time. Examples such as starting up the board from the Apple agent (Section 7.4.2.1), connecting sound to the board (Section 7.4.2.1), and emailing students in class (Section 7.4.6.3) flustered him.

Alan’s reactions to generic digital applications were interpreted as an issue with control. Alan relied on external control—the students, the IT technicians, and me on one occasion—when things went wrong. Alan made small humorous comments that
displayed self-consciousness about asking for help, such as “Talk about taking risks with technology” (Section 7.4.2.1). Relying on external control did not engender the same sense of certainty for Alan as the internal control displayed by Sarah, Tamara, and Helen. Alan believed in using digital technology in the classroom “provided that the technology works” (Section 7.4.6.6).

The evidence suggested that Alan did not see the need for digital technology other than the nongeneric Mathematica to fulfil the VCE curriculum requirement for digital technology use. A reliance on external support and an ambivalence towards the value of technology left Alan with a need to overcome a degree of uncertainty about using digital technology in lessons and a lack of competence and/or confidence in dealing with technology issues himself when they arose.

Refer to Table 9.6 for the analysis of Alan’s beliefs about the use of the digital board.

Table 9.6 Alan Pedagogical Beliefs–Interactive Whiteboard (IWB)

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>IUM-A Start</td>
<td>Influences</td>
<td>Schoolwide facility</td>
<td>Positive</td>
<td>Master</td>
</tr>
<tr>
<td></td>
<td>Intentions</td>
<td>Communication</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self-efficacy</td>
<td>Established</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>External reliance</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purpose</td>
<td>Communication</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-H</td>
<td>Unsuccessful</td>
<td>Booting board (AO1) failed due to power failure</td>
<td>Uncertainty caused by external effect</td>
<td>Master</td>
</tr>
<tr>
<td>IUM-G</td>
<td>Unsuccessful</td>
<td>Incompetent connecting sound to board (AO2)</td>
<td>Uncertainty due to lack of knowledge</td>
<td>Master</td>
</tr>
<tr>
<td>IUM-C</td>
<td>Successful</td>
<td>IWB working (AO3)</td>
<td>Efficient</td>
<td>Servant</td>
</tr>
<tr>
<td>IUM-I</td>
<td>Influence</td>
<td>External assistance</td>
<td>Negative self-efficacy</td>
<td></td>
</tr>
<tr>
<td>IUM-E</td>
<td>Influence</td>
<td>No assistance</td>
<td>Positive self-efficacy</td>
<td></td>
</tr>
<tr>
<td>Beliefs</td>
<td>External support</td>
<td>Facilitate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weak internal control</td>
<td>Obstruct</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9.4.2.3 Assessment tracking

Tamara was observed using assessment-tracking software twice (Section 6.4.2.1). She was new to the module and lacked confidence at first. Tamara mentioned the ease of using the software was offset by a duplication of effort in entering marks in the
assessment tracking and the reporting systems. Tamara was caught in a state of uncertainty about the application due to an imbalance in advantage and disadvantage. By the end of the year, Tamara said the application was well established as part of her teaching role, but the uncertainty remained. It seemed that her animosity was directed towards report writing, over which she had little control rather than the assessment-tracking software (Section 6.4.2.1). Refer to Table 9.7 for Tamara’s beliefs.

Table 9.7 Tamara Pedagogical Beliefs–Assessment Tracking

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>IUM-A Start</td>
<td>Influences</td>
<td>Schoolwide facility</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self-efficacy</td>
<td>Developing</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Developing</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purpose</td>
<td>Storing &amp; communicating assessment results online</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-C</td>
<td>Successful</td>
<td>Store SAC results</td>
<td>Efficient</td>
<td>Servant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide SAC marks &amp; teacher feedback</td>
<td>Effective</td>
<td>Partner</td>
</tr>
<tr>
<td>IUM-D</td>
<td>Influence</td>
<td>Report duplication</td>
<td>Negative self-efficacy</td>
<td></td>
</tr>
<tr>
<td>Beliefs</td>
<td></td>
<td>Efficient and effective feedback</td>
<td>Facilitate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duplicated effort</td>
<td>Obstruct</td>
<td></td>
</tr>
</tbody>
</table>

9.4.3 Pedagogical beliefs about the use of Mathematica

9.4.3.1 External influence

For some time, the VCE Study Design (VCAA, 2010–2015) has included the use of a CAS for students to produce results, develop mathematical ideas, and assist in the analysis of investigations and problem-solving. Students also needed to make their own decisions about when to use CAS. The participant school had been using the CAS application Mathematica for five years and, prior to that, a CAS handheld device. Alan was an experienced user of Mathematica, Tamara had used a CAS device previously but not Mathematica, and Sarah had used Mathematica for one year only. Evidently, the three teachers were at different stages of Mathematica certainty achievement.
9.4.3.2 Case Sarah: Continuing uncertainty

Sarah’s observed use of Mathematica indicated a state of continuing uncertainty for a number of reasons. Sarah appeared to be somewhat reluctant to use Mathematica. Her use was limited in the observed lessons to the graphing of a hybrid function and the solution of a three-variable set of simultaneous equations. Her confidence, competence, and control were high, but her demonstrations were tedious and slow (Section 5.4.6.1). The efficiency of using the software was offset by the inefficiency of teacher explanations. In addition, Sarah changed her mind about using Mathematica, preferring to demonstrate manual mathematical methods.

Sarah did not embrace independent student choice for using Mathematica, and its use was debated with students in every observed lesson. Sarah acknowledged her students lacked confidence; however, she expressed a dismissive attitude towards the student who was “bad at Mathematica” (Section 5.4.6.2).

During one interview, Sarah expressed doubts about using a calculator because it diminished mental agility (Section 5.4.6.4). This idea, combined with her reluctance to use Mathematica and the mixed message to students, contributed to an interpretation that Sarah prioritised manual computations because she associated the use of Mathematica with a loss of mental agility.

Sarah’s data analysis suggested gaps in the purpose and use of Mathematica, despite strong commitment to the curriculum. Mathematica remained uncertain for Sarah and perhaps posed a risk related to the loss of learning advantage of mathematical skills. Refer to Table 9.8 for Sarah’s beliefs about Mathematica.

Table 9.8 Sarah Pedagogical Beliefs–Mathematica

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>IUM-E</td>
<td>Influences</td>
<td>VCE curriculum</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mental agility beliefs</td>
<td></td>
<td>Uncertain</td>
</tr>
<tr>
<td>IUM-A</td>
<td>Self-efficacy</td>
<td>Developing</td>
<td>Uncertain</td>
<td>Uncertain</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Developing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purpose</td>
<td>Curriculum requirement</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-B</td>
<td>Successful</td>
<td>Produce results</td>
<td>Efficient</td>
<td>Servant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check answers</td>
<td>Effective</td>
<td>Partner (S)</td>
</tr>
</tbody>
</table>
IUM-F

Unsuccessful

Manual method before Mathematica

Inefficient

IUM-E

Curriculum Requirement

Negative self-efficacy

Beliefs

Self as a user
Facilitate

Manual method
Obstruct

Loss of mental agility
Obstruct

9.4.3.3 Case Tamara: Mathematica rookie

Tamara’s expertise with Mathematica was still developing (Section 6.4.7.1). She copied Alan’s Slideshow files and relied on Sarah’s Mathematica glossary and student expertise for command knowledge in lessons. Tamara displayed confidence, competence, and control when observed on the few occasions she used Mathematica or set a digital task for students. Students’ regular questions and teacher instructions indicated that student decision-making about using Mathematica remained an issue (Section 6.4.7.1).

Tamara’s valuing of Mathematica shifted over the duration of data collection from Mathematica being a curriculum requirement to a significant tool for graphical manipulation and tracking student thinking, and ultimately an efficient tool for solving problems (Section 6.4.7.1). Tamara promoted Mathematica to her students usually (Section 6.4.7.1) but also mentioned that its use was “to cheat” on one occasion (Section 6.5.2.1). Tamara was oscillating a little on the IUM but slowly acquiring greater certainty.

After the final observation, Tamara felt she had not modelled using Mathematica enough and attributed this to a lack of time and the fact that she was dealing with a new subject as well as a new software application. In her own words, her use of Mathematica “was still developing” (Section 6.3.4). Refer to Table 9.9 for Tamara’s Mathematica beliefs.

9.4.3.4 Case Alan: Experienced Mathematica

Alan’s sense of completeness about his lessons was indicated when he said, “The main thing is that when I prepare to teach, all that I do is in my head. So, to add additional technology, I would have to think I needed it and then find it.” (Section 7.4.3.2). Alan could teach every element of the curriculum without digital technology until the VCAA added digital technology use of a CAS to the curriculum. In significant
contrast to his use of generic technologies, Alan had embraced Mathematica (Section 7.4.6.4).

Table 9.9  *Tamara Pedagogical Beliefs–Mathematica*

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>IUM-E</td>
<td>Influences</td>
<td>VCE curriculum</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alan’s M-files</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sarah’s glossary</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student expertise</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-A</td>
<td>Self-efficacy</td>
<td>Developing</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Developing</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purposes</td>
<td>Curriculum requirements</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-B</td>
<td>Successful</td>
<td>Produce results</td>
<td>Efficient</td>
<td>Servant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop mathematical ideas</td>
<td>Effective</td>
<td>Partner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solve problems</td>
<td>Effective</td>
<td>Partner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tracking student thinking</td>
<td>Effective</td>
<td>Partner</td>
</tr>
<tr>
<td>IUM-F</td>
<td>Unsuccessful</td>
<td>Cheating</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student decision-making</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td>IUM-E</td>
<td>Successes</td>
<td>Curriculum requirement</td>
<td>Positive self-efficacy</td>
<td>Negative self-efficacy</td>
</tr>
<tr>
<td>Beliefs</td>
<td>Curriculum</td>
<td>Curriculum requirement</td>
<td>Facilitate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cheating</td>
<td>Obstruct</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teacher decision-making</td>
<td>Teacher decision-making</td>
<td>Obstruct</td>
<td></td>
</tr>
</tbody>
</table>

Alan was observed using Mathematica for understanding the behaviour of the logarithmic asymptote, checking student predictions of function factors, comparing the graphs of the first and second derivatives of a quadratic function, and problem-solving. He used the application fluently as “extension of self” (Goos et al., 2012). Alan modelled CAS choice for students by alternating between using Mathematica and manual computations and plots, without comment (Section 7.4.6.4). His students did not ask him if they should use Mathematica. Using Mathematica in his lessons had become normalised for teacher and students.
Alan recognised the value of Mathematica in facilitating his pedagogical beliefs, and he wanted to use it all the time. He said that he longed to take his students beyond the curriculum to new levels of problem-solving using Mathematica (Section 7.4.6.4). Driven by the authority of the VCE curriculum, time, and experience, Alan had become Mathematica’s greatest fan. Refer to Table 9.10 for Alan’s Mathematica beliefs’ results.

Table 9.10  *Alan Pedagogical Beliefs–Mathematica*

<table>
<thead>
<tr>
<th>IUM Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IUM-E</strong></td>
<td>Influences</td>
<td>VCE curriculum</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>School choice</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>IUM-A</strong></td>
<td>Influences</td>
<td>Inquiry-based learning</td>
<td>Positive</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td></td>
<td>Established</td>
<td>Certain</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>Established</td>
<td>Certain</td>
</tr>
<tr>
<td>Purposes</td>
<td></td>
<td>Curriculum requirements</td>
<td>Certain</td>
</tr>
<tr>
<td><strong>IUM-B</strong></td>
<td>Successful</td>
<td>Produce results</td>
<td>Efficient</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop mathematical ideas</td>
<td>Effective</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discovery learning, investigation, problem-solving</td>
<td>Effective</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student decision-making</td>
<td>Efficient</td>
</tr>
<tr>
<td><strong>Beliefs</strong></td>
<td>Curriculum</td>
<td>Facilitate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mathematica functionality aligns with pedagogical approaches</td>
<td>Facilitate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self as a user</td>
<td>Facilitate</td>
<td></td>
</tr>
</tbody>
</table>

9.4.4 Beliefs derived from the use of Maths Pathway

Despite leadership encouragement, Helen did not embrace the open plan learning initiative, a shared teacher role with colleagues, or Maths Pathway use (Section 8.3.3.5). Helen provided a range of reasons for her actions. She indicated she had the weakest mathematics students and was concerned for their progress in the combined class environment. She believed her students were intimidated by the ability of other students and would remain silent in a combined class and fall further behind (Section
8.3.3.4). Helen said that with the open plan learning you had to move the weakest group into a separated area to provide additional instruction (Section 8.3.2.4). Refer to Table 9.11 for Helen’s beliefs about Maths Pathway.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IUM-A</strong></td>
<td><strong>Influences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leadership collaboration</td>
<td>Uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team teaching</td>
<td>Uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individuated learning</td>
<td>Uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preservice teacher</td>
<td>Positive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maths Pathway personnel</td>
<td>Positive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open plan PD</td>
<td>Uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IB MYP assessment</td>
<td>Uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher agreement</td>
<td>Positive</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Self-efficacy</strong></td>
<td>New</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>New</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td><strong>Purposes</strong></td>
<td>Team teaching</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td>Individuated self-paced learning</td>
<td>Uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IUM-F</strong></td>
<td><strong>Unsuccessful</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team teaching &amp; combined classes</td>
<td>Purpose–failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maths Pathway worksheets</td>
<td>Purpose–adaption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher worksheet</td>
<td>Purpose–adaption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>override of self-paced learning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of established curriculum</td>
<td>Disruption</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IUM-E</strong></td>
<td><strong>Successful</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student engagement</td>
<td>Effective</td>
<td></td>
<td>Partner</td>
</tr>
<tr>
<td><strong>Beliefs</strong></td>
<td>Established Year 7 mathematics curriculum</td>
<td>Obstruct</td>
<td></td>
</tr>
</tbody>
</table>

During data collection, Helen maintained her normal classroom practices behind closed doors. She could not move past the established comprehensive Year 7
mathematics curriculum, much of which she had created. Her strongest belief was in the established curriculum (Section 8.3.3.5).

Helen trialled Maths Pathway for about six weeks but did not respond to its purposes of identifying students’ individual needs and self-paced learning. Instead, Helen assigned the software the servant role of individual worksheet generator. Maths Pathway worksheets proved to be too easy and repetitious for the students, who did not progress quickly enough through the established curriculum to fulfil IB MYP assessment requirements. Maths Pathway was rejected (Section 8.3.3.5).

9.4.5 Other digital technology usage beliefs

Sarah in particular demonstrated that she was keen to use digital technology for the teaching and learning of mathematics. She provided students multiple links to instructive and fun websites related to the topics she was teaching (Section 5.4.3.2). She had created a digital glossary of Mathematica commands for the benefit of teachers and students; however, the students did not use it, her colleagues did (Section 5.4.6.1). Sarah introduced new applications—Padlet, SimpleMind, and Slideshow—into her observed lessons.

Despite being a little wary of Mathematica, Sarah was a digital change agent. Her computing studies at university probably contributed to a level of competence and confidence that allowed her to experiment with purposeful digital ideas. Her influence on Alan and Tamara was evidenced by their use of her glossary and the YouTube clips. Digital change agent is a difficult role to negotiate because experiments do not necessarily work as expected.

9.4.5.1 Padlet

Sarah purposefully introduced Padlet to reduce student emails asking for help, to allow for discrete student questions in class, to provide solutions to students equally, and to provide a collaborative online platform for student interaction (Section 5.4.5.1). Sarah implemented Padlet professionally with testing and a student trial, explanation, and playtime and a post-implementation survey (Section 5.4.2.1). From the start, Sarah demonstrated a high level of control, confidence, and competence.
Padlet was successful in replacing the excessive student emails that Sarah had been experiencing. Padlet began as a communication servant but evolved into a collaborative partner as more class members became involved and more than just solutions were posted on the bulletin board. Padlet was not suitable for asking discrete questions in class. Sarah said she realised that she wanted students to ask questions aloud in class for “a more collaborative learning environment” (Section 5.4.5.1) and she could answer the in-class Padlet posts after class. There was no further evidence to show that discrete questions were or were not subsequently posted in class.

At her final interview, Sarah told me that Padlet had not worked in her other classes. She suggested Padlet worked for the VCE class because they were struggling and needed discreet support (Section 5.4.5.1), and the Year 10 class did not. Sarah’s multiple reasons for using and not using Padlet confused the teacher and complicated the analysis process.

My interpretation was that Padlet worked for the VCE class because a small group of students had initiated teacher emailing, and Padlet replaced this established activity. There was a direct gain of fewer emails for the teacher and, helped by thorough implementation, Padlet proved useful as a collaborative and equitable choice for additional students in the class. Sarah continued to provide solutions on Padlet and moderate VCE student Padlet use for the rest of the year. Refer to Table 9.12 for Sarah’s beliefs about Padlet.

<table>
<thead>
<tr>
<th>IUM</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>IUM-E</td>
<td>Influences</td>
<td>Preservice teacher idea</td>
<td>Positive</td>
<td>Servant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Excessive student emails</td>
<td>Positive</td>
<td>Servant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lack of questions in class</td>
<td>Positive</td>
<td>Servant</td>
</tr>
<tr>
<td>IUM-A</td>
<td>Self-efficacy</td>
<td>New</td>
<td>Uncertain</td>
<td>Servant</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>New</td>
<td>Uncertain</td>
<td>Partner</td>
</tr>
<tr>
<td></td>
<td>Purposes</td>
<td>Replace emails</td>
<td>Positive</td>
<td>Servant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discrete questioning in class</td>
<td>Positive</td>
<td>Partner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collaboration platform</td>
<td>Positive</td>
<td>Partner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equity</td>
<td>Positive</td>
<td>Servant</td>
</tr>
<tr>
<td>IUM-B</td>
<td>Successful</td>
<td>Emails replaced</td>
<td>Efficient</td>
<td>Servant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collaborative platform</td>
<td>Effective</td>
<td>Partner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equity for students</td>
<td>Effective</td>
<td>Partner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Out-of-class solution</td>
<td>Efficient</td>
<td>Servant</td>
</tr>
<tr>
<td>IUM-F</td>
<td>Unsuccessful</td>
<td>In-class solution</td>
<td>Disruptive</td>
<td>Servant</td>
</tr>
<tr>
<td>Beliefs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------</td>
<td>------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self as a digital change agent</td>
<td>Facilitate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student communications</td>
<td>Facilitate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equity of learning advantage</td>
<td>Facilitate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Online collaboration</td>
<td>Facilitate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparation</td>
<td>Facilitate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interruptions</td>
<td>Obstruct</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9.4.5.2 Slideshow presentation software

The action of creating digital notes for students was categorised by Goos et al. (2012) as an extension of the teacher self (Goos et al., 2012). The creation of notes required teacher time and effort, but efficiency was gained when notes were reused from year to year. The learning effectiveness of these tools depended on how and how often they were used by students (Section 5.4.3.2).

Sarah decided to switch her 2014 VCE notes from flipcharts to Slideshow presentation format, a module of Mathematica. Slideshow features two modes: the plain text mode, comprising basic text formatting features and mathematical expressions, and the manipulate/plot mode, which allows the user to interactively run Mathematica commands within the file. Sarah’s purpose for notes files in general was to share resources with students—notes, links to the online textbook, and other online resources (Section 5.4.3.2). Sarah’s notes gained an interactive Mathematica capacity when transferred to the Slideshow platform. Sarah said that she hoped to save preparation time with Slideshow’s basic features and mathematical nomenclature. She expressed the wish to increase student exposure to Mathematica (Section 5.4.1.2).

Creating Slideshow slides was demanding for Sarah with a loss of personal time and the loss of the flipchart reuse advantage. During the switch, Sarah learnt new skills which she saw as a personal gain (Section 5.4.6.3). As her skill level increased, her slides became more and more complex. She began creating elaborate titles and images using ActivInspire software to insert into Slideshow slides. Sarah was using multiple applications to create her notes files. Sarah did not use Slideshow for additional Mathematica exposure in observation lessons so there were no significant gains made in that area. She faced a minor loss of face due to inexperience in switching between plain text and manipulate/plot modes (Section 5.4.6.3).
Eventually, the demands of Slideshow overwhelmed Sarah. Once new learning had ceased for the teacher, the disadvantages of recreating the files outweighed the benefits. The teacher became caught up in a beliefs conflict between the way she taught and the way she wanted to teach. I believe the crisis was triggered by Slideshow and led to a complete revaluation of her teaching practice (Section 5.5).

Sarah had a positive attitude towards using Slideshow at first. She adhered to a basic teaching belief of passing information to students through instructions, notes files, and additional resources. Using Slideshow to facilitate notes creation generated a range of advantages and disadvantages that had Sarah moving forward and backwards on the IUM. Ultimately, she found herself at position IUM-J, which represented a complete re-evaluation of her competence, performance, and control in the classroom and a rejection of her regular teaching model. Refer to Table 9.13 for the analysis of Sarah’s beliefs about Slideshow.

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>IUM-A</td>
<td>Influences</td>
<td>Change agent</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manipulate/plot mode</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>New</td>
<td>Uncertain</td>
<td></td>
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<tr>
<td></td>
<td>Self-efficacy</td>
<td>New</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Passing information</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purposes</td>
<td>Save preparation time</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exposure to Mathematica</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-B</td>
<td>Successful</td>
<td>Teacher created Slideshow files</td>
<td>Effective</td>
<td>Extend self</td>
</tr>
<tr>
<td>IUM-F</td>
<td>Unsuccessful</td>
<td>Demanding effort</td>
<td>Failure of purpose</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unchanged exposure to Mathematica</td>
<td>Failure of purpose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IUM-J</td>
<td>Unexpected</td>
<td>Awareness of conflict</td>
<td>Crisis</td>
<td></td>
</tr>
<tr>
<td>Beliefs</td>
<td>Self as a digital change agent</td>
<td>Facilitate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teacher beliefs conflict</td>
<td>Obstruct</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conflicted pedagogical beliefs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The question remained: When the burden of notes creation became too much, why did Sarah continue to use Slideshow instead of reverting to her fully prepared flipchart notes? The answer lay in an additional function for Slideshow.
9.4.5.3 Slideshow online assessment

Slideshow was used as the platform for online assessment as part of the VCE Mathematical Methods trial (Section 6.5.3) that had been running at the school for five years at Year 12 level. Slideshow plain text mode was used for posing and answering questions. The manipulate/plot mode enabled Mathematica computations and graphing in the same file. These uses only emerged towards the end of the data collection year when online assessment was extended to include Year 11 Mathematical Methods tasks.

The VCE teachers had decided that the Part B (tech-active) sections of the final SAC and the end-of-year examination would be assessed online to prepare the students for assessment in the Year 12 subject the following year. Online assessment had proved to be cost effective and contributed to a positive rationalisation for student use of digital technology at the school (Section 6.5.3). The school’s continuing practice of using Slideshow for online testing was seen as “the way of the future” (Section 7.4.6.5). The VCAA supported the school in this endeavour and continued to provide external assessment on the Slideshow platform at Year 12 level.

9.4.5.4 Tamara’s Slideshow use

Tamara copied Alan’s Slideshow files. These contained accurate Mathematica command syntax in the manipulate/plot mode and lists of practice exercises in the plain text mode. Tamara adapted the files to also provide some notes for absent students when there was a need and she had the time to make changes (Section 6.5.2.2). Tamara had not previously invested time and effort into creating notes files. She was satisfied with Slideshow’s basic text formats. Giving students notes was only one of several strategies that Tamara had adopted for note taking (Section 6.5.2.2).

Tamara’s responded to the online assessment initiative with detailed preparations seen in Lesson TO3. The technicians came into class to update student laptops to run Slideshow in a secure and accountable assessment environment. When the computers were ready, Tamara gave her students an online practice SAC prior to the online SAC, prior to the online examination (Section 6.5.3), so that they would be well practised.
Tamara solved several issues that the students raised about the assessment’s digital logistics (Section 6.5.3). She also ensured that there were printed copies of the assessment tasks available at test time to alleviate any difficulties the student might encounter when reading questions from a screen. These actions were examples of taking responsibility for and control of the digital technology change. Tamara’s personal use of Slideshow in lessons was limited; she usually asked the students to perform the Mathematica manipulations and plots.

Tamara’s Slideshow actions indicate a belief in teacher collaboration and taking responsibility for digital change. Being new to the application, her Slideshow skills and control were still developing. Refer to Table 9.14 for Tamara’s beliefs about Slideshow.

Table 9.14  
**Tamara Pedagogical Beliefs—Slideshow**

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Effect</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IUM-A</strong></td>
<td>Influences</td>
<td>Mathematica trial</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self-efficacy</td>
<td>Alan’s files</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>New</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purpose</td>
<td>Command scripts</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lists of exercises</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Notes for absentees</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online assessment</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td><strong>IUM-B</strong></td>
<td>Successful</td>
<td>Resources for students</td>
<td>Efficient</td>
<td>Extension</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assessment tasks</td>
<td>communication</td>
<td>of self</td>
</tr>
<tr>
<td><strong>Beliefs</strong></td>
<td></td>
<td>Online assessment</td>
<td>Facilitate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collegial cooperation</td>
<td>Facilitate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedagogical priorities</td>
<td>Facilitate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Responsibility for new digital ideas</td>
<td>Facilitate</td>
<td></td>
</tr>
</tbody>
</table>

9.4.5.5  *Alan’s Slideshow use*

Alan’s students primarily used his Slideshow files for reference during tech-active assessment tasks in which students were able to consult either digital or handwritten
notes and use a CAS application to answer questions on a written paper (Section 7.4.3.5). Alan’s purpose for using Slideshow related to providing students the correct syntax of Mathematica commands in a digital format to copy. Slideshow files were efficient as a purposeful digital communication medium for Alan’s students and effective in providing them assessment advantage.

Alan was experienced in using Slideshow as an online assessment tool for VCE Year 12 Mathematical Methods tech-active assessment tasks. Alan’s Year 11 students had yearlong exposure to the normalised use of Slideshow text and Mathematica commands. The switch to online assessment late in the year was virtually seamless. Refer to Table 9.15 for the analysis of Alan’s beliefs about using Slideshow.

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
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<td>External Influences</td>
<td>Mathematica trial</td>
<td>Positive</td>
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</tr>
<tr>
<td></td>
<td>Self-efficacy Control Purpose</td>
<td>School future strategy</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-A</td>
<td>Self-efficacy</td>
<td>Established Command scripts</td>
<td>Certain</td>
<td>Certain</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Established Lists of exercises</td>
<td>Certain</td>
<td>Certain</td>
</tr>
<tr>
<td></td>
<td>Purpose</td>
<td>Command scripts Online assessment</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lists of exercises</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online assessment</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-B</td>
<td>Outcomes</td>
<td>Resources for students Online assessment</td>
<td>Efficient communication Progressive</td>
<td>Extension of self Servant</td>
</tr>
<tr>
<td>Beliefs</td>
<td>Online Assessment Pedagogical approaches Strategy for the future</td>
<td>Facilitate Facilitate Facilitate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9.4.5.6 Flowcharting

Sarah introduced SimpleMind mind-mapping software in Lesson SO3 (Section 5.4.5.2). She had previously created flowcharts of mathematical processes for her notes using the licenced version of SimpleMind. When Sarah asked her students to use free SimpleMind in Lesson SO3 to flowchart the quadratic formula, her introduction was in sharp contrast to the Padlet implementation (Section 5.4.2.1). Sarah had not tested the free version of SimpleMind. She had not spoken to students about their prior
knowledge of mind-mapping software. She did not arrange for a student trial. She did not ask students to play with the application. Instead, Sarah launched into a swathe of instructions (Section 5.4.5.2). The download was successful, but the free software did not have sufficient functionality for the quadratic equation.

The students’ response was to successfully complete the quadratic task as required using Inspiration, an alternative mind-mapping application on their laptops (Section 5.4.5.2). Sarah did not wish to participate in a post-observation interview. My interpretation was that the cracks were widening for the overworked Sarah.

The flowcharting event was a rooky mistake in assuming that the functionality of an application’s free version would match the functionality of its licenced version. The mistake was exacerbated by minimal preparation unlike the effective preparation she had exhibited with Padlet’s introduction. Refer to Table 9.16 for Sarah’s beliefs about the SimpleMind student task.

<table>
<thead>
<tr>
<th>IUM</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
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<td>Personal digital objectives</td>
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</tr>
<tr>
<td></td>
<td>Self-efficacy</td>
<td>New</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>New</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purpose</td>
<td>SimpleMind representation of a mathematical process</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-F</td>
<td>Failed outcome</td>
<td>SimpleMind representation</td>
<td>Inadequate capability</td>
<td></td>
</tr>
<tr>
<td>IUM-A</td>
<td>Successful Outcome</td>
<td>Inspiration representation</td>
<td>Adequacy &amp; experience</td>
<td>Partner (S)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beliefs</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alternative representations</td>
<td>Facilitate</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Self as a digital change agent</td>
<td>Facilitate</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Lack of preparation</td>
<td>Obstruct</td>
<td></td>
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</tbody>
</table>

### 9.4.5.7 YouTube clips

Each of the three VCE teachers mentioned showing Sarah’s YouTube clips, but only Alan showed a clip, *I Will Derive*, in an observed lesson. He told his class that it was because he wanted “to be a modern teacher” and he told me that it was to make a good impression. His actions demonstrate collegial cooperation and a belief in his
awareness of modern teacher status. Teacher status became a driver for change in this case. I thought that Alan’s participation in the study raised awareness of his teacher status.

Alan’s shaky start with sound demonstrated that he had not shown a YouTube clip in a lesson before, which he confirmed (Section 7.4.6.7). Alan’s immediate reaction to the *I Will Derive* clip was that it had no value. However, although apparently unaware, he back-referenced the clip on three occasions in subsequent lessons. Alan explained that he valued the *Mean Girls* clip for providing his students a female context for tackling the difficult mathematical concept of limits.

Alan said that the YouTube clips had animated his class and that he would use both clips again (Section 7.4.6.7). While he started with dubious purpose and control, Alan had learnt to appreciate the clips and had gained sufficient incentive to continue the activity in the future. Alan’s experiment with YouTube clips was successful. Refer to Table 9.17 for Alan’s beliefs about using YouTube clips in mathematics lessons.

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Benefit</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
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<td>IUM-A</td>
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<td>Colleagues</td>
<td>Positive</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Research participation</td>
<td>Positive</td>
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</tr>
<tr>
<td></td>
<td>Self-efficacy</td>
<td>New</td>
<td>Uncertain</td>
<td></td>
</tr>
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<td></td>
<td>Control</td>
<td>New</td>
<td>Uncertain</td>
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</tr>
<tr>
<td></td>
<td>Purposes</td>
<td>Impress the researcher</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gain modern teacher status</td>
<td>Positive</td>
<td></td>
</tr>
<tr>
<td>IUM-B</td>
<td>Successful Outcomes</td>
<td>Student relevance and energy</td>
<td>Enhanced engagement</td>
<td>Partner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual representation of mathematical ideas</td>
<td>Effective learning</td>
<td>Partner</td>
</tr>
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<td>Beliefs</td>
<td>Contribution to research</td>
<td>Facilitate</td>
<td></td>
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</tr>
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<td>Modern teacher status</td>
<td>Facilitate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Student engagement</td>
<td>Facilitate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alternative learning strategies</td>
<td>Facilitate</td>
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</tr>
</tbody>
</table>
9.4.5.8 *Concept videos*

Tamara sent concept videos that she had made or borrowed from Sarah to her absent students (Section 6.5.2.6). Tamara and Sarah had been creating concept videos using ActivInspire for several years. The purpose of videos was to reproduce worked example demonstrations for the benefit of absent students and those students who wished to revise.

Video creation reflects beliefs about the passing of information to students, the value of visual learning, student equity, and teacher responsibility for student learning. Refer to Table 9.18 for Tamara’s beliefs about creating concept videos.

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Effect</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td></td>
<td></td>
<td>Available time</td>
<td>Positive</td>
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</tr>
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<td>Self-efficacy</td>
<td>Established</td>
<td>Certain</td>
<td></td>
</tr>
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<td>Control</td>
<td>Established</td>
<td>Certain</td>
<td></td>
</tr>
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<td>Purpose</td>
<td>Produce resources</td>
<td>Positive</td>
<td></td>
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<td>Efficient</td>
<td>Extension of</td>
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<td>of small activity videos</td>
<td>effective</td>
<td>self</td>
</tr>
<tr>
<td>Beliefs</td>
<td>Equitable access to resources</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>Transmitting information</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

9.4.5.9 *Year 7 “other” digital technology*

Other than trialling Maths Pathway, the Year 7 teachers used limited digital technology for mathematical pedagogy in lessons. Teacher-generated ActivInspire flipchart files provided the platform for communicating concept knowledge and understanding in each lesson, reinforced by teacher–student interactions, and followed up with skills practice (Section 8.3.4.3). Helen had been using the flipcharts for several years in the role of servant providing efficient communication and of partner for effective learning. Helen’s flipcharts were an established resource used by the Year 7 teacher team.
IPads had replaced laptops as the preferred digital device for Year 7 students, and their use in mathematics lessons was spasmodic and still evolving. Students used iPads to link to Maths Pathway. Helen directed students to use an iPad app to practise multiplication skills (Section 8.3.4.1). Bec asked students to locate an online worksheet stored in the intranet LMS (Section 8.3.6.4).

Students were asked by teachers to put iPads away during board work “You don’t need anything” (Section 8.3.6.1). None of the observed Year 7 activities included experimentation, investigation, or mathematical problem-solving using the advantages of the iPad.

Contradictory beliefs about iPads were revealed in Lesson Y7O5 when the teachers encouraged students to bring a calculator to school to use during a problem-solving assessment task as iPads were not to be used. This was an example of the ripple effect of iPad functionality, which challenged the teachers’ concept of assessment advantage when compared to a single-use calculator (Section 8.5.1.5).

SMART online pre and post testing was an option for the Year 7 teachers that was not observed but discussed with Helen at her final interview as a replacement for Maths Pathway (Section 8.5.1.3). SMART had been introduced to Year 7 and 8 mathematics teachers at the school in about 2012 as a result of a schoolwide promotion of pretesting and post-testing strategies. The Catholic Education Office (CEO) supported SMART, and Helen had received professional development from the CEO in its use.

The SMART tests identified students’ mathematical gaps and misconceptions and offered rectifying strategies for teachers. Helen said that the test suite on decimals was good, but her colleagues did not want to use SMART in lessons because the results would not affect the way they taught. The teachers had no time to consider other options and believed in the efficiency and effectiveness of their existing practices. They did not see SMART functions as beneficial. This was an example of collegial influence increasing the uncertainty of digital technology use to the point of abandonment. Helen’s beliefs about SMART are presented in Table 9.19.
Table 9.19  *Helen Beliefs–SMART*

<table>
<thead>
<tr>
<th>IUM Step</th>
<th>Parameter</th>
<th>Interpretation</th>
<th>Effect</th>
<th>Digital Role</th>
</tr>
</thead>
<tbody>
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<td>CEO sponsorship</td>
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<td>Self-efficacy</td>
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<td>New</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>New</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purposes</td>
<td>Identify misconceptions</td>
<td>Positive</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Solution strategies</td>
<td>Positive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IUM-B</td>
<td>Successful</td>
<td>Easy to use application</td>
<td>Identify student needs</td>
<td>Partner</td>
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<tr>
<td>IUM-F</td>
<td>Unsuccessful</td>
<td>No time or inclination to deal with specific student needs</td>
<td>Application questioned</td>
<td></td>
</tr>
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<td>IUM-E</td>
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<td>Lack of teacher collegial support</td>
<td>Disruption</td>
<td></td>
</tr>
<tr>
<td>Beliefs</td>
<td>Team agreement</td>
<td>Obstruct</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimal benefit</td>
<td>Obstruct</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9.5 Disruptions

Observed disruptions and interruptions in the field and/or to the habitus of teachers caused by the use of digital technology, or for any other reason, were further analysed. Sometimes disruptions caused contradictory and intriguing responses in the teachers’ actions that supported or contradicted teacher-stated or interpreted beliefs. The beliefs in focus in this discussion were teacher self-efficacy, internal and external control, purposes, outcomes, gains and losses, and positive or negative external affirmation or influences that emerged from the disrupted event.

“Interruption” stops the continuous progress of an activity or process while a disruption is an interruption that causes a disturbance or problem (English Language Learners, 2018). A disruption is a challenge to teacher actions with similarities to an innovation. The difference is that the disruption is not planned, although one can plan to ameliorate a possible disruption in a proactive way. With a disruption there is a need to problem-solve on the spot with a purpose that is usually self-evident.
9.5.1 Disruptions

9.5.1.1 Alan and the power failure

Prior to Alan’s Lesson AO1, onsite technicians had restored the school’s networks after an overnight power failure. The problem to be solved by Alan at the start of the lesson was that the board was off. Alan spent precious time trying to boot the board using an unfamiliar operating system on the Apple agent computer. Eventually a student jumped up and booted the board for the teachers. Alan told me that he always asked the students if anything went wrong with technology in the classroom (Section 7.6.2). In this case, he had not asked a student, and the intriguing question was “Why not?” What had disrupted Alan’s regular behaviour?

Giulia, the preservice teacher struggled with the board throughout the lesson. She was a first-time user of Apple products. With the help of Alan’s “naughty” students (Section 7.4.4.1), the lesson rapidly deteriorated out of her control. Giulia solved her problem to some extent by asking a student to do the board work (Section 7.4.6.2).

There are important points to take from this incident. First, the power failure had a ripple effect across the school, as suggested in Section 2.2.1.3. It was not just a matter of restoring power and the digital infrastructure. Giulia needed software on her PC to run the board, but when the power was restored, there was insufficient time to download the ActivInspire application. Giulia’s planned lesson was negatively affected by the power failure with a visible loss of confidence shown in Giulia’s actions. Giulia did demonstrate an ability to problem-solve on the spot by recruiting student assistance.

Second, there was a simple solution for Giulia and Alan in which they swapped PCs. Alan’s PC had the required software and he could have used Giulia’s PC to write his notes about her teaching (Section 7.4.6.2).

Third, Alan’s reliance on student help to solve digital problems suggests that Alan had an issue with internal digital technology control, and this affected his ability to solve a simple digital problem. The issue of digital ownership, where someone does not want their PC used by anyone else, was perhaps an issue.
Fourth, Alan’s students were “naughty” under Giulia’s leadership but extremely well behaved when Alan was in charge. Alan subsequently told me that the class was a quiet cohort. The students played out an obvious behavioural contradiction during Giulia’s lesson.

This incident provided evidence of a disruption to normal lesson behaviours caused by any or all of the following parameters: the ripple effect of digital technology failure across the school, the effect of visitors on classroom dynamics, an issue for Alan in solving his own digital technology problems, and perhaps an issue of digital ownership.

9.5.1.2 Alan’s brush with YouTube clips

A field disruption occurred when Alan wanted to show a YouTube clip on the board for the first time (Section 7.4.6.6). He did not know how to get sound to the board. Alan’s confidence and competence were low; his uncertainty was high. I helped him plug the board’s sound cable into his computer before the lesson started. This incident supports the previous idea that Alan lacked a sense of internal digital control and relied on external support when things went wrong.

The lack of digital control did not particularly affect Alan’s use of digital technology in the classroom, given the close proximity of expert help. However, he did not achieve his aim of being seen as “a modern teacher”, and that was a personal negative outcome to be negotiated.

9.5.1.3 Computer technicians disrupt Tamara’s field

Tamara’s classroom field was disrupted by the presence of computer technicians to upgrade student laptops prior to an impending assessment task (Section 6.4.8). Tamara had acted to ameliorate the effect of digital change to online assessment. She engaged the technicians as soon as the decision had been made. Tamara needed the student laptops fixed immediately so she could give a practice task before the assessable tasks (Section 6.4.8).

Tamara demonstrated a proactive response to the innovation of online assessment. When she explained the situation to the students in Lesson TO3, they tested her
problem-solving capability by asking both expected and unexpected questions. When she could not answer some questions she said, “Leave it with me” (Section 6.5.3).

When the technicians arrived, their presence had a visible effect on the field dynamics. Tamara started to speak uncharacteristically quickly and loudly. She kept repeating herself (Section 6.4.8). Once the students had given the laptops to the technicians, Tamara engaged a traditional lesson format. She worked an example in detail on the board (Section 6.4.3.3) and wrote up notes to be copied (Section 6.4.3.2). The students “played their part” by paying attention to the teacher, copying down notes, and working on practice exercises in silence. There was very little student–teacher interaction and no movement around the room.

After the laptops had been returned and the technicians had left, Tamara asked a student to come to the board, and the regular interactive lesson returned (Section 6.4.3.3). The students were then set an engaging problem-solving activity, which they performed in near silence (Section 6.4.4.2).

The effect of this disruption was for the teacher and students to revert to some sort of traditional lesson by way of teacher-centred board work, a lack of teacher–student interaction, and attentive students performing as instructed. Perhaps this occurred because students did not have laptops and they could not work independently ahead of the teacher. With the computers back, Tamara reverted to normal but the students did not! It seemed that they had been affected by their own attentive behaviour, or perhaps they found the problem-solving exercise to be more engaging than the more usual practice activities.

9.5.1.4 Student effect for Sarah

When students asked questions while Sarah was working at the board, some of her responses were unexpected. As discussed in Chapter 5, when a student working ahead of the teacher asked a question (Section 5.4.3.5), and when Sarah encountered her first Padlet question (Section 5.4.5.1), the rhythm of her board demonstrations was disrupted.

A second disruption occurred in a lesson when Sarah introduced SimpleMind for a flowchart activity. The inadequacy of the application gave students an opportunity to use an alternative, familiar mind-mapping application that they had on their laptops
(Section 5.4.5.2). While Sarah continue to give out instructions and fixes for SimpleMind the students shifted to using Inspiration.

These incidents indicate that Sarah did not handle interruptions or disruptions well. She gave the impression that she was working from a script or from memory. When interrupted, Sarah found it difficult to halt, answer questions, or change direction.

9.5.1.5  *Maths Pathway and the open space initiative*

The Year 7 open space initiative was a disruption to the previous typical arrangement of single-class mathematics lessons. Removing her class to a classroom after instructions had been given in Lesson Y7O1 indicates Helen’s struggle with the initiative. Helen argued, “I already have the weakest group” (Section 8.3.2.1) with the implication that this was the equivalent to a Maths Pathway targeted group for specialist attention. Her class was not a targeted group and possibly not made up of the weakest students (Section 8.3.3.4). Helen was reluctant to change: “I thought we were doing well, why do we have to change every year?” (Section 8.3.3.5).

Helen had been integral to the creation of the well-documented, detailed, resource-laden established curriculum used by the Year 7 teachers for several years (Section 8.3.4.3) and was perhaps struggling with a sense of loss.

Helen had considered the combined classes and open space challenge and adapted the initiative to suit her purposes with minimum disruption to established routines. The result was minimal if any effect on established pedagogical approaches.

9.5.1.6  *Helen and the “rich task” disruption*

Finally, the bedlam that ensued in Lesson Y7O4 provided an example of using a regular lesson formula on an untypical rich task activity. The students seemed to enjoy the chaos, but the teachers did most of the work, first in setting up the tables and then continually instructing students, as individuals or groups, on how to identify a pattern and generate a rule (Section 8.3.5). The teachers were doing their regular instructional job in a more difficult field.

The lesson was a lost opportunity to promote and develop collaborative learning and problem-solving skills for students. It was missing rich learning outcomes and
purpose other than to identify a pattern and generate a rule according to written and/or verbal instructions.

9.5.1.7 Tamara’s confusing messages about using digital technology

Tamara gave out mixed messages to students about using digital technology. She said Mathematica was a means of “cheating” (Section 6.4.7.1), a confusing message considering that she was usually positive about using Mathematica.

Tamara used a calculator rather than estimating skills to rescue students during a collaborative concept activity in which students had been told they could not use digital technology (Section 6.3.4). Tamara demonstrated the benefit of the calculator, but the inconsistency of her actions dented her authority in whichever way it was interpreted.

Tamara introduced the Wolfram Project file in Lesson 04 and demonstrated its features rather than letting students play, as was her stated intention (Section 6.3.4).

These examples were interpreted as indicative of the teacher losing sight of her intentions and student learning objectives. The actions were attributed to Tamara’s newness with the subject and the technology, an idea that she suggested (Section 6.3.4). Tamara was moving backwards and forward on the IUM as she came to grips with the new subject.

9.5.1.8 Sarah’s uncertainty crisis

After Observation Lesson SO4, Sarah suspended her participation in the study and any further interviews until the end of the year. In her final interview, she explained that at the time of her withdrawal, she had begun to question the way she taught, which was in complete contradiction to the way she wanted to teach (Section 5.2). Sarah had become aware of a beliefs conflict.

The crisis climaxed with a realisation that providing students digital notes was an example of “spoon-feeding”, a technique promoting student dependency (Section 5.5). Yet Sarah’s expressed beliefs of a collaborative, constructivist learning environment centred on students, a class where students were required to think, contribute to learning progress, and become lifelong learners (Section 5.5).
The crisis that Sarah faced was indicated as possible in Priest’s risk-taking cycle (Section 3.4) and is included in the Innovation Uncertainty Model. Being unable to teach in the way she wanted led Sarah to IUM-J, a complete re-evaluation of the activity (refer to Figure 3.1).

Then a new thought occurred to me, triggered by Sarah’s statement that she “had recently discovered that Mathematica has a Slideshow format” (Section 5.4.1.2). Sarah possibly did not mean Mathematica when she said that she wished “to expose students to Mathematica more”; rather, she meant Slideshow. She needed to switch to Slideshow early in the year because the team, Sarah, Alan and Tamara, had just decided to introduce their students to online assessment, and Slideshow was the assessment platform. The timing was right for such a decision, but the decision was not confirmed until much later in the year when online assessment technical issues had been resolved (Section 6.5.3).

Sarah’s crisis rested primarily in the effort required to switch notes to Slideshow. At first, it was an interesting learning and problem-solving activity. Eventually, it became a tedious and grand exercise. It seems that Sarah felt she had no choice about using Slideshow and could not simply go back to using her flipcharts. It is also possible that participation in the study contributed to the crisis by raising Sarah’s awareness of her actions, purposes and outcomes (Section 5.4.6.3).

9.6 Beliefs’ Results

9.6.1 Case Sarah

Sarah expressed beliefs in a collaborative, constructivist leaning environment but enacted mathematics absolutism and a teaching model indicated as primarily direct instruction and passing information with the teaching characteristics of teacher-centred learning and constant student interaction. Sarah initiated behaviourist learning activities of writing, listening, practising, memorising, and revising. Some collaborative interaction was initiated by groups of students maintaining their own pace within the teacher’s structure and by individual students questioning Sarah aloud on occasions.

Sarah used generic digital technology in lessons to achieve efficiency gains in communications with students and digital storage of resources. Sarah was also
observed using a range of digital technology innovations in lessons including Mathematica computational software, Padlet bulletin board, flowcharting software, and Slideshow notes. She was an experienced creator of ActivInspire flipchart notes and concept videos. Sarah believed in her ability to introduce digital innovation and the need to do so. She was a digital change agent.

Sarah showed some hesitancy in using Mathematica. Her self-efficacy and control of the application were still developing. Her purposes for using Mathematica were limited to servant tasks of computations and plotting for efficiency gains. Some VCE Study Design requirements were not addressed in observed lessons. On several occasions, Sarah changed her mind about using Mathematica, which indicated a belief in manual computations in preference to digital computations perhaps based on a belief that digital computations eroded cognitive skills.

Sarah’s self-efficacy, control, and some intended purposes for Padlet were sound and Padlet was proved successful as a communication tool supporting out-of-class student collaboration. Padlet implementation also solved a problem of excessive student emails for Sarah, provided a more equitable means for distributing mathematics solutions to all students in the class, and provided the opportunity for students to ask questions anonymously and ultimately collaborate outside the classroom. Sarah maintained the structure and moderated Padlet’s posts throughout the year.

In class, Padlet created a problem for Sarah who reacted poorly to interruptions while she was presenting at the board. Sarah did not initiate any other specific collaborative activities in observed lessons, and Padlet implementation highlighted a contradiction in Sarah’s stated and enacted beliefs about student collaboration.

A flowcharting activity that Sarah set for her students was marred by a lack of preparation and led to a loss of teacher control over the activity. The students used a more suitable mind-mapping application. At the time, the teacher had not recognised the initiative students had shown in making their own choices. The loss of face for the teacher appeared to be a small setback on the IUM. The lack of preparation for SimpleMind was a contradiction to the preparation belief indicated with Sarah’s implementation of Padlet.
Finally, Sarah made sophisticated and functional digital notes for her students, “an extension of self”. The notes allowed students to work at their own pace and provided additional resources for further study. The notes indicated a teaching model of direct instruction and student dependence with a teaching concept of passing information. Providing additional resources in the notes indicated a belief in student independence for acquiring further knowledge within a structure provided by the teacher. Overall, Sarah’s actions and statements in classroom lessons and discussed over email provided examples of contradiction, interruption and disruption to her dominant interpreted beliefs.

9.6.2 Case Tamara

Tamara’s teaching was interpreted as having a traditional basis with responsibility towards the curriculum and assessment requirements and the use of additional collaborative learning techniques for student cognitive understanding. Her dominant belief about mathematics was absolutist, but her actions in the classroom supported a relativist perspective. Tamara’s mathematics learning beliefs shifted between cognitive constructivism with the teacher driving the lesson and student interaction to know and understand prescribed content, and a social constructivism facilitated by teacher scaffolding with the outcomes of a shared learning experience and greater student learning independence.

Besides demonstrating an established expertise with generic digital technology in observed lessons, Tamara used or discussed Mathematica, Slideshow files, Wolfram Project file, the scientific calculator, the assessment-tracking module and concept videos to support her teaching practice.

Tamara exhibited a balanced approach to facing the uncertainty of a new subject and its requirement to incorporate digital technology use. She benefited from her colleagues’ experience and resources such as Alan’s Slideshow files and Sarah’s Mathematica glossary, and from her students’ greater experiences in using Mathematica in lessons. Tamara believed in collegial collaboration.

Tamara facilitated student use of Mathematica, and by the year’s end, Tamara expressed confidence, competence, and control of the application for herself, although she regretted that she had not used it more often in class. Tamara had discovered a
benefit of Mathematica in command scripts that exposed students’ levels of process understanding. She also said that to use Mathematica for plotting was “cheating”, thus revealing mixed beliefs about the purpose of the algebraic software.

Tamara was responsible for the class’s smooth transition to online assessment and showed she was able to respond effectively to student concerns. Tamara appeared confident, competent in the classroom despite the newness of the subject and the digital innovations.

9.6.3 Case Alan

Alan’s mathematics pedagogical beliefs facilitated student understanding of clearly stated concept goals and the application of that understanding to completing exercises and solving problems. Understanding was achieved through teacher-guided discovery or teacher-scaffolded investigation and student practice indicative of a mixture of discovery learning techniques and a cognitive apprenticeship for students. The teacher was constrained by the curriculum but not so much by impending examinations and results. Alan’s actions indicated a belief that understanding was the basis of assessment success and reflected both absolutist and relativist mathematics beliefs.

Alan’s lessons were characterised by significant interaction between teacher and individual students during concept activities and lengthy silences for practice exercises and problem-solving. Alan believed in teacher control, but mathematics learning was the centre of attention for teacher and students. A high level of student independence was displayed. Alan believed in student responsibility for their own learning.

Alan used or mentioned an array of digital technologies in lessons or at post-observation interviews. He had been using the school’s generic digital technologies for at least five years, and these facilities were established in Alan’s classroom activities. Despite this, Alan displayed a degree of uncertainty that was attributed to a lack of internal control over general technologies with a reliance on others if something went wrong. This approach obstructed his ability to solve his own digital problems.

Alan was self-conscious of the researcher’s scrutiny of his digital technology uses, and he was aware of a pedagogical status to be “a modern teacher”. He had a strong sense of self but perhaps was not modern enough. Alan believed he did not really need
digital technology to teach mathematics. However, given Mathematica, he believed its use should not be restricted, and students challenged to solve more difficult problems.

There was a contradiction between Alan’s hesitancy with generic digital technology and his seamless, smooth use of Mathematica. The latter indicated that Alan believed in the authority of the VCE curriculum and the authority of the school and as a result had adapted to the requirements for Mathematica use demonstrated in lessons and fully participated in the VCAA Mathematica trial of online assessment. Purposeful Mathematica use was easily slotted into his goal-directed pedagogical strategies.

9.6.4 VCE teacher team

The most compelling idea about the VCE teacher team is that they were very cooperative with each other, but they did not necessarily collaborate. Collaboration requires a common purpose, and the team did not agree on teaching model and learning outcomes beyond the scope of curriculum content knowledge and skills. Alan’s teaching was goal directed, Tamara’s teaching was collaborative, and Sarah’s teaching was the delivery of a complete package. Alan’s students needed to think, Tamara’s students needed to interact, while Sarah’s students needed to memorise. These agendas achieved different aims, which were compatible and deserved to be shared.

9.6.5 Case Y7 Team

Helen’s teaching model was indicated as primarily direct instruction with characteristics of teacher-centred learning and constant student interaction in lessons. Helen used carefully constructed language to guide students through a concept or task and posed leading questions that prompted memory responses. Her efforts were nonstop in presenting at the board or moving around the room from one student to the next, always encouraging, always ready to help.

Helen was an artful user of generic digital technologies for administration and communication purposes. Helen had made a significant contribution to the development of the Year 7 mathematics established curriculum. Her efforts included a suite of ActivInspire flipchart resources to support concept presentation and understanding. The flipcharts were important to curriculum communication and the
passing of information but did not contribute much to changing the traditional nature of mathematics teaching and learning without a flipchart.

Helen had adapted the curriculum assessment tasks to reflect the IB MYP assessment requirements. She found that Maths Pathway’s self-paced learning and diagnostic formative assessment conflicted with these summative tasks, which she believed in. Evidence also suggests that Helen doubted that fixing individual misconceptions or filling gaps in student understanding could progress their mathematics learning. Helen expressed doubts about other initiatives attempted by the Year 7 mathematics teacher team, irrespective of where the idea came from. Helen resisted the Catholic Education Office promotion of SMART pre and post testing and the leadership initiatives for individuated and/or collaborative learning and team teaching.

Helen’s reluctance to change was attributed to a lack of self-efficacy about mathematics and mathematics education, perhaps dating back to her schooldays, which had not been rectified by tertiary education choices, mathematics teacher training, or her teaching experiences.

9.6.6 Year 7 teacher team

The trial of Maths Pathway exposed some misconceptions and gaps not just in student learning but also in the teachers’ understandings of mathematics learning. Data collected included evidence of limited reasoning by the team to deal with issues about Maths Pathway and identifying target groups of students.

As a group, the Year 7 teachers could not believe that so many students could have mathematical misconceptions dating back to Year 3 or Year 4 level and blamed Maths Pathway for misdiagnoses. The teachers made no allowances for or investigated other circumstances or intervened with repeated poor performance from students. Instead, the teachers agreed that “they are not that bad” (Section 8.3.2.2) and skipped the students ahead.

In the same way, class streaming, based on a single test of Year 6 students in an alien environment and unexpected circumstances, was a limited perspective on the students’ potential for learning mathematics (Section 8.2.3). The indicator of flawed
streaming was evident in the advancement of many students from different classes to reach Fractions (Sections 8.3.3.2, 8.3.3.4).

Helen spoke about her lagging students and not the progressing students (Section 8.3.3.2). Luci was focused on her progressing students and not the lagging ones (Section 8.3.3.4). This reasoning suggested that the teachers used the diagnostics to justify their beliefs rather than using the diagnostics and then other circumstances to evaluate individual learning progress.

The Year 7 mathematics teachers were bound to the established curriculum and instructional teaching model that passed mathematical information and knowledge to students. The three teachers agreed to maintain the status quo. The teachers accepted that some students could just do mathematics rather than all students could learn mathematics. These ideas led me to believe that the Year 7 teachers had limited connection with strategies for achieving specific mathematics learning outcomes.

9.7 Conclusion

This chapter has seen a discussion of the beliefs derived from the analysis of participant teacher data. Refer to Table 10.1 for a summary of the resulting beliefs. Chapter 10 provides further discussion of the belief contradictions, inconsistencies, and disruptions that the data also revealed. A new idea, requiring a return to the literature and a great deal of thought, emerged.

An analysis of my table tennis progress hinged on the idea that shots or sequences of shots were generated by physiological actions learnt through repetition. When perfected, the shots automatically appeared in a game cued by the environment “there’s a gap” and/or the opposition “that’s backspin”. Automation was enhanced by a clear prefrontal cortex that allowed the physiology to perform.

The consistency of my shots provided the opponent with a physiological cue or vision of what was happening and this in
turn may have also initiated in the opponent an unconscious automated response.

One remaining issue did not make sense to me: the role of strategy during the game. Through trial and error, I had learnt to limit strategising and keep the cortex clear. Some opponents I had beaten came back with new game plans, and I was newly flummoxed. Devising new strategy during the game complicated the automatic routines. I did not understand what I needed to do next.
CHAPTER 10
DISRUPTED DISPOSITIONS

Uncovering research about two distinct behaviours, goal-directed behaviour and habitual behaviour, with each coordinated in a different part of the brain (Shah, 2013), contributed to clarifying the table tennis dilemma. The automatic skills were a form of habitual behaviour. They needed clear passage through the prefrontal cortex, the bridge between the right and left sides of the brain, for a coordinated outcome. Strategic thinking, a goal-directed behaviour, occurred in the prefrontal cortex. Over-thinking strategies and other goal-directed ideas such as “I want to win” could block the automatic skills. Understanding how the brain worked meant I now knew how to approach an opponent with unfamiliar strategies—create a conflict in their brain.

10.1 Disruptions and Contradictions

Observation lessons, post-lesson interviews, and teachers’ related experiences provided data that were analysed in Chapter 9 to identify underlying teacher beliefs about mathematics, mathematics education, and digital technology use from the teachers’ intentions, actions, and statements (Reay, 2004). The treatment of the classroom as a site of social interaction brought into consideration aspects of teacher beliefs derived from the environment and the students, and external influences of power and status (Bourdieu, 1977). In addition, events that caused disruption to regular teacher routines were analysed to provide insight into changed behaviours and the teachers’ abilities to solve problems. The outcomes of analysis were teacher beliefs that explained their actions and some behaviours that were harder to understand.

This chapter commences with a discussion about the commonality and differences of interpreted teacher beliefs and the contexts and influences in which beliefs were embedded. The purpose of the discussion is to identify patterns of behaviour and make
further sense of actions and statements arising from interruptions or disruptions or inconsistent digital technology uses seen in classroom observations or discussed at interview.

10.2 Teacher Beliefs in the Classroom

Digital technology uses were considered to be innovative, developing, or established practice for the mathematics teacher predicted by beliefs in self-efficacy, control, purpose, benefit, and importance (Section 9.4). These beliefs reflected a personal sense of certainty for the teacher: the more established the behaviour, the more certain the belief. Teacher reflection on success of digital innovation and the influences of others were seen as increasing or decreasing innovation certainty and hence the likelihood of repeated use of digital technology (Section 9.4.1).

The teachers’ actions also reflected personal beliefs and beliefs about mathematics as a discipline, and its pedagogical practice. Participants’ pedagogical beliefs were identified under the categories of teaching model, concept of teaching, and concept of learning (Section 9.3.1). Refer to Table 10.1 for a summary of resultant participant beliefs for comparison purposes.
Table 10.1  **Beliefs Comparison Table**

<table>
<thead>
<tr>
<th>Beliefs Focus/Purposes</th>
<th>VCE Sarah Beliefs</th>
<th>VCE Tamara Beliefs</th>
<th>VCE Alan Beliefs</th>
<th>Year 7 Helen Beliefs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interpreted beliefs about mathematics and mathematics education</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics</td>
<td>Absolutism</td>
<td>Absolutism with relativist actions</td>
<td>Absolutism with relativist actions</td>
<td>Absolutism</td>
</tr>
<tr>
<td>Teaching model</td>
<td>Direct instruction Teacher centred</td>
<td>Collaborative learning Cognitive apprenticeship</td>
<td>Discovery learning Cognitive apprenticeship</td>
<td>Direct instruction</td>
</tr>
<tr>
<td>Concept of teaching</td>
<td>Passing information Content driven Assessment focus Student concern</td>
<td>Transmitting information Content driven Assessment focus Student concern Social activity</td>
<td>Knowledge construction relative to achieving goals Adapted cognition Content driven</td>
<td>Passing information Content driven Assessment focus</td>
</tr>
<tr>
<td>Concept of learning</td>
<td>Behaviourism Some collaboration</td>
<td>Social &amp; cognitive constructivism</td>
<td>Radical &amp; cognitive constructivism</td>
<td>Behaviourism Some collaboration</td>
</tr>
<tr>
<td><strong>Interpreted beliefs about the use of digital infrastructure and applications</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Generic applications</strong></td>
<td>Established Self-efficacy Control Purpose Vulnerable access Servant</td>
<td>Established Self-efficacy Control Purpose Vulnerable access Servant</td>
<td>Established Self-efficacy Control Purpose Vulnerable access Servant</td>
<td>Established Self-efficacy Control Purpose Vulnerable access Servant</td>
</tr>
<tr>
<td>ActivInspire</td>
<td>Established Self-efficacy Control Purpose Extension of self</td>
<td>Established Self-efficacy Control Purpose Extension of self</td>
<td>(Giulia used a flipchart in Lesson AO1)</td>
<td>Established Self-efficacy Control Purpose Extension of self</td>
</tr>
<tr>
<td><strong>Mathematica (VCE)</strong></td>
<td>Developing Self-efficacy Control Limited purposes Servant Loss of mental agility</td>
<td>Innovation Self-efficacy Control Purpose Partner Misconceptions identified</td>
<td>Established Self-efficacy Control Purpose Extension of self Extend use</td>
<td></td>
</tr>
<tr>
<td>Slideshow (VCE)</td>
<td>Innovation Self-efficacy Taking control Multipurpose Purpose–adaptation Extension of self/ Servant Beliefs crisis</td>
<td>Innovation Self-efficacy Taking control Purpose Extension of self/ Servant Collegial sharing</td>
<td>Established Self-efficacy Control Purpose Servant Collegial sharing</td>
<td></td>
</tr>
</tbody>
</table>

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**Mathematics Absolutism**

**Teaching model**

- Direct instruction Teacher centred
- Collaborative learning Cognitive apprenticeship
- Discovery learning Cognitive apprenticeship
- Direct instruction

**Concept of teaching**

- Passing information Content driven Assessment focus Student concern
- Transmitting information Content driven Assessment focus Student concern Social activity
- Knowledge construction relative to achieving goals Adapted cognition Content driven
- Passing information Content driven Assessment focus

**Concept of learning**

- Behaviourism Some collaboration
- Social & cognitive constructivism
- Radical & cognitive constructivism
- Behaviourism Some collaboration

**Generic applications**

- Established Self-efficacy Control Purpose Vulnerable access Servant
- Established Self-efficacy Control Purpose Vulnerable access Servant
- Established Self-efficacy Control Purpose Vulnerable access Servant
- Established Self-efficacy Control Purpose Vulnerable access Servant

**ActivInspire**

- Established Self-efficacy Control Purpose Extension of self
- Established Self-efficacy Control Purpose Extension of self
- (Giulia used a flipchart in Lesson AO1)
- Established Self-efficacy Control Purpose Extension of self

**Mathematica (VCE)**

- Developing Self-efficacy Control Limited purposes Servant Loss of mental agility
- Innovation Self-efficacy Control Purpose Partner Misconceptions identified
- Established Self-efficacy Control Purpose Extension of self Extend use

**Slideshow (VCE)**

- Innovation Self-efficacy Taking control Multipurpose Purpose–adaptation Extension of self/ Servant Beliefs crisis
- Innovation Self-efficacy Taking control Purpose Extension of self/ Servant Collegial sharing
- Established Self-efficacy Control Purpose Servant Collegial sharing
10.2.1 Inconsistencies, confusion, and contradictions

The following discussion addresses the inconsistencies, confusion and contradictions that emerged during analysis of the intentions, actions, and statements collected from participants’ pedagogical practices and the use of digital technology.

10.2.1.1 Case Sarah

Sarah demonstrated a contradiction between her stated beliefs and enacted beliefs about her pedagogical practices. During data collection, Sarah suffered a beliefs crisis about her teaching practice. Contributing factors that were identified include her “digital change agent” identity seeking digital change, the introduction of online
assessment, and some effect perhaps of raised awareness of teaching practices from participating in this study. Sarah ultimately realised her teaching style to be “spoon-feeding”, which was very different to achieving student-centred collaboration and cognitive constructivism, which is how she wanted to teach (Section 5.2).

Other contradictions appeared in Sarah’s practice with the most notable being the complex array of purposes and benefits for Padlet (Section 9.4.5.1). Padlet was successful in providing an out-of-class online collaborative and communication platform for her VCE class. Using Padlet as a means of asking discrete questions in class disrupted classroom dynamics, and this purpose was abandoned. Sarah reasoned that she had changed her mind about Padlet because it was better for students to hear each other’s questions. Sarah reasoned that Padlet out-of-class success was due to the weakness of the VCE class and their need for assistance. Sarah provided a classic example of shifting from one perspective to another and ultimately confusing the rationale for using the digital technology.

When Sarah heard Slideshow was a platform for online assessment, she used the presentation application to create comprehensive notes files that would enhance the use of Mathematica in class (Section 5.4.6.3). The jazzed-up notes exceeded the editorial capacity of the application and became a burden for Sarah. They were not efficient to create, nor were they more effective for deriving better student learning outcomes than her original flipcharts. The way to get Mathematica used in class was to use it and stop changing her mind. That did not require Slideshow. Sarah had reasoned her way into a dilemma yet again.

Sarah’s implementation of the mind-mapping application SimpleMind was contradictory to her superior implementation of Padlet. I interpreted the innovation hiccup as an indicator of the growing pressure that Sarah was experiencing. However, exactly what beliefs were driving Sarah’s actions and faulty reasonings?

10.2.1.2 Case Tamara

Unlike Sarah, Tamara demonstrated a consistency between her stated beliefs and her enacted beliefs. Tamara said she was a problem-solver, an idea that was consistent with her goal-directed approach to implementing online testing for her students, for example. Tamara said she favoured collaboration with evidence seen in classroom
activities. In addition, her collaborative approach to working with colleagues saw her benefit from her colleagues’ prior experiences with curriculum content, activities, and resources (Section 9.6.2). Tamara was an experienced team player and was subsequently well resourced when she began teaching the subject in 2015.

In contrast to her colleagues, collaborative investigative tasks appeared in Observation Lessons TO1 and TO4. Other lesson activities were very similar to those used by Sarah; however, there was more student interaction, fewer instructions, and a greater emphasis on mathematical reasoning in her worked examples.

Tamara used Mathematica sparingly in lessons, focusing on teaching small skills only such as labelling a plot. Some students were experienced Mathematica users and she engaged them to help her and each other when problems arose. Tamara’s actions indicated developing Mathematica skills, one small function at a time, developing competence and confidence, with external Mathematica control provided by students. In this case, reliance on others was considered a collaborative gesture while Tamara was developing knowledge and understanding about the new subject that she was teaching.

Over the course of the study, Tamara articulated a growing belief in Mathematica benefits (Section 9.4.3.3) unlike Sarah who struggled with benefits. Her statement that to use Mathematica was “to cheat” expressed a lingering doubt (Section 6.5.2.1). Student choice-making for digital use was not observed in her lessons, but she did reason with students about the choices that she had made on their behalf (Section 6.5.2.1). Tamara’s ban on digital technology use in the collaborative Lesson TO4, turned out to be short sighted disruption (Section 6.5.2.3).

Tamara demonstrated both internal and external control of digital technology when she organised technicians to come into the classroom to update student laptops for online assessment (Section 9.4.5.4). Tamara took responsibility for the solution, but the technicians did the work. When the students questioned her closely about online assessments, she handled their concerns or at least promised to find out answers before the next lesson. She followed up with answers and provided students a practice digital SAC and printed SAC to ease her students into online assessment.
When the technicians were present in Tamara’s lesson, there was a noticeable shift in dynamic. The teacher demonstrated a traditional instructional lesson with the teacher working examples on the board. When the technicians left, the teacher reverted to her regular guiding role with the students doing the work. I thought the change of behaviour odd (Field Notes SO3). This was not explored at interview as we were caught up in a discussion about online assessment.

10.2.1.3 Case Alan

Alan was an experienced teacher of the VCE subject, and the fluidity of his lessons indicated his self-efficacy and control of the mathematical content and the Mathematica digital application. In contrast to Sarah’s approach, these regular strategies in Alan’s pedagogical repertoire aligned with the VCE digital requirements. Alan switched seamlessly between manual and digital processes, as did his students without instruction (Section 9.4.3.1). His actions indicated his beliefs in the VCE Study Design pedagogical intentions. He took responsibility for using Mathematica in his lessons as prescribed.

By contrast, Alan relied on external control when confronted with more generic digital problems; he asked for help. Minor digital problems in observed lessons confirmed Alan’s reliance on external assistance (Section 9.4.2.2). These examples indicated a personal belief that problems with generic digital technologies were not his responsibility.

As seen in Section 9.4.2.2, the power outage was an exceptional event for Alan because on this occasion he tried to solve the digital problem himself and did not succeed. Eventually, a student intervened. A simpler solution of booting the board from his PC laptop, an action he performed in every lesson, was available to him, but Alan did not think of it (Section 7.4.2.1). His action of not asking for help was inconsistent with his regular reaction to digital problems on this occasion, while the inability to solve the problem himself remained a mystery.

Alan showed his first YouTube clip I Will Derive in Lesson AO2 for the purpose, as his statements indicated, of impressing me and achieving status as a modern teacher (Section 7.4.2.1). In evaluating the clip at the final interview, Alan suggested that I Will Derive had no particular benefit but a second one Mean Girls had energised his
class. His “no benefit” statement for *I Will Derive* highlighted an inability to identify the clip’s merits despite replicating the clip’s animation in class at the board on three subsequent occasions (Section 7.4.6.6).

The YouTube event demonstrated that it was possible for Alan to experiment with digital technology in a lesson successfully despite doubts about mathematical learning advantage. He said he would show the clip again as if he subconsciously knew the benefits.

Finally, despite experience and skill, Alan was caught out on a couple of occasions in observation lessons when, in the moment, he could not provide reasonable mathematical answers to student questions, instead telling the students what they needed to know for assessment purposes. His response at interview, “I didn’t study physics” was a contradiction to his goal-directed pedagogical approaches and outside his teaching responsibility for the subject (Section 7.4.2.3).

**10.2.1.4 Case Y7 Team**

Helen and her team of Year 7 mathematics teachers were in a quandary about using digital technology in mathematics lessons. This confusion may have been exacerbated by the use of two sets of curriculum guidelines. The team used local education guidelines of the Australian Curriculum (ACARA, 2015) to define lesson content (Section 8.2.4), while the IB MYP guidelines were relegated to assessment tasks only and were not evident in day-to-day lessons (Section 8.3.6.6). The Year 7 teachers seemed to overlook digital technology learning outcomes from both curriculums.

The Year 7 teachers were in complete agreement about curriculum delivery and pedagogical approaches. Supporting teacher actions in lessons was an existing resource-laden curriculum created to deliver the required knowledge and skills. The curriculum involved topical flipcharts, practice exercises, “rich tasks”, and assessment tasks designed to measure progress. Helen had been integral to curriculum development, particularly creating the flipcharts, and she did not want to change (Section 8.3.3.5).

Digital technology was used in the Year 7 mathematics classroom for administration tasks and communications. Otherwise, Helen’s use of digital technology for pedagogical reasons was limited to the flipcharts that provided the basis for
efficient and effective communication and the use of an iPad app to advance student multiplication skills. These uses aligned with Helen’s observed teaching strategies of direct instruction, passing information, and skills practice. Evidence suggested that Helen used digital technology when it suited her teaching strategies rather than using digital technology to achieve particular learning outcomes (Section 9.4.2).

When the Year 7 team experimented with Maths Pathway, Helen adapted or overlooked the benefits of self-paced learning and the diagnosis of mathematical gaps and misconceptions that Maths Pathway offered (Section 8.3.3.5). Ultimately, Maths Pathway was rejected because the content was not sufficiently well covered in time for the planned IB MYP assessment task (Section 8.3.3.5). The existing curriculum and assessment regime overran the Maths Pathway experiment.

In mathematics lessons, Year 7 students accessed calculators on their iPads but calculators were not mentioned or observed being used in Helen’s mathematics lessons. Helen said, “If you are on your iPad, I am taking it away from you” (Section 8.3.4.2) and “Put your iPads away” (Section 8.3.4.1). The exclusion of iPads from mathematics tasks was a confusing ripple effect of having calculators and other, perhaps distracting, apps on iPads. The suggestion of Year 7 teacher confusion caused by a digital ripple effect was reinforced in Lesson Y7O5 when Bec instructed students to bring calculators from home to use in an assessment task because they were not to use their iPads (Section 8.3.6.5).

Helen’s beliefs about mathematics pedagogy conflicted with suggested changes irrespective of the influences for change. The influence of school leadership initiatives including open plan lessons and team teaching (Section 9.4.4) did not initiate change for Helen. The school’s initiative for IB MYP pedagogy resulted in change to assessment tasks and not much else. The school’s initiative for pre and post testing, backed by professional development (PD) and support from the Catholic Education Office, did not initiate the uptake of SMART. Instead, the lack of collegial agreement influenced the rejection of digital applications for pre- and post-testing.

The interviews and discussions with Helen revealed that she was satisfied with her lessons for the time being (Section 8.3.3.5). But then she thought Observation Lesson Y7O3 was a failure, and she did not know why. I detected in Helen a lack of self-belief in delivering mathematics pedagogy and digital technology use, which I attributed to
her early education experiences. Self-belief is a component of self-efficacy. Helen was schooled in an era when girls rarely pursued mathematics, and digital tools were nonexistent. Helen received mathematics teacher training as part of her special needs and science education courses and not as a tertiary qualified mathematics preservice teacher. Digital strategies were not included in her teacher training.

In addition, Helen had a tremendous drive to assist the disadvantaged mathematics student, which made me think that she felt disadvantaged about mathematics. I thought Helen was resistant to change because she lacked self-belief. Similarly, Luci and Bec were “out-of-field” mathematics teachers (Section 8.5.1.2). The Year 7 mathematics teacher team had insufficient self-belief to initiate and follow through on making changes to the curriculum.

10.2.2 Beliefs challenge

The results of analysis revealed four individual teacher practices at different stages of digital technology use in mathematics lessons. In general, the teacher strategies were effective for facilitating student learning of content knowledge and skills that the teachers had articulated as intended learning outcomes. The links between teacher beliefs and other student learning outcomes were not readily perceived. In addition, other than Sarah, the teachers rarely articulated purpose and benefit of digital technology uses. Evidence suggested that the digital technology uses were taken for granted and that uses relevant to existing teacher strategies were more likely to be adopted.

The VCE Study Design with clearly defined digital purposes facilitated the VCE teachers’ use of Mathematica when these aligned with the teachers’ pedagogical routines. The interpreted benefits of these purposes were the development of digital skills for computations, mathematical plots and routine processes, and enhanced cognitive development of mathematical understanding using techniques of exploration, experimentation, analysis, and problem-solving.

Alan, the most proficient Mathematica user, believed in and addressed cognitive development of mathematical understanding using small, goal-directed activities. These activities were readily adapted to include digitally facilitated computations, exploration of mathematical ideas, mathematical experiments, and problem-solving.
Alan was dubious about using other digital technology for mathematical reasons. He did experiment with YouTube clips but found it hard to articulate pedagogical purpose and benefit, and evaluate success. He gained an intuitive sense of benefit and was committed to clip use in the future (Section 9.4.3.4).

Tamara, in her first year of teaching the subject, was still finding her way through the VCE subject curriculum and stipulated digital technology use. The invention of collaborative tasks to suit her belief in the social construction of mathematical skills and understanding lent itself to the inclusion of digital technology uses according to VCE Study Design requirements. She had not had sufficient time to create as many collaborative tasks as she would have liked. Unlike her colleagues, Tamara found and articulated Mathematica benefits as the year progressed (Section 9.4.3.3).

Sarah was most conflicted with limited teaching strategies that did not achieve the learning outcomes that she wanted. In using Mathematica and Slideshow, she adapted the applications to her existing teaching strategies rather than develop new strategies to facilitate mathematical understanding and prepare for online assessment. Sarah found it difficult to negotiate the links between teaching strategies and learning outcomes. She was stuck using teaching strategies that she had always known and used (Section 9.4.3.2).

Helen appeared resistant to any change, regardless of the pressure to do so. However, she was not completely resistant to digital change because she had created a suite of flipcharts to facilitate the communication of mathematical ideas to students. The flipcharts aligned with her teaching strategies of passing information and knowledge. Having made the flipcharts and gathered other resources together for a comprehensive curriculum, she did not want to change to team teaching, combined classes, self-paced learning, identification of mathematical misconceptions, targeted small groups of students, or add further digital activities. Neither did her colleagues and altogether they negated the pressure to change (Section 9.4.4).

The participant teachers took learning outcomes for granted (Section 9.3.3), which cast a shadow over the idea that the relevance of digital technology use to student learning outcomes facilitated its successful uptake in the classroom (Ertmer at al., 2012).
In trying to make sense of teacher belief systems and practices, a nagging idea began to take hold. An underlying assumption was that both personal and professional teacher beliefs drove teacher actions in the classroom to achieve student learning outcomes. These actions included the uptake of digital technology (Section 2.4.4). Was it possible that the beliefs of teachers and student learning outcomes had become disconnected? It that had happened what was driving teacher actions in the classroom and for what purpose?

The nagging idea originated from a chance reading of *The Power of Habit* (Duhigg, 2012). The book’s primary focus was the development of advertising strategies by commercial companies to manipulate customer habitual behaviours. Duhigg described how new habits were created just like normal learning “by putting together a cue, a routine and a reward” (Duhigg, 2012, p. 49). Repetition cultivated a craving that drove the loop. If this were like normal learning then was it possible that teachers’ well-practised classroom strategies were habits driven by a craving and not by beliefs about learning. If so, did this make a difference to the adoption of digital technology for pedagogical reasons? I was compelled to revisit literature to find out more about the connection between teacher habits and learning outcomes.

The following section is a summary of relevant recent findings in behavioural psychology and neuropsychology. The theory uncovered was not specific to education, but results were compelling and raised the possibility of purpose disconnection from beliefs under various circumstances. The literature could not be ignored. A discussion about whether the participants’ classroom behaviours were habits and how habitual behaviour affected innovative use of digital technology follows the literature summary.

### 10.3 Habits and Goals

#### 10.3.1 Literature

Research literature revealed two control processes of relevance to this study, namely, control of goal-directed cognitive behaviour and control of habitual automatic behaviour (Shah, 2013). Processes are controlled in essentially different components of the brain, and each has advantages and disadvantages.
Goal-directed behaviour uses prediction of the outcome of an action in order to select and initiate the action. In other words, if you perform an action, there is the possibility of achieving a particular goal. The action–outcome switching in the *dorsomedial striatum* of the basal ganglia uses the working memory capabilities of the prefrontal cortex to initiate goal-directed behaviour (Shah, 2013). The goal-directed process is flexible and does not require much experience, but it does require cognitive effort, memory, and computations (Shah, 2013).

Habitual processes are trained by repeated experiences gained from goal-directed behaviour in a recurring context (Neal, Wood, Labrecque, & Lally, 2012). These processes can also be built from random behaviour or by copying behaviour (Nielsen, 2006). The advantage of habitual behaviour is speedy, effortless, and often unconscious decision-making.

Habit is the psychological disposition to repeat past routines that when successful initiate an intrinsic reward (Neal et al., 2012). With sufficient repetition, the routine becomes associated with the context of repetition called a cue. The cue for the routine could be almost anything: an idea, a sequence of thoughts, a place, a person, an emotion, an advertisement, and so on. The routine could be very simple, very complex, or anything in between. The reward is personal and related to the senses or emotions.

With repetition and a consistent context, control of the behaviour develops in the brain’s *dorsolateral striatum* of the basal ganglia (Shah, 2013) and becomes an automatic response to the cue. With sufficient repetition, a craving, stimulated by the cue, develops in anticipation of the reward. The craving or combination of cue and reward is a very strong motivator for performing the action and its existence indicates the development of a strong habit (Duhsigg, 2012). In a period of transition from goal-directed to habitual behaviour, moderate habits are activated consciously by goals but could also be activated unconsciously by the context cue. Strong habits are not triggered by goals (Neal et al., 2012).

Daw et al. (2005) believed that a conflict between choosing a goal-directed routine or an habitual routine is mediated in the basal ganglia using the action’s associated levels of uncertainty: “We suggest a Bayesian principle of arbitration between them according to uncertainty, so each controller is deployed when it should be most accurate” (p. 1704). More recently, Schultz (2017) discovered a correlation
between a successful outcome and the activity of dopamine neurons. This may be a physiological measure for sensing levels of uncertainty.

Applying these ideas to the choice a teacher might make between the use of a digital technology innovation in a lesson, loaded with uncertainty about its purpose and outcomes against a teacher’s long-term teaching habits loaded with certainty and decision-making speed, the technology choice would come off second best on most occasions.

10.3.2 Teacher behaviour

These literature findings gave a possible explanation for inconsistent, confusing, and contradictory teacher behaviour in the classroom and the effect of disruptions to their practices. Data collected were compared to characteristics for identifying habits gleaned from Duhigg (2012) (refer to Table 10.2). Observation of only four lessons for each participant teacher is an impediment to making claims about repeated behaviour. The following sections describe suggestions only of habitual behaviour and goal-directed behaviour in the intentions and pedagogical approaches for the four case studies.

Table 10.2 Characteristics of Habitual Behaviour

<table>
<thead>
<tr>
<th>Development</th>
<th>Frequent performance in a stable context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cue</td>
<td>Location, idea, time, emotional state, people, prior action</td>
</tr>
<tr>
<td>Routine</td>
<td>Executed often without thinking, inflexible, sensitive to interruption, irrational</td>
</tr>
<tr>
<td>Reward</td>
<td>Personal, physiological; for example, when praised for an action, it is the ensuing rush of endorphins that constitutes the reward</td>
</tr>
<tr>
<td>Craving</td>
<td>Anticipation of success, derived from a merging of the cue and the reward, stimulates the habit</td>
</tr>
</tbody>
</table>

Note. Adapted from information found in C. Duhigg (2012). *The power of habit: Why we do what we do in life and business.*

10.3.2.1 Case Alan

Alan was an experienced teacher of the VCE Mathematical Methods subject. Over 17 years, he had negotiated change in the VCE Study Design, including the introduction of CAS applications. He had maintained a focus on prescribed learning
outcomes and had adjusted his pedagogical strategies accordingly. He used Mathematica for its recommended purposes in observation lessons (Section 9.4.3.1).

Alan did not have an habitual approach to daily lesson plans or intentions. While Alan’s lessons contained similar activities to those used by his colleagues, there was no uniform structure. In three lessons, he set three different types of homework (Section 7.4). In Lesson AO4, Alan demonstrated lesson plan flexibility when he changed the lesson and homework within an hour of discovering that the students had not understood the previous lesson’s concept (Section 7.4.3.1).

Alan’s pedagogical approaches were goal directed in both teaching and learning activities (Section 9.3.3.3). He modelled reasoning and making connections when he unpacked concepts in lessons. He set thought-provoking activities for students (Section 9.3.3.3). Alan relied on decision-making, and choosing Mathematica use was one option amongst the many different decisions he made during lessons. His goal-directed learning tasks similarly allowed students the opportunity to make decisions to choose to use digital technology or not. Alan’s use of goal-directed activities in lessons provided an environment of flexibility, reasoning, and choice, and these facilitated the use of digital technology in lessons.

Alan did enact routines that were possibly classroom habits. It was quite likely that Alan’s U-shaped room arrangement and silence in the classroom were habits and that these behaviours inhibited his adoption of collaborative student-to-student learning activities.

Alan also confronted situations that resulted in conflicted behaviour. The inability to reason out unexpected student questions or solve simple digital problems remained a mystery; they should have been simple for a goal-directed problem-solver. Perhaps these events indicate a habit of relying on others when confronted with digital or mathematical problems outside his immediate area of expertise or responsibility.

10.3.2.2 Case Tamara

Tamara exhibited a formulaic lesson plan that seemed moderately habitual (Section 9.3.3.1). Her treatment of concept routines varied considerably, and this gave the four observed lessons quite a different look and feel each time. Tamara commenced three of her four observed lessons with a collaborative, goal-directed concept task.
When the technicians were in the room during Lesson TO3, Tamara used teacher-centred routines for concept understanding, notes, and worked examples (Section 9.3.3.3). The unusual presence of outsiders in the classroom may have created a decision-making conflict for Tamara, resulting in the emergence of an old traditional habit.

Tamara’s lessons were marked by a consistent plan, goal-directed concept activities at least one of which used Mathematica, student collaboration for concept learning, and practice activities. Student–student collaboration was observed in Tamara’s class, but also some structured traditional teaching strategies such as handing out notes. As an experienced teacher with a new subject, it was as if Tamara was building her teaching repertoire for the subject, and as such, there were strong indications of goal-directed routines but insufficient repetition to have developed into habits.

10.3.2.3 Case Sarah

The multiple purposes and rationalisations that Sarah made when reflecting on innovation suggested that she faced an obstruction to change, and possibly the obstruction was caused by her habitual teacher routines.

Sarah’s formulaic lesson plans seemed habitual. Her board demonstrations of worked examples revealed a dislike of interruption (Section 9.3.3.3) and the change of mind of planned Mathematica use in preference to manual procedures (Section 5.4.6.2). The change of mind possibly represented a basal ganglia conflict in which the certainty of manual methods defeated the uncertainty of Mathematica use, even though its use represented a required learning outcome (Section 9.4.3.2).

Sarah also exhibited a very strong drive to give complete sets of information to students indicated by her attention to detail in worked examples (Section 9.3.3.3) and the comprehensive notes and references that she shared with students (Section 9.3.3.2). This habitual behaviour might well have been instigated in Sarah’s childhood. Sarah related that she just wanted the teacher to teach and then she would practise the exercises at school or at home (Section 5.1). Perhaps as a student, Sarah wished the teacher would give her everything, and so she tried to do that for her students. Perhaps she wished she had had more help at home and that idea initiated out-of-class student
help and hence the Padlet experiment. Habits that had been instigated in Sarah’s schooldays could be very strong.

When pressed into reflection, Sarah’s thinking was like shifting sand, rational but half-formed, with disconnections between the stated beliefs and enacted beliefs, between purposes and learning outcomes, and between processes and mathematical concepts. There was more happening than just a conflict of habit certainty and goal-directed uncertainty.

An explanation lay in the idea that habits could be copied (Section 10.3.1). Perhaps Sarah had copied her teaching approaches from her own teachers. In this case, the belief behind her teaching practice was not to achieve learning outcomes but to reproduce her childhood experiences or even a better version of her childhood experiences in the classroom. Sarah’s habitual actions based on copied behaviour initiated its own reward for Sarah. Her certainty about her teaching approaches outweighed the uncertainty of change in the classroom.

On the other hand, Sarah had not formed out-of-class habits and Sarah was free to explore the internet for ideas, implement the collaborative Padlet platform, and assist students with solutions to problems. Outside the classroom, Sarah modelled contemporary collaborative learning objectives using digital innovation. As Sarah became more successful outside the classroom, in-class practices were challenged. The certainty of tradition met the certainty of contemporary education. I believe it was like an epiphany, a moment of great realisation that led to a complete re-evaluation of her teaching practice.

10.3.2.4 Case Y7 Team

Helen displayed a resistance to change in her teaching practice and the use of the established Year 7 curriculum. Resistance was also evident in her outright rejection of the shift to team teaching and the collaborative and individuated learning strategies, innovations that had been seriously endorsed by school leadership to the extent of renovating the classroom learning environment (Section 8.3.2).

In addition, Helen had resisted the implementation of the IB MYP another school leadership initiative (Section 8.3.4), the use of pre and post testing of SMART, which had been endorsed by the Catholic Education Office, and the diagnostics and processes
Maths Pathway (Section 9.4.4). In essence, Helen was unable to relate to the learning outcome benefits of these innovations.

I concluded that Helen’s approaches to the teaching and learning of mathematics was habitual behaviour and resistant to new ideas. Her attempts to change were thwarted by strong habits. An underlying lack of self-belief about mathematics and about using digital technology fed her uncertainty (Section 8.1.3). Her irrational excuses and disconnected ideas about change led me to believe that she, too, had copied her teaching practices and lacked a purposeful foundation. Her habits had not been initiated by student learning goals other than covering content.

While the interpretations above may seem a little speculative, the reasoning was based on events that had occurred in observed lessons and post-observation discussions with participant teachers. My reasoning developed after investigating habitual behaviour and goal-directed behaviour. By the time that I did so, the opportunity to explore these ideas with the participants had long expired.

10.4 Reconceptualising the Innovation Uncertainty Model

Having found recent neuropsychological understandings of goal-directed and habitual behaviour, it seemed that innovation was the initial step of a larger process of acquiring certainty about a new idea, consolidating its purposes and benefits, identifying application contexts, and perhaps developing habitual behaviour around the idea in recurring contexts. This conclusion identified an extension to the definition of beliefs found in literature (Section 2.4.1).

The Innovation Uncertainty Model (Fig 3.1) was developed using the risk-taking model suggested by Priest (1993). Priest’s model is two-dimensional with arrows pointing in all different directions to account for numerous contingencies in outdoor education risk-taking activities. The IUM that I originally developed had fewer arrows but was ultimately too simple to deal with contingencies of both negative and positive progress. My IUM didn’t account for a positive outcome diminished by situational negativity and vice versa. Certainty about an idea does not uniformly move in a positive direction or negative direction on each activation of the innovation uncertainty model.
The two-dimensional model (Figure 3.1) was not sufficient to fully represent uncertainty and contribute to understanding the use and acceptance of a new idea in classroom practice. A new model named the Uncertainty Model was conceived with four phases (refer to Figure 10.1). Based on the idea that an innovation spirals inwardly towards certainty or spins off in the other direction to oblivion (Prochaska, DiClemente, & Norcross, 1992), the two-dimensional model of the innovation phase has been replaced by a three-dimensional spiral. While clearly still cyclic, the 3D-model better represents the possibility of minute changes to certainty that may be positive or negative or disruptive. The spiral represents both the achievement of certainty and the possibility of never achieving it.

10.4.1 Phase 1: Innovation

Innovation activation is initiated by personal teacher beliefs about teaching and learning strategies. Uncertainty of new action is poised on a balance of self-efficacy, control, and purpose or expectations (Ajzen, 1991; Bandura, 1986; Priest, 1993). When innovation activity has a successful outcome, in isolation of other events, self-efficacy is increased, control issues and expectations are consolidated, and/or purpose is confirmed, and in turn, innovation uncertainty decreases. The activity is likely to be repeated.

Sarah’s preparation for Padlet was significant; her implementation in Unit 1-2 Mathematical Methods was excellent and isolated from other activities in the lesson at the time. Sarah found the innovation had two sound purposes of reducing student–teacher emails and providing a platform for class collaboration, both out-of-classroom activities. Some students in this class had initiated out-of-class digital collaboration with each other and the teacher. These factors combined for a positive outcome for Padlet use outside the classroom for this class (refer to Section 5.4.5).

Despite the preparation Sarah found that Padlet was less successful when used in the classroom. Sarah’s control of questioning in the classroom was diminished when Padlet was employed. Certainty of her habitual teaching behaviour overshadowed any Padlet advantages in the classroom and was immediately rejected by the teacher (Daw et al. 2005).
These two examples show that the success of digital technology use is also influenced by the context of use.

**Figure 10.1** Uncertainty Model

### 10.4.2 Phase 2: Consolidation

The model suggests that with success, perhaps refinement, support and sufficient repetition uncertainty about the innovation decreases and the innovation emerges as a regular activity or a regular idea in the classroom.

Tamara implemented collaborative activities in the lessons whenever possible. Tamara believed that collaborative activities improved student learning. In this case, it was not the activities that were innovative; it was the idea of using collaboration for learning concepts in the mathematics classroom that was an innovation when compared to a more traditional lesson. Tamara repeated the collaborative idea rather than actual activities (refer to Section 6.4.3.1).

### 10.4.3 Phase 3: Transition

When repeated often enough in the same context, the regular activity or idea becomes associated with the context of action by way of a cue (Bourdieu, 1977; Duhigg, 2012). The activity is controlled by the context cue or by conscious teacher choice in a period of transition from regular activity to cued habit. Control of the action
remains with the *dorsomedial striatum* of the basal ganglia and begins to develop in the *dorsolateral striatum* of the basal ganglia (Shah, 2013).

Alan used Mathematica in observed classes without falter or statement about its use. However, when he introduced a problem-solving activity, he said, “We are going to use Mathematica” (Section 7.4.6.4) as if he was cued by the idea “problem-solving activity”. The use of a CAS application for problem-solving was specifically stated in the VCE Study Design (VCAA, 2010–2015).

**10.4.4 Phase 4: Habituation**

When a cued habit is repeated often enough, anticipation of success develops and emerges as a craving to act (Duhigg, 2012). Action is initiated by cue and driven by craving. The action is automatic and unconscious, while the behaviour is considered habitual. Strong habits are not triggered by goals (Neal et al., 2012). Control of the action has fully transferred to the *dorsolateral striatum* of the basal ganglia (Shah, 2013). The certainty of the action overrides the uncertainty of innovation unless goal-directed measures are enacted with deliberate awareness.

Certainty peaks and remains constant. The habit itself remains effective as long as its original purpose remains relevant to the environment.

When the leadership team changed the Year 7 learning environment, Helen resisted the change and took her class into a separate classroom, and teaching and learning continued unaltered. Helen was driven by a strong sense of the value of her carefully prepared mathematics curriculum but also by a craving perhaps to help her disadvantaged students. Helen’s room change was indicative of a Phase 1 uncertain leadership innovation conflicting with the certainty of Helen’s strongly embedded Phase 4 habitual practices (Section 9.5.1.5).

The Uncertainty Model (Fig 10.1) provides a macro illustration of the integration of a digital innovation to habitual classroom behaviour. The model represents the uncertainty a teacher faces in adopting a new classroom action. The new idea forms the basis of an evolving belief associated with the action. Action repetition evokes further development in emotional and contextual belief elements that affect the certainty of the belief.
The model does not include the micro points of decision making that were included in the IUM (Fig 3.1). All the Uncertainty Model phases are needed to develop a habit. Successful innovations may not turn into habits. The pivotal factors of the phases include teacher beliefs about self-efficacy, control and purpose and, success, repetition, and a consistent context. It seems that a school classroom is an ideal location in which to develop some habits.

10.5 Changing Habits

Duhigg (2012) suggested that changing habits lies in raising awareness, or bringing into working memory, the repeated routines, associated cues, and rewards of habits. This is relatively straightforward for a moderate habit, while the goal-directed action is readily assessable to working memory. With sufficient motivation, the goal-directed behaviour could be adjusted to accommodate an innovation. The context of the moderate habit would be changed by the adjustment and this would diffuse the development of the original habit.

The Year 7 teachers had associated the idea of homework with Maths Mate worksheets, and that was taken for granted by the teachers although they may have also set additional homework (Section 8.3.4.6).

To change a strong habit, where control of the behaviour has shifted entirely to cues and cravings, is more challenging (Duhigg, 2012).

Helen thought Lesson Y7O3 was a failure because the students did not complete the exercises as expected. She had no idea why. Helen could not articulate a single problem with the lesson either immediately or later when she had time to reflect (Section 8.3.4.7). Her habitual lesson routines obstructed her ability to notice and reason about the ways in which students were not able to complete the activities as expected.

To change an existing habit, Duhigg suggested keeping the cues and reward and changing the routine in the middle. To be successful, the new routine needs a high level of certainty about its purpose and self-belief in performing the routine. These ideas imply that if the routine involves digital technology, the teacher needs sufficient knowledge of learning goals and sufficient preparation in the digital uses.
There was evidence in her comments about SMART and Maths Pathway that Helen was uncertain about the teacher role of intervening with an individual student’s mathematical misconceptions when compared to completing the curriculum with the entire class (Section 8.3.4.7). Colleagues who felt the same way reinforced this idea. In order to change, commitment to the fundamental goal of addressing mathematical misconceptions needed to be made prior to assigning SMART or Maths Pathway to the identification and intervention role.

The facilitating factors for implementing a new idea drive the Uncertainty Model. An innovation implementation methodology needs preparation, an introductory activity, reflection, refinement, and repetition. Disconnecting the preparation activity from the normal lesson routine has the advantage of avoiding teaching habits, as Sarah found in her Padlet experiment (Section 5.4.5).

Preparation for a digital innovation outside the classroom includes garnering collegial support, defining the purpose of the digital technology and the benefits to be gained, taking professional development steps to be sufficiently confident and competent, consultation with students, test and trial of the application, use in lessons, reflection on outcomes compared to purposes, and evaluating benefits after several iterations. While this may seem arduous involving “extra work”, starting with a very small innovation would help reduce the load.

10.6 Performance

There is one more aspect of this cognitive theory to consider, which is the concept of performance. Finely honed skills are the backbone of smooth performance: automatic, speedy, and unconscious decision-making. According to Beilock (2012), performance requires a clear prefrontal cortex bridge between the two sides of the brain to bring all the skills needed to fruition. Strategising, over thinking, anxiety, fears, ideas, and emotion could block the prefrontal cortex and obstruct skills (Beilock). In other words, goal-directed behaviour and emotional reactions could block habits and the performer could “choke”.

These ideas give rise to the consideration of a regular mathematics classroom in which the experienced teacher performs teaching, while the students are learning and practising mathematics. Students perform learning when being assessed in a formative
assessment or summative assessment task. The collected data contained examples of teacher performance disruption.

Alan’s behaviour in Lesson AO1 when he tried to boot the board after the power failure is such an example (Section 10.2.1). His usual behaviour was to boot the board from his own laptop. His usual behaviour when in trouble with technology was to ask the students for help. In this particular lesson, he did neither. Instead, he tried to fix the problem himself while the preservice teacher, students, and I watched. Instead of his fluid lesson start, Alan concentrated on a goal-directed, problem-solving, prefrontal cortex-laden task, and this interfered with his usual behaviour, especially as he could not reach a solution. Then a student intervened; was that his usual behaviour?

An example of the opposite occurred when Sarah introduced SimpleMind in Lesson SO4. Sarah was prepared with the instructions for students to use SimpleMind (Section 9.5.1.4). When the students said, “Can we use Inspiration?” Sarah ignored the question at first and then agreed, but all the while, she continued to give out instructions on using SimpleMind. Sarah eventually recognised that SimpleMind was not working as expected. Sarah was resistant to the interruption of her performance for such a long time on this occasion.

Interesting questions arose. Was smooth and efficient mathematics teaching and learning detrimental to the development of goal-directed mathematical reasoning and application? Did mathematics teachers perform automatic mathematics in the classroom without reasoning? On occasion, both Sarah (Section 5.4.3.3) and Helen (Section 8.3.4.2) adopted strategies of recall and/or instruction in favour of reasoning and connection. Alan was caught out by unexpected student questions that he just could not process in the moment (Section 7.4.3.1). Tamara was not caught by questions, possibly because being new to the subject she had not developed habits around its routines. Actually, she did say using Mathematica was cheating, and that was possibly an habitual idea about using technology for computations.

Performance actions engendered doubts about the underlying beliefs, which may have had nothing to do with student learning outcomes but rather something to do with copying the actions. Intricate cognitive connections could not be copied directly and still needed construction in the brain. The copied actions might be effective when accompanied by connected reasoning. Bec may have habitually said, “Follow the
instructions”, but she failed to detect that her instructions were inconsistent and unreasonable (Section 8.3.6.4). Given the reliance of mathematics on reasoning, I believe that teacher performance in the mathematics classroom is a significant topic for further research.

10.7 Revisiting Bourdieu

My study has led me to recognise in Bourdieu’s (1977) field theory the importance of culture being passed down from generation to generation in the habitual practices of families and social surroundings, education, and then workplace training and experiences. Habits save time and effort and provide an efficient way of transferring culture. As a result, we are moulded into functioning, useful beings ready to perform and contribute to our cultural communities.

The cultural practices of education make a significant contribution to the conditioning processes. The seeds of how teachers teach and students learn are planted in childhood school experiences and then cultivated with teacher training and professional experiences. The teacher brings these experiences into the classroom, and these inform teacher practices and help sustain cultural education.

Perhaps, like Tamara who was influenced by home and school experiences, a teacher develops into a problem-solver and collaborator. Perhaps, like Alan, a teacher rejects early education experiences and invents their own. Perhaps, like Sarah, a teacher embraces their childhood experiences but then continues to learn until they are confused about how to teach. Perhaps, like Helen, the teacher sticks with what they know best. There is evidence in the data collected that each participant teacher brought childhood experiences into the classroom (Section 9.2.1).

As the teacher gains further professional learning and experience, their classroom actions are refined by necessity under the influence of the educational institution and their own cognitive constructions (Reay, 2004), but only in small ways (Bennison & Goos, 2010). With repetition, teacher actions in the classroom become habitual, enhanced by the teacher certainty and the satisfaction they gain from doing it (Duhigg, 2012).

In a time of cultural upheaval, field theory unravels a little when the requirements for significant new actions and reactions, goals, and objectives clash with established
culture. Reay (2004) suggested that the outcomes of such clashes are change, new awareness, and resistance (Reay, 2004). Change was evident in Alan’s use of Mathematica, new awareness was indicated in Sarah’s crisis that led to a reconceptualisation of her teaching practices, while resistance came from Helen. These outcomes are evidence of a new culture in development at the school at the time of this study.

Applying Bourdieu’s analogy of playing a game to the situation of cultural change, the need to differentiate between the field of learning and practice and the field of performance arises. The teacher’s field of learning or introduction to and preparation for a new teaching strategy needs to be separated from the classroom field in order to avoid a cognitive clash between the goal-directed innovation and habitual teaching practices. Sarah was well prepared to implement Padlet (Section 5.4.5.1). Alan was sufficiently prepared for his YouTube clips (Section 7.4.6.6) knowing that help was on hand for unexpected problems. Both teachers succeeded in introducing these innovations into the very beginning of the lesson before the rhythm of the lesson had been set. Ultimately, Sarah needed to choose between Padlet and her habitual practices, and the latter won. Ultimately, Alan was able to back-reference the video clip during subsequent lessons. His ability to make unconscious connections was perhaps an aspect of his goal-directed teaching practice.

Helen was not sufficiently prepared to introduce Maths Pathway or to team teach or provide collaborative and individuated learning opportunities for her students (Section 8.3.2.1), and habitual practices dominated her lessons and affected her ability to reflect and adapt to change.

10.8 Conclusion

The study has concluded. Discussion of additional research findings has resulted in identifying teacher habits as an obstruction to the use of digital technology in the classroom and goal-directed behaviour a means of rectifying habits. In the final chapter, research questions are answered and further findings of the study are outlined. The implications for the research community and further research questions for professional practice and for policymakers are also discussed.
Understanding the ideas in Choke and applying them to table tennis performance contributed to my study of mathematics education in several different ways. The book introduced me to recent research in neuropsychology, so that when I began to read about goal-directed and habitual behaviours, I was already attuned to that context.

I learnt that my table tennis skills were habits that I had honed over time. I became aware of cues that initiated automatic responses, and I am still working on changing some routines and developing multiple cues to stimulate more appropriate shots under different conditions. This led to the consideration of how mathematics teachers approached the development of process cues with their students.

Previously, I had not differentiated performance, training, and practice behaviours in table tennis. I knew I behaved differently in all three, but differences were overshadowed by table tennis actions that were the same in all three. Over time, I have adapted my approach to training, practice, and performance. My table tennis performance has become more automatic during match play and very strategic during breaks between games. I have shifted the mindset of my coach to address my small objectives during training sessions, and I now choose my practice partners more wisely.

When I applied the idea of learning, practice, and performance to mathematics lessons, I realised that mathematics teachers were often expected to perform and learn (or practise) innovative techniques at the same time, a sure recipe for cognitive conflict. The more habitual the teacher in lesson activities, the less chance there was for success with digital innovation. The more goal-directed and better prepared the teacher is with digital innovations, the greater the chance of overriding habits and succeeding with innovation. I realised that students were taught
many mathematical techniques to facilitate smooth automated responses on mathematics tests and questioned whether this student learning outcome was warranted. However, this question was beyond the scope of my study.
CHAPTER 11
CONCLUSIONS

11.1 Findings

This study sought to understand mathematics teachers’ uses of digital technology for pedagogical advantage in the classroom. Based on the sociology of institutional influence on the teacher in the classroom (Bourdieu, 1977), the psychology of risk-taking (Priest, 1993), and the philosophy of mathematics education (Ernest, 1991), the study’s theoretical framework and methodology revealed known complexities of previous research and new insights facilitated by more recent research in neuropsychology.

The study focused on the pedagogical practices of six mathematics teachers in their classrooms. Three of the teachers taught at VCE level and held similar beliefs about the importance of the subject Unit 1–2 Mathematical Methods (CAS) but very different beliefs about how to teach and how students learn. One teaching model was interpreted as inquiry based, one was collaborative, and one was based on instruction.

Three teachers taught Year 7 mathematics as a collaborative team. They taught an agreed established curriculum by mainly passing on information and knowledge with a learning model of memory, recall, and repetition. One teacher had been instrumental in establishing the curriculum, and the data collected from her practice were considered representative of the team. The team met regularly to coordinate their efforts, share resources and exchange ideas. This resulted in a uniform approach to lesson delivery.

The statements and actions of the participant teachers viewed and expressed during lessons and at interviews were interpreted to reveal beliefs. My interpretations were tempered by my cultural beliefs and experiences gained over a lifetime. In particular, I spent nearly 20 years in the IT industry, learning, using, and managing digital technology, followed by an equal time working in education.

I was well versed in digital objectives, implementation methodology, and criteria for success. These attributes informed the decisions I made about the study and my interpretations of data and research literature. Research literature led me to the consideration of the digital challenge to educational actions of cultural reproduction.
The results of my interpretations may continue to challenge traditional thinking and inform innovative practices.

In the following sections, the research questions are answered, further findings of the study are suggested, possible implications of these results are discussed and my conclusion is revealed.

11.2 Research Questions Revisited

11.2.1 Research Question 1

How is digital technology being used in mathematics lessons and for what pedagogical advantages?

For most digital technology used during data collection, the teachers could not articulate their intentions for using digital technology and recognise or articulate benefit to student learning. Hence, the pedagogical advantage or benefit to student learning outcomes was interpreted from the digital technology use or purpose.

11.2.1.1 School’s generic digital technology infrastructure

The school’s comprehensive digital network enabled significant digital functionality in VCE and Year 7 mathematics lessons. The network infrastructure and its links to the internet were accessible from all classrooms through wi-fi. The infrastructure supported a range of administrative digital applications related to teacher duties, such as recording attendance and assessment results. Teachers and students accessed the infrastructure using personal devices to send email, to access online textbooks, and to create, store, and research digital documents and other resources.

One teacher had found benefit in efficient and effective just-in-time communication on student progress with students and parents using the intranet’s assessment-tracking module. Gains made were compromised by the duplicated effort of report writing.

In general, the school’s infrastructure represented efficiency gains, without essentially affecting pedagogical approaches. The online VCE textbook was based on a traditional text and did not have additional interactive features to further enhance learning. The benefits of the online text were efficiency gains in cost, time, and effort rather than any mathematical education advantages. The digital infrastructure was
needed to access mathematical tools such as Maths Pathway, for example, resulting in an indirect effect on mathematical pedagogical outcomes.

11.2.1.2 VCE mathematical digital applications

The use of CAS Mathematica was observed in VCE mathematics lessons in response to the VCE Study Design requirement to address digital technology outcomes for computations, exploration of mathematical ideas, analysis, and problem-solving. The VCE teachers perceived Mathematica benefits in checking answers and tracking student thinking by way of the Mathematica command structure. The teachers did not articulate other benefits such as efficient and effective computations and problem-solving, and the cognitive linking of mathematical ideas. These were assumed benefits contained in the curriculum requirements.

The Slideshow module of the Mathematica suite was a presentation application used by teachers to distribute study notes and linked resources and as the platform for online examination of tech-active assessment tasks. The VCE teachers believed online testing was the way of the future and introduced online testing at Year 11 to prepare students for Year 12 Mathematical Methods assessment tasks with the assumed benefit for Year 11 students of gaining familiarity and skill within the context of online assessment.

The Padlet application was successfully used as an online bulletin board platform outside the classroom with the benefit of equitable collaboration and efficient communication by one VCE class. The teacher did not succeed in introducing Padlet to her other mathematics classes, partly because a multiplicity of purposes and benefits muddled the reflection process (Section 10.2.3.3). The experiment had not been shared with colleagues.

The VCE teacher team shared with each other and students a wide range of online links to YouTube clips, mathematical games, and tutorials. Two YouTube clips were mentioned or seen in lessons. The teachers recognised the clips as being relevant to the lives of their students, and that the clips had engaged students. The teachers did not acknowledge the benefit derived from back-referencing the clips in lessons to reinforce mathematical ideas.
The VCE teachers were building a bank of concept videos using flipchart software for students who had missed a lesson and/or for revision purposes. The interpreted benefit was in fulfilling a teacher sense of responsibility towards providing efficient and effective resources for the students.

One VCE teacher experimented with flowcharting mathematical processes using a digital mind-mapping application that had the interpreted benefit of providing alternative visual representations of processes and decision-making.

11.2.1.3 Year 7 digital mathematical applications

The Year 7 teachers acknowledged the use of flipcharts displayed on interactive whiteboards as a teacher partner for efficient and effective means of conveying mathematical information to students.

The Year 7 students used iPads in lessons for the benefit of accessing online worksheets, honing mathematical skills, and possibly performing computations efficiently and effectively.

The Year 7 teachers experimented with Maths Pathway, an online mathematics teaching and learning application, for several cycles. During this time, the teachers continued with their established flipchart-based curriculum and used Maths Pathway mainly as a personal worksheet generator for individuals. The teachers could not find benefit in the worksheets because they did not cover sufficient material in a timely fashion. Maths Pathway was discarded.

The Year 7 teachers had access to SMART, an online database of tests and remediating teacher strategies for the identification and redress of mathematical misconceptions. It had been rarely used because the teachers could not agree about the benefit of addressing mathematical misconceptions as well as completing content delivery in time for planned assessment tasks.

11.2.1.4 Scientific calculator

The teachers generated confusion about the use of scientific calculators in observed lessons, at times. Calculators were banned from some activities and assessment tasks. On one such occasion after banning students’ digital technology use, a VCE teacher used the calculator on behalf of the students to compute difficult arithmetic problems.
Year 7 teachers suggested that students bring a calculator to school for an assessment task as they would not have access to their iPads during the task.

11.2.2 Research Question 2

Which teacher beliefs facilitate or obstruct uses of digital technology in secondary school mathematics lessons?

The belief that clearly facilitated the use of digital technology by the teacher was usage that supported the teacher’s pedagogical approaches. The teachers exhibited strong beliefs in the way they taught. Teacher uses of Mathematica reflected instruction, inquiry, discovery, and collaborative teaching and learning strategies in line with curriculum requirements. Teachers adapted Maths Pathway and Slideshow to suit existing teaching approaches and in doing so negated the benefits, such as self-paced learning and efficient instructions and computations.

A combination of beliefs was needed to obstruct digital technology use. The uncertainty beliefs—self-efficacy, control, and benefit or loss—were significant determinants for introducing digital innovations successfully, but they were not conclusive. Weak self-efficacy and control were evident in the use of flowcharting and video clip innovations, which were ultimately successful in my opinion. Lack of subject teaching experience was evident in confusion about choosing and using digital technology. Some residual ideas about digital technology benefit were reflected in the words “cheating” and “loss of mental skills”. Teacher uncertainty beliefs did not inhibit the digital activity outright, and some digital activities were successful and were repeated in lessons.

The influences of colleagues, school leadership, and external others resulted in mixed outcomes to digital innovations and change. Collegial influence facilitated the use of video clips for the VCE teachers. Leadership influence was effective for initiating the trial of VCE online assessment. The VCE curriculum required the uptake of a CAS. A preservice teacher in training facilitated the choice of Padlet.

Collegial influence obstructed the Year 7 teachers’ use of Maths Pathway and SMART. Leadership influence was ineffective on Year 7 mathematics teacher to change to individuated student progress pre and post testing and collaborative learning activities. In addition, leadership influence to adopt the IB MYP was only partially
realised by the Year 7 mathematics teachers, despite comprehensive training. A preservice teacher influenced the trial of Maths Pathway, which was abandoned after six weeks. The Catholic Education Office-influenced SMART was rarely used.

None of the participants were able to articulate learning outcomes for a lesson other than content. Student learning outcomes were not a conscious driver for teacher actions in the classroom in general and not the driver for change to contemporary learning outcomes. From their schooldays, two teachers had learnt that certain activities made learning mathematics easier. One included goal-directed learning activities while the other included collaborative activities in lessons. Both teachers used digital technology in their lessons purposefully in these activities, but neither associated the use of technology directly with the benefits of these activities.

The inconclusive results for beliefs-driven obstruction to digital technology use for student learning led to consideration of a fourth research question and new understanding about uncertainty and change, found in Section 11.3 Additional Findings.

11.2.3 Research Question 3

What mathematical pedagogical practices no longer make sense in a contemporary learning environment?

Teacher practices that do not deliver contemporary student learning outcomes do not make sense in contemporary learning environments. Indications of these practices include taking learning for granted, learning outcomes limited to knowledge acquisition, teaching strategies with limited and repetitive approaches, disengaged students, ignoring influences, and resistance to change.

The weakness of habitual practice lies in the reproduction of traditional actions seemingly impervious to change and the simplicity of copying behaviour. Copied behaviour does not guarantee that the underlying rational cognitive connections supporting goal-directed choices for initiating the behaviour have been established. Copied behaviour may account for the teacher’s lack of consistent adherence to a singular philosophy of mathematics education (Ernest, 1991). Copied behaviour may account for the difference between stated beliefs and expressed beliefs (Reay, 2004).
Finally, copied behaviour challenges the idea that you can identify teacher beliefs about their practice from their actions and statements in the classroom.

11.3 Additional Findings

11.3.1 Habitual teaching practice

The absolute resistance shown by one teacher to change in team teaching, individuated student progress, collaborative learning opportunities, and the reluctance to use digital technology other than flipcharts indicated another facet to digital use obstruction in the classroom. Goal-directed behaviour facilitates teacher uptake of digital technology, while habitual behaviour obstructs teacher uptake of digital technology.

Although habitual behaviour is derived from the repetition of belief-driven actions in a uniform context, teacher habits are not necessarily derived from or driven by beliefs about student learning outcomes. Teacher actions may have been copied, and if so, the teacher would not necessarily “know” the originating belief driving the behaviour and its expected outcomes (Section 10.3.1). The belief driving copied behaviour is “to copy”, and the outcome is reproduction of behaviour. This idea explains to some extent why the participant teachers were unable or reluctant to articulate expected learning outcomes other than content knowledge, or the purpose and benefit of using digital technology.

Either way, strong teacher habits are detached from the derivative belief and are driven by a contextual cue in the classroom environment and a personal craving for the teacher to perform as “usual”. The agreement between Year 7 mathematics teachers on a uniform pedagogical approach is an example of normalising teacher practice. One teacher was an apprentice to the normalising process (Section 8.5.1.1).

New understanding in neuropsychology research has found that control of habitual and goal-directed behaviours occurs in different parts of the brain. Behaviour conflict arises when the teacher needs to choose between an habitual action and goal-directed action. The choice is mediated by a physiological measure of certainty, which favours the habit. However, cognitive activity in the prefrontal cortex about innovation benefit, confidence, competence, self-belief, control, support, influence, and self-awareness could block habit flow and allow the innovation to flourish. The neuropsychological
research casts a shadow of doubt over earlier research findings that teacher practices were driven by beliefs about student learning and that the relevance of digital technology to student learning had the biggest impact on successful digital integration (Ertmer et al., 2012)

Habitual teaching practice was found to be prevalent amongst the teacher participants. Classroom habits may or may not have been formed from beliefs about student learning and have little connection in the teacher’s brain to learning outcomes. Habits were driven by the classroom environment and not by beliefs. The certainty of habits was compulsive and resistant to change.

Habitual practices obstructed the use of digital technology by teachers in mathematics lessons. Goal-directed digital innovation could overcome obstructive habitual practices.

11.3.2 Uncertainty Model

It is suggested that the uncertainty model (refer to Fig 11.1) is a continuum from a state of uncertainty to acceptance in some contexts to perhaps the development of habit in a repeated context. An innovation evokes uncertainty and requires goal-directed actions to establish certainty. Innovation actions are directed by purpose or by finding purpose and are facilitated by self-efficacy, control, success, benefit, and a supportive environment. These are the characteristics that can be enhanced by professional development activities.

Not all innovations become habits. Some are rejected in Phase 1; some become irregularly repeated activities in one or more environments in Phase 2; some are repeated often enough in a consistent environment to become semi-automatic in Phase 3; while some are repeated often enough in a consistent environment to be automatically triggered by an environmental cue. The certainty of the automatic response over-shadows the uncertainty of innovation, unless the teacher’s pre-fontal cortex has been loaded with purpose, plans, encouragement and expectations to block the automatic responses.
11.3.3 Digital technology ripple effect

A finding of the study is that digital technology is underestimated in terms of complexity and the potential for ripple effect when used. In particular, multiple digital technology outcomes can affect the success of a single purpose use. The contemporary mathematics teacher requires a level of digital resilience to reflect on the veracity of outcomes and not be obstructed by unexpected events.

The implementation of a digital innovation for classroom lessons would benefit from a structured methodology initiated and prepared outside the classroom in a supported environment. A structured methodology was seen in the Padlet implementation. Had the teacher been given support and input from her colleagues, the Padlet implementation may have been refined of excessive purposes so that the innovation or an alternative routine could more reasonably be conceived. The implementation would have benefited from collaboration between colleagues.

11.4 Implications for Further Research

Several ideas evolved from the study that suggest the need for further research. The innovation uncertainty continuum stretching from a new idea to a state of habitual behaviour evoked a sense of learning. How does the model compare to learning theory?

The assumption that teacher pedagogical beliefs can be interpreted from actions in the classroom is open to conjecture if the actions of the teacher are habitual and have
been copied. The teacher’s actions still reflect beliefs, but if the originating belief was to copy the techniques of their favourite mathematics teacher in Year 4, for example, the actions may have never been cognitively connected to specific pedagogical outcomes.

An implication of the study is the need for a much greater emphasis on problem-solving activities and less emphasis on memorised skills and processes that might be more efficiently and effectively computed using digital tools in the mathematics classroom. Further research is needed to define a mathematics education paradigm that is more suitable for today’s world.

Mathematics teacher performance has been identified as posing an interesting juxtaposition of habitual and goal-directed behaviour. Efficient and often unconscious decision-making by the teacher has the potential of overshadowing more effective practices. What does teacher performance look like?

Many professional development programs for contemporary teacher change already exist. Which of these programs is suited or adaptable to address the difficulty in changing habitual behaviour?

### 11.5 Implications for Professional Practice

The implications for professional practice of teachers lie in the facilitation of mathematical learning goals comprising complex cognitive constructions that encompass the understanding and use of mathematical rules, symbolism, language, history, application, performance, and problem-solving. Critical to achieving mathematics pedagogical complexity is collaboration with peers for understanding of individual variations and collective solutions.

One teacher’s experience of cognitive conflict contains the key characteristics of changing practice—the realisation of a disconnect in beliefs, self-reflection, potential melt down, and withdrawal, then the awakening and fronting up to classes with revised purposes. Ideally, there is collegial support and perhaps guidance from practitioners to lead the way through change.
11.6 Implications for Policymaking

The implications of this study suggest that a response from policymakers is not to make more or new policy but rather to implement existing policy thoroughly before reacting to new ideas. Introducing new policy in a response to a perceived failure of existing policy leads inevitably to practitioner change burnout and/or cynicism and/or resistance. For example, learning outcomes are well established as a policy, but teachers still cannot/do not/will not articulate them in lesson plans or teach them explicitly. Teachers conduct lessons mainly around content and fret about how they will teach, rather than how students will learn.

How could the Year 7 mathematics teacher participants get away with their interpretation of team teaching and individuated learning? Where were the support personnel, reflection opportunities, and success indicators? Their “trial and error” method was not adequate to achieve success, and basically, the teachers did not change one thing in their established curriculum in response to the challenge. In the same way that teachers are bound by habits, policymakers are bound by habits. Policy needs to be implemented with a clear goal and methodology that ensures the possibility of success.

11.7 Conclusion

This study addressed the issue of mathematics teacher use of digital technology in the classroom for pedagogical advantage. Data revealed previously known findings – inconsistent behaviours from different mathematics philosophies, assumed learning outcomes, adaption of digital purpose, successful digital integration, and resistance to change. Previous research has identified these conditions. This study suggests a reason for why this happens.

Recent neuropsychology research has compared the cognitive differences between goal-directed behaviour and habitual behaviour and identified the potential for a cognitive conflict. Teacher goal-directed behaviours are driven by the achievement of goals related to student-learning outcomes. Teacher habits are driven by a combination of cue and reward developed through repetitious goal-directed behaviour in a constant context, by a random event or by copying teacher actions. Teacher habits may be effective in achieving student learning outcomes. However, they may be disconnected from initiating beliefs and driven instead by a combination of cue and craving for
reward. This knowledge casts a shadow over the assumption that the actions of mathematics teachers in the classroom are indicative of their beliefs about student learning outcomes.

Problems arise with teacher habits in a situation of change. When confronted with choice between a habit and an innovation a cognitive conflict ensues that is mediated by certainty. The habit is favoured. Strong habitual actions have a stable high level of certainty while innovative goal-directed actions such as digital technology use, have reduced certainty based initially on uncertain outcomes and other personal factors.

The power of habit can be ameliorated by well-prepared goal-directed actions. These can affect both the issues of uncertainty and the flow of habit through the prefrontal cortex. The uncertainty issues include teacher self-efficacy, control, purpose and benefit of the goal-directed action, and external support on-hand for its implementation.

When introducing an innovation in the classroom the teacher’s adherence to an action plan can block the flow of habit and allow the innovation to succeed. Other desirable factors are a thorough preparation outside the classroom, introduction at the lesson’s commencement before the rhythm of the lesson takes over, and, the support of colleagues.
REFERENCES


Wilson, B., Sherry, L., Dobrovolny, J., Batty, M., & Ryder, M. (2002). Adoption of learning technologies in schools and universities. In H. H. Adelsberger,


APPENDICES

Appendix 1

Approval to Conduct Research MUHREC

Monash University Human Research Ethics Committee (MUHREC)
Research Office

Human Ethics Certificate of Approval

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the National Statement on Ethical Conduct in Human Research and has granted approval.

Project Number: CF14/995 - 2014000416
Project Title: Old Habits Die Hard but What is Their Value?
Chief Investigator: Dr Wee Tiong Seah
Approved: From: 14 April 2014 To: 14 April 2019

Terms of approval - Failure to comply with the terms below is in breach of your approval and the Australian Code for the Responsible Conduct of Research.

1. The Chief Investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash University letterhead and the Monash University complaints clause must include your project number.
6. Amendments to the approved project (including changes in personnel): Require the submission of a Request for Amendment form to MUHREC and must not begin without written approval from MUHREC. Substantial variations may require a new application.
7. Future correspondence: Please quote the project number and project title above in any further correspondence.
8. Annual report: Continued approval of this project is dependent on the submission of an Annual Report. This is determined by the date of your letter of approval.
9. Final report: A Final Report should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected date of completion.
10. Monitoring: Projects may be subject to an audit or any other form of monitoring by MUHREC at any time.
11. Retention and storage of data: The Chief Investigator is responsible for the storage and retention of original data pertaining to a project for a minimum period of five years.

Professor Nip Thomson
Chair, MUHREC

cc: Ms Marguerite O'Bryan
Appendix 2

Approval to Conduct Research CEO

GE14/0009       Project #2007 O’Bryan
15 December 2014

Ms Marguerite O’Bryan
19 Willandra Ave
CANTERBURY VIC 3126

Dear Ms O’Bryan

I am writing with regard to your research application received on 1 April 2014 concerning your forthcoming project titled, Old Habits Die Hard but what is Their Value? You have asked approval to approach Catholic schools in the Archdiocese of Melbourne, as you wish to involve teachers.

I am pleased to advise that your research proposal is approved in principle subject to the eight standard conditions outlined below.

1. The decision as to whether or not research can proceed in a school rests with the school's principal, so you will need to obtain approval directly from the principal of the school that you wish to involve. You should provide the principal with an outline of your research proposal and indicate what will be asked of the school. A copy of this letter of approval, and a copy of notification of approval from the organisation’s/university’s Ethics Committee, should also be provided.

2. A copy of the approval notification from your institution’s Ethics Committee must be forwarded to this Office, together with any modifications to your research protocol requested by the Committee. You may not start any research in Catholic Schools until this step has been completed.

3. A Working with Children (WWC) check – or registration with the Victorian Institute of Teaching (VIT) – is necessary for all researchers visiting schools. Appropriate documentation must be shown to the principal before starting the research in the school.

4. No student is to participate in the research study unless s/he is willing to do so and informed consent is given in writing by a parent/guardian.
5. Any substantial modifications to the research proposal, or additional research involving use of the data collected, will require a further research approval submission to this Office.

6. Data relating to individuals or the school are to remain confidential.

7. Since participating schools have an interest in research findings, you should consider ways in which the results of the study could be made available for the benefit of the school community.

8. At the conclusion of the study, a copy or summary of the research findings should be forwarded to the Catholic Education Office Melbourne. It would be appreciated if you could submit your report in an **electronic format** using the email address provided below.

I wish you well with your research study. If you have any queries concerning this matter, please contact Ms Shani Prendergast of this Office. The email address is apr@ceomelb.catholic.edu.au.

Yours sincerely

Anna Rados
MANAGER ANALYSIS, POLICY & RESEARCH
Appendix 3

Teacher Explanatory Statement

EXPLANATORY STATEMENT

Group 2: Case Studies Participants

Project (#LR 201400416): Old Habits Die Hard But What Is Their Value?

Dr Wee Tiong Seah
Faculty of Education
Phone: 61 3 9904 4088
e-mail: WeeTiong.Seah@monash.edu

Ms Marguerite O’Bryan
Faculty of Education
e-mail: mjobr1@student.monash.edu

You are invited to take part in Stage 2 of a PhD student project. Please read this Explanatory Statement in full before deciding whether or not to participate in this research. Your participation is voluntary. If you would like further information regarding any aspect of this study, you are encouraged to contact the researchers via the phone numbers or email addresses listed above.

Thank you for responding to the questionnaire in Stage 1 of this research study, in which you had also indicated your interest in taking part in this current Stage 2. The research is focused on secondary school mathematics teachers and their beliefs about mathematics education, the use of digital technology in the mathematics classroom and risk-taking. The purpose of this stage of the project is to obtain an in-depth understanding of these beliefs for three individual teacher participants. An intention of the research is to uncover strategies to empower mathematics teachers to take risks with digital technology for pedagogical advantage by addressing the following question:

What teacher beliefs underlie or prevent pedagogical uses of digital technology in the Years 7-10 mathematics classroom?

Participation in this stage involves an initial interview to essentially clarify the process. This will be followed by lesson observations and post-lesson interviews on up to six occasions over one year of your teaching. To facilitate the analysis process, the observed lessons will be video/audio taped, while the interviews will be audio taped with your agreement. The audio recordings will facilitate more accurate transcripts of the lessons and interviews. The video recordings serve the function of stimulating recall of chosen events during the interviews following the lessons observed.

Your participation will be confirmed when you sign and return the attached consent form. If you confirm your participation, you have the right to withdraw from further participation at any point in future and in this case data collected through your participation may be withdrawn if you so wish.

Observation of lessons and follow-up interviews are not expected to lead to any discomfort beyond which is normally experienced in our day-to-day living. Nevertheless, a list of counselling services in the vicinity of your school is attached to this Explanatory Statement for your reference if needed.

To preserve anonymity of data collected, it will be encoded using pseudonyms applied to both you and your school’s identities during the research process and in subsequent publications. Data collected will be stored in accordance with Monash University regulations during and after completion. Video will be destroyed immediately after the corresponding interview session. Digital data will be secured at all times with restricted access to researchers only. Hardcopy data will be stored in a locked cabinet in the University for a period of 5 years after this research is completed.
Results

A summary of the research results is available upon request. Please feel free to contact me should you wish to receive this summary.

Complaints

Should you have any concerns or complaints about the conduct of the project, you are welcome to contact the Executive Officer, Monash University Human Research Ethics (MUHREC):

Executive Officer
Monash University Human Research Ethics Committee (MUHREC)
Room 111, Building 3e
Research Office
Monash University VIC 3800

Tel: +61 3 9905 2052  Email: muhrec@monash.edu  Fax: +61 3 9905 3831

Thank you,

Dr Wee Tiong Seah
Senior lecturer & Chief Investigator
### Lesson Observation Checklist

<table>
<thead>
<tr>
<th>Observation Checklist</th>
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<tbody>
<tr>
<td>Teacher</td>
</tr>
<tr>
<td>Observation Number</td>
</tr>
<tr>
<td>Class</td>
</tr>
<tr>
<td>Number of Students</td>
</tr>
<tr>
<td>Date</td>
</tr>
<tr>
<td>Duration</td>
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<tr>
<td>Topic</td>
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<table>
<thead>
<tr>
<th>Digital Technology</th>
<th>Use</th>
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<tbody>
<tr>
<td></td>
<td>Purpose</td>
</tr>
<tr>
<td></td>
<td>Self-efficacy</td>
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<td></td>
<td>Control</td>
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<td>Success</td>
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<td></td>
<td>Influences</td>
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<tr>
<td></td>
<td>Repeat</td>
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<td></td>
<td>Experience</td>
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<table>
<thead>
<tr>
<th>Lesson</th>
<th>Intentions / Plan</th>
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<tbody>
<tr>
<td></td>
<td>Start routine</td>
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<tr>
<td></td>
<td>Concept</td>
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<tr>
<td></td>
<td>Application</td>
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<td></td>
<td>End Routine</td>
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<table>
<thead>
<tr>
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<table>
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<tr>
<th>Incidents</th>
<th>Change of Mind</th>
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<tbody>
<tr>
<td></td>
<td>Interruption</td>
</tr>
<tr>
<td></td>
<td>Problem</td>
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</table>
Appendix 5

Sample Field Notes

Lesson Observation Field Notes

TEACHER: Sarah  
OBSERVATION: Ob4

CLASS: Year 10 Enhanced Mathematics  
STUDENTS: 27 students

DATE: 25 August 2015  
DURATION: 65 minutes

TOPIC: Quadratic Equations: Finding equations given the graph or information

<table>
<thead>
<tr>
<th>Digital Technology</th>
<th>Purpose</th>
<th>N</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent mac to board; IWB pen, projector;</td>
<td>Display Slideshow notes and run Mathematica;</td>
<td></td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Intranet / WIFI for attendance roll;</td>
<td>Record student attendance;</td>
<td></td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Mathematica calculations and graphing;</td>
<td>Generate functions from data;</td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slideshow digital notes;</td>
<td>Documented lesson and additional resources for students</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher laptop;</td>
<td>Access attendance, etc</td>
<td></td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>SimpleMind flowchart;</td>
<td>Visual process;</td>
<td>D</td>
<td></td>
<td>E</td>
</tr>
<tr>
<td>Email students</td>
<td>Distribute notes</td>
<td></td>
<td>E</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Lesson Plan</th>
<th>Stated intentions:</th>
</tr>
</thead>
</table>
| 0:00 | Start; Recall; Notes; Concept, Practise exercises; End. | Slideshow  
SimpleMind |
| 0:02 | Recall: Review of quadratics so far - finding the characteristics of a graph and graphing. | There is a Chinese interpreter in the class for 5 new international students who started at the beginning of Semester 2.  
Teacher very quick to take the first suggestion from a student and then fill in all the other information. |
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:05</td>
<td>Notes: Students directed to copy notes from <em>Slideshow</em> displayed on board. Students copy notes from board to books. Also have the notes emailed by teacher. The issue of teacher notes and student note-taking. There seems to be little direct advantage for the teacher notes. The students copy and don’t have to think.</td>
</tr>
<tr>
<td>0:09</td>
<td>Concept: Mind map of choices: Worked examples on board Teacher refers student to the mind map of the options for generating an equation from a graph or from given characteristics of a graph. Three examples - Option 1: three intercepts. The teacher uses an example to manually generate solution, then generates the solution using <em>Mathematica</em>. Option 2: turning point and one other intercept – second example. The teacher gives the students a head start and then handwrites the solution and generates the solution using <em>Mathematica</em>. Option 3: three random points – third example. In this case there is no need for the students to generate the solution without <em>Mathematica</em> help. The teacher demonstrates two methods of setting up <em>Mathematica</em> to do the calculation. In the first way she substitutes the values of the three points by hand to set up the set of simultaneous equations to be solved using <em>Mathematica</em>. In the second method she uses the single command in <em>Mathematica</em> to solve the problem. The teacher reminds the students to formally communicate answers. Manual before digital Time-consuming manual method not required.</td>
</tr>
<tr>
<td>0:30</td>
<td>Application: Students work on practise exercises Sarah helping new student with <em>Mathematica</em> MYP</td>
</tr>
<tr>
<td>1:00</td>
<td>Homework: Finish exercises for homework Same as usual</td>
</tr>
<tr>
<td>Incident</td>
<td>Some hesitation switching from manipulate/plot mode to plain text mode; Student assistance External control;</td>
</tr>
</tbody>
</table>
Appendix 6

Post-Observation Semi-Structured Interview Protocol

Use
How long have you been using …?
How would you describe the use in terms of new, developing, established?

Control
How you normally handle a technology problem?

Benefits
What benefits have noticed about using …?
In what ways did the use enhance student learning?
In what ways did the use facilitate your teaching?

Self-Evaluative Outcome Expectations
In what ways was the use a success?

Social Outcome Expectations
What type of response would you expect from your colleagues about today’s lesson?
Appendix 7

Sample Post-Observation Interview

FAB Observation 3

13 October 2015  Lesson 4  2:00pm – 3:05pm

Subject: Unit 2 Maths Methods  Topic: Maximum, Minimum and Rate of Change

9 students

Technology: IWB, Mathematica, Slideshow notes file, personal computers, IWB pen with Apple agent and projector

Post observation interview.

How do you introduce students to Mathematica?

Mathematica is introduced in Year 10, so the Year 11 students have already been using it for one year. The Year 10 students have had no exposure so I go through the commands in detail. The students have a copy of the Mathematica guide written by Sarah. I rely on the Year 11 students to know how to do things.

What is the purpose of using Mathematica?

I think the purpose is to help solve problems. If provides a more efficient and effective way of doing that. I would have used it more effectively if there was time. Ideally, I would have gone through the problems, modelling it a bit more.

How confident are you in using Mathematica?

Well I have only been using it this year and I am still feeling my way. I find myself needing to think on my feet and it’s been a few iterations only so I’m not completely confident. I haven’t taught this subject for 12 years and so I need to be relearning the maths and dealing with the technology.

What about the IT technicians coming into the class? Was that an imposition?

Yes, it was but a small one for a large positive outcome. It would be hard for them to individually find the students and in class they are all in the one place. By doing it
early it gives us an opportunity to practice, to have a practice SAC and iron out all the technical details before the end-of-year exam.

**Final Interview (part)**

*How have you found Mathematica in terms of enhancing teaching and enhancing learning? How does it compare to the CAS calculator?*

I think that *Mathematica* is a much more useful teaching and learning tool as a teacher. The misconceptions a student has made are much easier to see as the file shows all the calculations.

*How did the online SAC and exam go? Did teachers and IT people consider them a success? Were there any more problems other than students pinching the exam file?*

SAC and Exam on *Mathematica* were successful due to the support from IT. Having individual USB keys solved the possible issue of sharing resources.
Appendix 8  Data Coding

<table>
<thead>
<tr>
<th>Heading</th>
<th>Categories</th>
<th>Sub-categories</th>
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<td>Luci</td>
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<td></td>
<td>BDG</td>
<td>Helen</td>
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<tr>
<td></td>
<td>CRS</td>
<td>Bec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DLT</td>
<td>Sarah</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ETG</td>
<td>Alan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FAB</td>
<td>Tamara</td>
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<tr>
<td>Memo Identification</td>
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<tr>
<td>Participant Code</td>
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<tr>
<td>Memo number</td>
<td>A - F</td>
<td></td>
<td>FAB06 for example</td>
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<td>Intention</td>
<td>I</td>
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<td>Theme etc.</td>
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<td>Influence</td>
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<td>Colleagues</td>
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<td>Beliefs</td>
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<tr>
<td>Teaching &amp; Learning</td>
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<td>Passing Information</td>
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<tr>
<td>etc.</td>
<td>Transferring</td>
<td>Transmitting Information</td>
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<td>Digital Role</td>
<td>Master</td>
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</tr>
<tr>
<td></td>
<td>Servant</td>
<td>DT2</td>
<td></td>
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<td></td>
<td>Partner</td>
<td>DT3</td>
<td></td>
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<td>Extension of Self</td>
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<td>Delivery</td>
<td>Innovation</td>
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<td></td>
<td>Developing</td>
<td>D</td>
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<tr>
<td></td>
<td>Established</td>
<td>E</td>
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<td>Risk Taking (no, perhaps, yes)</td>
<td>Self-efficacy</td>
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<td>Control</td>
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<td>Outcome Expectations</td>
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<td>Success</td>
<td>RT4</td>
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</table>

An example of coding and memo writing in the second stage of analysis has been inserted on the following page. The larger data file has sorted by the sub-theme being digital technology used, in this case D1 Mathematica. The page refers to the events (incomplete) in which Tamara used Mathematica.
<table>
<thead>
<tr>
<th><strong>Memo</strong></th>
<th><strong>Ref</strong></th>
<th><strong>Theme</strong></th>
<th><strong>SUB</strong></th>
<th><strong>OB</strong></th>
<th><strong>Thoughts/words/actions</strong></th>
<th><strong>Belief/Induction</strong></th>
<th><strong>T&amp;L/Technology</strong></th>
<th><strong>Discussion</strong></th>
<th><strong>LO1</strong></th>
<th><strong>LO2</strong></th>
<th><strong>LO3</strong></th>
<th><strong>LO4</strong></th>
<th><strong>LO5</strong></th>
<th><strong>RT1</strong></th>
<th><strong>RT2</strong></th>
<th><strong>RT3</strong></th>
<th><strong>RT4</strong></th>
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<th><strong>Habit</strong></th>
<th><strong>m</strong></th>
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<tbody>
<tr>
<td>FAB06</td>
<td>Ob1-16</td>
<td>CA</td>
<td>D1</td>
<td>Ob1</td>
<td>FAB: 'That is my tip on Mathematica today. If you have got a graph, it is quite easy to write these points in. You may have known that.'</td>
<td>IS Mathematica graphing easy prior learning</td>
<td>TL1 D72</td>
<td>D y y y y y n</td>
<td>420</td>
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<tr>
<td>FAB06</td>
<td>Ob1-22</td>
<td>CA</td>
<td>D1</td>
<td>Ob1</td>
<td>FAB: [Is it such a straight line or is it really a curve?] OK It is just the way it is drawn. If you zoom in closer and you can see the shape of the curve.</td>
<td>IMS</td>
<td>TL2 D73</td>
<td>D y y y y y n</td>
<td>450</td>
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<td>FAB6</td>
<td>Ob1-22</td>
<td>CA</td>
<td>D1</td>
<td>Ob1</td>
<td>FAB: Mathematics is good because you can manipulate it.</td>
<td>IMS</td>
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<tr>
<td>FAB06</td>
<td>Memo</td>
<td>CA</td>
<td>D1</td>
<td>Ob1</td>
<td>FAB: Dealing with the concept of graphing cubic and quartic functions by student presentation based on previous knowledge, collaboration and student-centredness interrupted by coaching, cupcakes, instructions, skills training, questioning and tech confusion. She does not fully achieve student-centred learning as such. Her questioning style as an audience member passes a tight problem. It is like a litany of what the student should be presenting. With her questions she is modelling what she knows rather than what she would like students to learn as a question. The activity is entertaining and somewhat engaging for the students. Mathematics is the core of the show for its ability to generate and manipulate algebraic graphs and the students handle it well.</td>
<td>IS Variety of approaches; Collaboration; Sharing results; Cupcakes care; Coaching; Modelling; M functionality</td>
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<tr>
<td>FAB08</td>
<td>Ob1-19</td>
<td>TC</td>
<td>D1</td>
<td>Ob1</td>
<td>FAB: Ladies, so obviously when we do the questions you'll need to draw them manually and you can check on Mathematica as well.</td>
<td>IS M for checking</td>
<td>TL1 D72</td>
<td>D y y y y y n</td>
<td>500</td>
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<tr>
<td>FAB08</td>
<td>Ob1-PI</td>
<td>TC</td>
<td>D1</td>
<td>Ob1</td>
<td>FAB: In relation to VCE there is a specific outcome related to the effective use of technology.</td>
<td>IG-VCE requirement</td>
<td>TL1 D72</td>
<td>D y y y y y n</td>
<td>510</td>
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</tr>
<tr>
<td>FAB08</td>
<td>Memo</td>
<td>TC</td>
<td>D1</td>
<td>Ob1</td>
<td>FAB: You can also do it on Mathematica as well though. In general these 'when do I use a calculator/mathematica/manual' conversations come across as a lot of confusion about digital technology use. The indicator is why do the students continually ask the question. Why have they not learnt yet? FAB answers by telling them they have choices but do they allow them to make the choices and do the students practise making choices?</td>
<td>IS M value e&amp;c</td>
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</tr>
<tr>
<td>FAB13</td>
<td>Ob2-09</td>
<td>IN</td>
<td>D1</td>
<td>Ob2</td>
<td>FAB: So today we will look at doing it (gradient) from what is called first principles. So we won't be using much technology and then we'll be using Mathematica to find the gradient.</td>
<td>IS manual then digital</td>
<td>TL1 D72</td>
<td>N y y y n</td>
<td>750</td>
<td></td>
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</table>
## Appendix 9

### Observation Lesson Tasks by Time Spent

<table>
<thead>
<tr>
<th>Tamara Observation</th>
<th>Ob1 Date and Time</th>
<th>Ob2 Date and Time</th>
<th>Ob3 Date and Time</th>
<th>Ob4 Date and Time</th>
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<tr>
<td></td>
<td>6 May 15 8:50am</td>
<td>25 Aug 15 10:50am</td>
<td>6 Oct 15 10:50am</td>
<td>23 Oct 15 1:50pm</td>
</tr>
<tr>
<td>Start Routine</td>
<td>0m Roll (3m)</td>
<td>0m Roll (2m)</td>
<td>0m Roll SAC (5m)</td>
<td>0m Grouping (12m)</td>
</tr>
<tr>
<td>Concept</td>
<td>3m: <em>Transforms</em></td>
<td>2m: <em>Recall</em></td>
<td>5m: <em>Absolute max &amp; min</em></td>
<td>12m: <em>Circular functions</em></td>
</tr>
<tr>
<td></td>
<td>Presentation (22m)</td>
<td>Derivatives (9m)</td>
<td>Notes (8m)</td>
<td>Notes (32m)</td>
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<td></td>
<td>Notes (8m)</td>
<td>MWE (24m)</td>
<td>Sketch (14m)</td>
<td>68m: <strong>Wolfram</strong></td>
</tr>
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</tr>
<tr>
<td>Application</td>
<td>33m: Exercises</td>
<td>35m: Exercises</td>
<td>19m: Problem</td>
<td>44m: Exercises</td>
</tr>
<tr>
<td></td>
<td>(30m)</td>
<td>(25m)</td>
<td>solving (45m)</td>
<td>(24m)</td>
</tr>
<tr>
<td>End Routine</td>
<td>63m: Homework</td>
<td>60m: SAC</td>
<td>64m: Homework</td>
<td>71m: Homework</td>
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<tr>
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<td>(2m)</td>
<td>(5m)</td>
<td>(1m)</td>
<td>(4m)</td>
</tr>
<tr>
<td>Duration</td>
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<td>65m</td>
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<tr>
<th>Sarah Observation</th>
<th>Ob1 Date and Time</th>
<th>Ob2 Date and Time</th>
<th>Ob3 Date and Time</th>
<th>Ob4 Date and Time</th>
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<tbody>
<tr>
<td></td>
<td>24 Apr 15 1:50pm</td>
<td>20 May 15 11:55am</td>
<td>6 Aug 15 12:00pm</td>
<td>25 Aug 15 12:00pm</td>
</tr>
<tr>
<td>Start Routine</td>
<td>0m: <strong>Padlet</strong></td>
<td>-2m: Roll SAC (6m)</td>
<td>-3m: Slide Roll (4m)</td>
<td>-1m: Intro Roll (6m)</td>
</tr>
<tr>
<td>Concept</td>
<td>15m: <em>Hybrid</em></td>
<td>4m: <em>Cubic</em></td>
<td>1m: Notes (5m)</td>
<td>5m: <em>Simultaneous Equations</em></td>
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<td>MWE (28m)</td>
<td>MWE (37m)</td>
<td>MWE (23m)</td>
<td>Notes (9m)</td>
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<td><em>Inverse</em></td>
<td>MWE (31m)</td>
<td><em>Matica</em> (5m)</td>
<td>MWE (17m)</td>
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<td><em>Matica</em> (18m)</td>
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<td>Application</td>
<td></td>
<td>45m: Exercises</td>
<td>50m: Exercises</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>(27m)</td>
<td>(13m)</td>
<td></td>
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<tr>
<td>End Routine</td>
<td>74m: Homework</td>
<td>72m: Homework</td>
<td>51m: Homework</td>
<td>63m: Homework</td>
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<td>(1m)</td>
<td>(1m)</td>
<td>(2m)</td>
</tr>
<tr>
<td>Duration</td>
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<td>75 m</td>
<td>55 m</td>
<td>65 m</td>
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### Alan

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<thead>
<tr>
<th>Observation</th>
<th>Ob2</th>
<th>Ob3</th>
<th>Ob4</th>
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<tbody>
<tr>
<td>Date and Time</td>
<td>6 Aug 2015 9:50am</td>
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<td>20 Oct 2015 12:00pm</td>
</tr>
<tr>
<td>Start Routine</td>
<td>0m: SAC Revision (3m)</td>
<td>0m: YouTube clip (7m)</td>
<td>0m: Introduction (2m)</td>
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<tr>
<td>Concept</td>
<td>3m: Logarithms Exploration (38m) Transformations (12m)</td>
<td>27m: Derivative Exploration (33m)</td>
<td>2m: Acceleration revisit (28m)</td>
</tr>
<tr>
<td>Application</td>
<td></td>
<td>7m: Homework Exercises (20m)</td>
<td>30m: Problem solving (35m)</td>
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<tr>
<td>End Routine</td>
<td>53m: Homework (2m)</td>
<td>60m: Flipped concept homework (5m)</td>
<td>65m: Homework (+1m)</td>
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<td>65m</td>
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### Helen

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<tr>
<th>Observation</th>
<th>Ob1</th>
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<th>Ob3</th>
<th>Ob4</th>
</tr>
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<tbody>
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<td>Date and Time</td>
<td>24 Apr 15 8:45am</td>
<td>20 May 15 10:30am</td>
<td>6 Oct 15 10:30am</td>
<td>23 Oct 15 1:50pm</td>
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<tr>
<td>Start Routine</td>
<td>0m MP introduction (9m)</td>
<td>0m Roll (2m)</td>
<td>0m Roll Tables App (12m)</td>
<td>0m Roll Homework (6m)</td>
</tr>
<tr>
<td>Concept</td>
<td></td>
<td>2m: Equivalent Fractions (15m)</td>
<td>12m: Cartesian Plane (30m)</td>
<td>6m: Linear Patterns (19m)</td>
</tr>
<tr>
<td>Application</td>
<td>9m: Roll MP sheets (51m)</td>
<td>17m: Exercises MP sheets (53m)</td>
<td>42m: Exercises (20m)</td>
<td>25m: Linear Patterns (45m)</td>
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<tr>
<td>End Routine</td>
<td>60m: Anzac (15m)</td>
<td>70m: Homework (5m)</td>
<td>62m: Homework (3m)</td>
<td>70m: Homework (5m)</td>
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<tr>
<td>Duration</td>
<td>75m</td>
<td>75m</td>
<td>65m</td>
<td>75m</td>
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## Appendix 10  Digital Technology Use and Pedagogical Advantages

<table>
<thead>
<tr>
<th>Device/Application</th>
<th>Use / Purpose In Lessons</th>
<th>Pedagogical Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VCE Teacher laptop</strong>&lt;br&gt;personal device</td>
<td>Email to students and to teachers; Intranet assessment tracking; Intranet attendance; Intranet document storage and retrieval (LMS); Mathematica; Connect to IWB (Alan)</td>
<td>Efficient and effective for personal communication and access to resources and digital tools.</td>
</tr>
<tr>
<td><strong>YR7 Teacher laptop</strong>&lt;br&gt;personal device</td>
<td>Email to students Intranet attendance; Intranet document storage and retrieval (LMS); Internet Maths Pathway administration; <strong>Discussed</strong> Internet SMART; Internet Atlas curriculum mapping; Intranet assessment tracking</td>
<td>Efficient and effective for personal communication and access to resources and digital tools.</td>
</tr>
<tr>
<td><strong>VCE /Year 10 Student laptop</strong>&lt;br&gt;personal device</td>
<td>Email&lt;br&gt;Flipcharts&lt;br&gt;Inspiration&lt;br&gt;Internet online textbook&lt;br&gt;Internet Padlet&lt;br&gt;Internet SimpleMind&lt;br[Mathematica]</td>
<td>Communications&lt;br&gt;Computations&lt;br&gt;Organising learning&lt;br&gt;Alternative representations; Collaboration</td>
</tr>
<tr>
<td><strong>Year 7 Student iPad</strong></td>
<td>Calculator computations&lt;br&gt;Email&lt;br&gt;Internet Maths Pathway&lt;br&gt;Intranet LMS resources&lt;br&gt;Multiplication tables app</td>
<td>Efficient&lt;br&gt;Communications, Computations, Online tuition</td>
</tr>
<tr>
<td><strong>Internet</strong></td>
<td>Textbook&lt;br&gt;Email between teachers and students&lt;br&gt;YouTube clips&lt;br&gt;Wolfram demonstration project&lt;br&gt;Padlet&lt;br&gt;SimpleMind application&lt;br&gt;Maths Pathway application</td>
<td>Efficient&lt;br&gt;Multiple connections to educational resources held online, Communications</td>
</tr>
<tr>
<td><strong>Email</strong></td>
<td>Email teacher- students &amp; teacher-teacher&lt;br&gt;Instructions&lt;br&gt;Notes&lt;br&gt;Links to learning resources</td>
<td>Efficient communication</td>
</tr>
<tr>
<td><strong>Flipchart</strong>&lt;br&gt;Teaching resources</td>
<td>Flipcharts with interactivity; <strong>Discussed:</strong>&lt;br&gt;*Concept videos – Sarah &amp; Tamara</td>
<td>Effective&lt;br&gt;Student engagement, Multimedia representations, Creative tool for text, images &amp; video recording. Efficient Reusable Shared</td>
</tr>
<tr>
<td><strong>Mind-mapping software applications</strong></td>
<td>Create flowcharts of mathematical processes to include in notes.</td>
<td>Effective for alternative representations of ideas and processes</td>
</tr>
<tr>
<td>Device/Application</td>
<td>Use/Purpose in Lessons</td>
<td>Pedagogical Advantage</td>
</tr>
<tr>
<td>--------------------</td>
<td>------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Intranet eWorkspace application</td>
<td>Demonstrated in lessons&lt;br&gt;Recording attendance,&lt;br&gt;Document retrieval from storage,&lt;br&gt;Assessment tracking</td>
<td>Efficient&lt;br&gt;Assessment tracking balanced against duplication of effort with School reports</td>
</tr>
<tr>
<td>Promethean ActivBoard, ActivWall</td>
<td>Demonstrated in lessons:&lt;br&gt;Whiteboard facility with interactive capability and digital network access</td>
<td>Efficient and effective Communication, Collaboration</td>
</tr>
<tr>
<td>SMART Pre- and post-testing online system</td>
<td><strong>Discussed:</strong>&lt;br&gt;Teachers had access to tools and training but couldn’t agree on use</td>
<td>Identification of mathematical misconceptions and approaches to fixes.</td>
</tr>
<tr>
<td>Wolfram Mathematica Application</td>
<td>Algebraic computations such as solving 3 simultaneous equations,&lt;br&gt;Graphing a range of functions,&lt;br&gt;Experimenting with transformations, scale and mathematical ideas.</td>
<td>Efficient and effective Computations, Algebraic function plots, Visual representation of mathematical processes</td>
</tr>
<tr>
<td>Wolfram Mathematica Slideshow Module</td>
<td>Presentation slides with text &amp; Mathematica interactivity in a single file,&lt;br&gt;Teacher-generated resources files <strong>Discussed:</strong>&lt;br&gt;Online assessment tasks</td>
<td>Effective&lt;br&gt;Dual functionality, Access to digital mathematical symbols</td>
</tr>
<tr>
<td>Maths Pathway Application Trial</td>
<td>Maths Pathway worksheets, videos, worked solutions, diagnostics.</td>
<td>Effective&lt;br&gt;Identification of concept misconceptions and self-paced learning. Conflict in purpose and uptake&lt;br&gt;Student engagement</td>
</tr>
<tr>
<td>Microsoft Office 365 Word processing Equation Editor</td>
<td><strong>Discussed:</strong> Making note files</td>
<td>Efficient&lt;br&gt;Note creation, Assessment creation, Sharing, Online storage</td>
</tr>
<tr>
<td>Padlet Online bulletin board</td>
<td>Implementation successful&lt;br&gt;Use not successful in class but worked out-of-class</td>
<td>Effective&lt;br&gt;Collaborative communication</td>
</tr>
<tr>
<td>Student phone</td>
<td>Personal phones for image capture of board and wall work. <strong>Discussed:</strong>&lt;br&gt;Use in student presentation</td>
<td>Efficient for image capture&lt;br&gt;Effective as an alternative communication medium</td>
</tr>
<tr>
<td>Teacher phone</td>
<td><strong>Discussed:</strong> Communication with students</td>
<td>Efficient communication</td>
</tr>
</tbody>
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