A Study Investigating Teachers' Use Of, and Views On, Tablets in the Teaching of Mathematics

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Abstract

Digital technologies are often positioned as having great potential for teaching and learning. However, adoption, particularly in mathematics education, has been slow. More recently there has been increasing focus on the role teachers play in the way digital technologies are used in the classroom. When considering the available research in this area, we observe that there is still little work that is integrated in the busy and unpredictable school environment in which teachers use digital technologies. With the added complexity that many of the digital technologies adopted by schools, such as tablets, incorporate a wide spectrum of programs it is crucial to understand how teachers use and view digital technologies.

In partnership with a comprehensive British school that has implemented a one-tablet-per-student programme, this study investigated the way four Year 8 mathematics teachers' use of, and views on, tablets in their teaching developed over time, and the factors impacting them. The study was situated in a natural school setting, with the added dimension that teachers met as a group to discuss their use of, and views on, tablets while exchanging knowledge about using tablets in their teaching. The data collected included audio recordings of the group meetings, individual teacher interviews at the start of the study, classroom observations, and short interviews with teachers directly following each observed lesson.

Building on research that has looked at the ways teachers can, or do, use digital technologies in the teaching of mathematics, this study developed a framework that incorporated a wide spectrum of ways digital technologies can be used in mathematics classrooms. The framework, named the Teacher Adoption of Digital Technologies framework, articulates the increasing complexity with which technology can be used in the teaching and learning of mathematical tasks and incorporates characteristics of tasks that teachers use in the classroom such as their instrumental evolution, efficiency, engagement, and focus. In addition, the framework captures the teachers' views of using technology and the knowledge exchanged during group meetings.

The key findings of this study highlight that: (1) teachers used tablets to support mathematics teaching in tasks that had little variation in their instrumental evolution but were designed to promote efficiency, engagement, and focus; (2) teachers viewed tablets as useful but had mixed self-efficacy in their ability to use them in new ways; (3) factors that impacted teachers' decisions to use the tablets were mainly classroom management, finding useful resources, and having appropriate support from school leadership; and (4) teachers found the group meetings useful to exchange their knowledge and experience of using technology and to develop their use and views of tablets. It is hoped that the outcomes of this study will guide future implementations of technologies in schools and teacher development, contributing to the way teachers can use and innovate with tablets in teaching mathematics.

To my dear parents

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1

INTRODUCTION

1.1 Research Context

Over the years, digital technologies have been increasingly introduced in schools with little impact on achievement. The Organisation for Economic Co-operation and Development (OECD) has declared that “despite considerable investments in computers, Internet connections and software for education use, there is little solid evidence that greater computer use among students leads to better scores in mathematics and reading” (OECD, 2015, p.145). This outcome raises questions regarding the reasons why powerful technologies, that have the ability to perform complex computations and demonstrate concepts in new ways, have not had an impact on scores in mathematics. This is particularly pertinent as the history of mathematics – which is the discipline this study is focused on – has examples showing that the availability of certain tools has influenced the course of the conceptual development of mathematics as a scientific discipline (Laborde & Staber, 2010). Why then have digital technologies, such as computers, not improved students' success in the subject?

The reasons for this may be because digital technologies, such as mobile devices, are increasingly being introduced in schools with little evidence to guide how they are implemented (Kiger, Herro, & Prunty, 2012). It has been found that, rather than providing innovation, technology is often used as a replacement for previously existing technology (Mifsud, Morch, & Lieberg, 2013). An example of this would be an interactive whiteboard being used simply to project static slides, in the same way a projector would be used. As there is an increasing number of developments in educational technology, there is also increased scepticism in the potential that digital technologies hold for teaching and learning (OECD, 2015). The OECD Programme for International Student Assessment (PISA) in 2012 involving 15-year-old students from OECD countries found that, on average, students who do not use information communication technology (ICT) in mathematics lessons performed better on mathematics assessments than students who do use ICT in mathematics lessons, after accounting for differences in socio-economic status. This is the case even though 2012 was the first year that PISA tests were computer based. Students in Korea and Shanghai-China were among the top performers in the PISA computer-based mathematics test, however only 42% and 38% respectively, reported that they used computers in school (OECD, 2015). But is it the technology that it is not attuned to improving teaching and learning or are there other factors inhibiting teachers and students from leveraging the technology's potential?

1.2 The Potential of Technology in the Mathematics Classroom

Digital technologies offer a wealth of new possibilities for teaching and learning. The Internet has opened more information to students than has ever been possible, allowing students to instantly find information on any topic, both in and outside of the classroom. Digital tools have also provided opportunities for innovative teaching, such as the interactive and collaborative nature of interactive whiteboards and classroom clickers, as well as a wealth of resources and videos to support topics being taught in the classroom.

Digital technologies can be used in a wide variety of ways in classroom teaching. One popular use is for watching tutorial videos on the Internet. Such videos can explain the details of mathematics problems, which can be accessed any time of the day for extra help. There are many interactive games that help students practice skills, and problem sheets that dynamically change to fit the ability of the students as they progress through mathematical problems. Access to customised classroom quizzes that instantly show the teacher what every student answered, allows the teacher to focus their attention on concepts that the class has not grasped and also direct their attention to specific students who are not understanding the lesson. This instant diagnostic function can help teachers focus their attention where it is most needed. These are only a few examples of the ways in which digital technologies can be used in teaching, including mathematics teaching.

Digital technologies are also understood to hold great potential for some concepts in mathematics education – a subject that relies heavily on the use of shapes, symbols, and graphs – allowing for mathematical concepts to be more easily visualised using drawings and graphs that can be manipulated (Galligan et al., 2010). An example of how digital technologies can help people understand mathematical concepts would be the ability to quickly generate graphs. Doing this allows the user to make connections in how changes to an equation correlate to the graph that it generates. Such a connection is possible by having the ability to quickly generate graphs of several equations and allowing the user to see the changes that occur, which is extremely time consuming to do manually. Another example includes the ease and dynamic nature by which geometrical shapes can be manipulated on a screen, as the dimensions and properties of the shape are varied. This type of dynamic manipulation of shapes allows for greater understanding of the geometric properties that is more difficult to obtain using a paper and pencil method. Presenting mathematics in such ways can enable students to grasp complicated concepts faster than they could without the technology. This is particularly important in the lower secondary years, which my study focuses on, when research has shown that mathematical understanding is at a risk of dwindling (Blackwell et al., 2007).

In addition to the possible potential that digital technologies may hold for mathematics education, it is important to consider the specific tool in which mathematics is expressed. Hoyles and Noss (2009) state that the mathematical knowledge and its pedagogy are linked to tools – physical, virtual, cultural – in which they are expressed. Mathematics education may benefit greatly from the representations that different digital tools provide. Hoyles and Noss (2009) present the following four categories of digital tool use and their differing potential to shape mathematical cognition: (1) dynamic and graphical tools; (2) tools that outsource processing power; (3) new representational infrastructures; and (4) the implications of high-bandwidth connectivity on the nature of mathematics activity. Different types of digital technologies offer different possibilities in teaching and learning, making it important to understand the different characteristics of digital technologies.

Mobile technology refers to a subgroup of digital technologies that are characterised by their physical characteristic of being easily used in different locations, such as tablets, smartphones, and graphing calculators. Mobile technologies are thought to have particular affordances that make them unique. Studying the use of mobile technologies in teaching and learning is argued by some to be particularly interesting because of the physical and social affordances they provide (Roschelle, 2003). For example, a mobile device allows students to move around with the device, which may help students to seamlessly construct their knowledge of the subject in different locations (physical and digital, personal and social, informal and formal), times, learning styles, and device types (Wong, 2012). Importantly, this cross-contextual nature of mobile technologies provides an opportunity for teachers to shift the way they teach, dynamically moving between teaching, assessing, individual, and group work in the classroom, as well as to the nature of the work they assign outside of class.

Tablets, which are the focus of this study, are a particular type of mobile technology that combines properties of many different previously available digital technologies. Tablets have Internet access, they can be used as a laptop computer, and have the mobility and camera options of a smartphone. Tablets use applications (apps), like a smartphone, that have extensive features that combine many other digital as well as physical tools, both used for mathematics and other subjects. Tablets have also combined many mathematical tools – graphing calculators, digital games, and mathematics manipulatives being just a few – into an individualised tool that students can use anywhere and anytime. Tablets allow students and teachers to access a wealth of information and combine extensive tools, both mathematical and non-mathematical, with Internet capability, collaboration tools to work with anyone around the world, camera, and mobility, opening endless opportunities for how tablets can be used, inside and outside of class. These diverse and extensive uses of tablets, combined with the cross-contextual nature of mobile technology, make them particularly valuable to investigate, specifically how teachers view and use tablets in mathematics education. Because of the multiple functionalities and wide-ranging potential of tablets in teaching mathematics, I chose to focus on tablets as a whole, rather than on a specific mathematical application that teachers may use. The tablets are also one of the newest technologies being introduced into schools, which makes them a timely focus of research.

As outlined in Section 1.1 and 1.2, there is a duality between the possible usefulness of technology in mathematics education and the lack of impact that it has had on learning. As the examples demonstrated above, this duality is not new, it was the case for different technologies at different points in time, such as interactive white boards and computers. Looking beyond the technology and the impact it has on learning, it is important to also look at the teachers, who are the people who will decide on whether and how to use a particular technology in the classroom.

1.3 Teachers Uptake and Use of Educational Tools

As I have outlined above, digital technologies, and particularly tablets, can provide rich opportunities for teaching and learning of mathematics. However, some argue that in spite of this potential, their use in secondary mathematics education has been significantly lower than the expectations in recent decades (Drijvers et al., 2010). This may not be surprising since historically the uptake of other tools in education has also been slow (Dockterman, 2018).

Brock and Price (1980) go back one hundred years to describe the history of how squared paper (graph paper) was first introduced into schools. At a time when science was beginning to be taught in schools, there was a more practical approach to education which meant a more active role for the learner. This new tool (squared paper) and new philosophy called for teachers to adapt a new way of teaching. As Brock and Price (1980) state, “in all this there was much enthusiasm, experimentation and also confusion in the schools” (p. 378). Changing the way mathematics was taught was challenging and many teachers did not use the graph paper in their class, blocking the introduction of practical mathematics in schools. Brock and Price (1980) point out that this resistance gave rise to calls for new teacher training, hiring teachers with different educational backgrounds, and production of many new textbooks and instruction manuals. This new form of graphical mathematics might have meant different things to different teachers, and the implementation might have been diverse. In time, square paper became ubiquitous in mathematics classrooms.

Similarly, when the cost of hand-held calculators became viable for schools to adopt, the conversation surrounding the teachers' use of calculators seems to have been similar. As Hembree and Dessart (1986) outline, The National Council of Teachers of Mathematics (NCTM) issued a statement in 1974 urging calculators to be used in schools. However, twelve years later, calculators were still not used in most mathematics lessons in the United States, with less than 20% of elementary teachers and less than 36% of secondary teachers using calculators in their lessons. Although many studies have been done on the use of calculators in education, East and Moursund (1979) say that they have mostly been ignored by school teachers, who preferred to use them based on their own insights, if they used them at all. The question of why teachers ignore particular uses of calculators is unclear, but there may be a disconnect between what studies find as being useful in the classroom and what teachers find useful. East and Moursund (1979) predicted that calculator use in schools will increase as "more and better materials become available, as teachers become more knowledgeable, and as educators become convinced that they are a useful aid to education" (p. 17). However, today technology is changing at a much faster rate, where computers are quickly followed by laptops and then tablets. The reasons why teachers need so long to leverage the potential benefits of educational technology needs to be addressed.

As with any tool, teachers play a significant role in defining the ways in which technology is used in the classroom and how this use impacts student learning (Darling-Hammond, 2000, 2010), which is why it is important to study and understand teaching practices (Schrum et al., 2005). Regardless of how innovative new digital tools may be in helping improve students' mathematical understanding, if teachers do not leverage these resources they will not have any impact on teaching and learning. What teachers choose to use in their classroom, and how they use these resources, will greatly determine how useful the resources will be. There is a need for better understanding of how teachers use and view digital technologies in their daily teaching to better address their needs when adopting technology in schools. As with the square paper and the calculator, adoption of new tools has often been a slow process. However, with the currently increasing pace of technological change, before a technology can fully be adapted, something new will be there to replace it. I am not suggesting that every technology that promises to improve mathematics education should be adopted by teachers, but there is an increasing need to understand the teachers' perspective on the adoption of new tools. In this thesis, I study the reality that the teachers work in and try to understand what they do with tablets and why. By understanding how teachers use and view tablets, as well as the factors that influence their use and views, support and professional development can be designed to help teachers in appropriate ways.

Professional development for teachers is widely used to train teachers in using technology. However, research indicates that professional development is often ineffective (Opfer & Pedder, 2011). Increasingly, it is being recognised that more focus needs to be placed on the teacher's role in how to enhance teachers' professional knowledge (Noss & Hoyles, 1996, p. 184). Teaching networks have been found to be extremely useful by many teachers (Trust, Krutka, & Carpenter 2016) in that they provide a peer community in which knowledge and resources can be shared. As Trust et al. (2016) indicate, such networks have developed online, and teachers have indicated that their practice has developed because of the support and resources that they found in these networks. Teachers went back and forth between the online community and their classroom, continuously incorporating what they learnt in their online network into their classroom teaching. With the "ever-changing nature of technology and what it can afford for teaching and learning" Dawson (2012, p.123) expressed a similar need for teachers to participate in regular cycles of integration. Dawson (2012) also expressed a need for researchers to study these cycles and the ways the teachers' classroom practices change over time.

1.4 Scope of the Study

With the technology available today, some argue that there is a need for renewal of pedagogy (Jouneau-Sion & Sanchez, 2013). There is a need to further explore fundamental questions about the unique nature of mobile technology and contextualised learning (Schuck, 2013) and further to understanding the teachers' perspectives and use of technologies in schools (Ertmer, 2005). In the past, research has focused on the role that teachers could play in technology-rich classrooms, but more recently there is increasing research on "the unique demands and opportunities of the teacher teaching with digital technology" (Clark-Wilsom, Robutti & Sinclair, 2014, pp. 2). The aim of this study is to contribute and fill some of these gaps by addressing the overarching question of *how* a group of Year 8 mathematics teachers at a comprehensive English school – who meet regularly as a group to reflect and discuss how they use tablets in their teaching – use and view tablets in teaching mathematics, and *why* they make the choices they do. To address these issues, the study spans over the course of one year and focuses on two key research questions, with the first one being:

1. How do teachers develop over time (if at all) their use of and views on tablets in the teaching of mathematics?

Stanhope and Corn (2014) say that identifying factors that impact the effectiveness of 1:1 models, such as tablets in this study, informs policies and decisions about 1:1 implementation and enhances outcomes offered to stakeholders, such as students, teachers, and administrators. In light of this, to understand *why* the teachers use and view tablets as uncovered by the first research question, the study also investigates the reasons for the changes observed, as well as the possibility of there not being any changes. In order to investigate the reasons that influenced teachers' choices in how they use and view tablets in their mathematics teaching, the second research question focuses on this aspect:

2. What factors contribute to teachers' decisions of how, and why, they use and view tablets in the teaching of mathematics?

It has been shown that to observe changes in the way teachers use technology can take several years (Laborde, 2001). Both because of my own time limitations, as well as the fact that schools are likely to want faster ways of integrating technology, I incorporate a strategy of reflection, discussion, and learning among the teachers, as a way of encouraging possible development (Moon, 1999) in their use and views on tablets in the form of group meetings that I facilitate. This type of knowledge exchange among the teachers is intended to help them learn from each other and possibly develop their use and views of tablets in their teaching.

To answer the two research questions above, data is gathered in the following four ways:

1. Interviewing teachers at the start of the project to understand how they use and view tablets in their teaching.
2. Conducting classroom observations to see how tablets are being used.

3. Interviewing the teachers after each observation to understand what their objectives were for the use of tablets, how they intended to use them, and the factors that influenced their choices.
4. Facilitating discussions among the teachers during the group meetings in which teachers talk about their use of and views on tablets and exchange knowledge on how to use the tablets in their teaching.

My study aims to contribute to academic research by developing knowledge of how teachers use and view digital mobile technologies (in my case, tablet technology, specifically the iPad mini) in the classroom setting, and the factors that may influence them. To capture this knowledge, I develop a framework called the Teacher Adoption of Digital Technologies (TADT) framework, which is developed and expanded throughout the thesis. This thesis directly addresses criticisms of educational research that it does not investigate questions that are important to teachers, such as the introduction of technology in the classroom that has many different applications and uses. This may be part of the reason why technology has not had the predicted impact on teaching and learning in schools (Bull et al., 2005; Pring 2002, p. 122). This kind of knowledge can help guide future initiatives in implementing new technologies in schools by addressing the factors that are involved in the way teachers use technology. The findings can also have implications for teacher preparation and professional development of teachers by enabling training to address the ways teachers view and use technology, thereby enabling teachers to better utilise the potential of learning technologies.

1.5 Outline of the Thesis

This thesis is organised into five chapters. The current chapter introduced the problem addressed in this study, the need for the research study in the way mathematics teachers use mobile technology, and the scope of this study. Chapter 2 presents a review of the theoretical and research literature of the current state of practice and research with regards to the ways in which teachers experience the integration of mobile technologies and what has taken place in terms of integration practices in schools. This chapter gives rise to the initial version framework on which this study builds and develops in subsequent chapters. Chapter 3 gives the philosophical stance and methodology used in this research, including the context in which the research was situated. Organised in the two phases of the study, this chapter also outlines the methods for data collection and analysis, as well as the ethical considerations. Chapter 4 outlines the results that emerged from the different data sources in each phase of the study and explains how the outcomes resulted in the final version of the framework. Chapter 5 concludes the dissertation and outlines limitations of this study as well as implications and directions for future research.

2

LITERATURE REVIEW

2.1 Introduction

With the aim to better understand teachers' experiences of using technology in teaching mathematics, the purpose of this chapter is to review the literature that frames the key concepts and develop an initial framework which will be used and developed throughout the study.

The literature review is organised into four main sections, aligned to my research questions: (1) **Use** of technology in mathematics education; (2) **Views** teachers hold about the technology in teaching and learning; (3) **Factors** that impact teachers' use of and views on technology; (4) **Development** of teachers' use of and views on tablets in teaching mathematics. Each of these sections is broken down into further subsections that organise the literature. The final section in this chapter summarises the way the literature addresses the two research questions and outlines the initial Teacher Adoption of Digital Technology (TADT) framework that is used in this study.

2.2 Use of technology in mathematics education

Teachers use technology in incredibly diverse ways. In this section I focus on how it is used in the classroom, beginning with an overview of the impact of educational technology on teaching and learning and how it is integrated into schools, before presenting some of the reasons teachers use technology in their teaching.

2.2.1 An Overview of the Impact of Educational Technology

Throughout the history of mathematics there are many examples showing that the availability of certain tools greatly influenced, if not decided, the course of the conceptual development of mathematics as a scientific discipline, as well as the teaching and learning of mathematics. An example of this is the ruler and compass for the development of geometry (Laborde & Sträße, 2010). Regarding teaching and learning of mathematics, the development of graph paper had great impact on the way students were able to learn mathematics in the early 20th century. School students were able to experience the graphical side of mathematics by using squared paper to draw graphs (Brock & Price, 1980). Tools also greatly influence how mathematics is taught in the classroom. However, there are questions on the level of impact one of the most recent tools – mobile technologies – may have on the way mathematics is taught and learned. Mobile technologies are increasingly being introduced in schools with little evidence to guide how they are implemented (Kiger, Herro, & Prunty, 2012). To better understand the current research, it is important to have a brief introduction to the history of the impact other educational technologies have had.

Throughout history, technologies have been adopted in education but the effect on teaching and learning has not always met expectations. Reiser (2001) discusses the history of instructional media in education and reflects on Edison's belief that motion pictures would make books obsolete in schools. Radecki (2009) indicates that there is a parallel between the visual instruction movement of the early 20th century and the technology instruction movement of the late 20th and early 21st centuries in education. The audio-visual instructional movement grew in our society but did not have much effect on the educational community. Similarly, technology is becoming an integral part of society, but the educational community is not changing at the same pace (Bruning et al., 2004). Even though, Ertmer et al. (2016) found that teachers said they used technology to enrich or supplement the existing curriculum and to provide a different pedagogical approach, which might be assumed to improve the lesson. It is important to learn from our past and understand why the full potential of previous technologies has not been effectively incorporated into the education sector. There are a variety of reasons that may be responsible for this, some of which are outlined in Sections 2.3, 2.4, and 2.4. One of the reason, as Joubert (2013) suggests, for why technology is not incorporated effectively in education, include research not sufficiently accounting for the interests, issues, concerns, and developments of the researchers and stakeholders in mathematics education. My study aims to contribute toward addressing these gaps by focusing on key stakeholders, being the teachers, and their experiences of using technology in their daily classroom teaching.

Oliver (2011) argues that "technology should not be understood to operate on a causal model; it does not have straightforward 'impact' in some simple, mechanical way on the practices that it encounters" (p. 381). Increasingly researchers (e.g. Friesen, 2008; Selwyn, 2010) argue for the need to develop a critical perspective on educational technology use, one that looks beyond the immediate context of learning gains or patterns of interaction to question how technology has been adopted in the first place. This is important since using technology in education is difficult for most teachers, as it implies organisational changes as well as changes in the way that lessons are taught (Heitink et al., 2016). According to Oliver (2011), simplistic explanations of technology's role remain widespread in studies of technology, assuming technology has straightforward impact in a mechanical way. I tried to avoid such a simplistic view of technology by focusing on how teachers use and view technology, and their possible development over time.

Understanding the affordances, weaknesses, and the skills required to use a tool is key to successfully harness its power. Even with the internationally growing popularity of mobile learning in the field of educational technology, there is under-theorisation about the nature, process, and outcome of mobile learning (Sharples et al., 2005, 2007; Wali et al., 2008). Cuban (2001) states "the overwhelming majority of teachers employed education technology to sustain existing patterns of teaching rather than to innovate" (p. 134). There have even been examples cited of teachers actively avoiding the use of technology in otherwise technology-enabled classroom settings. Evan-Andris (1995) observed a variety of avoidance strategies adopted by teachers, including allowing non-technology based instructional activities to exceed their allotted time in order to squeeze out activities that involved technology. According to Goddard (2002), teachers must first integrate technology into their personal lives before they can use technology effectively for educating their students. However, there needs to be further research in naturalistic school settings on the link between teachers' technology use, particularly technology that offers multiple non-mathematical programs like tablet, and their classroom instructional practices (Rakes, Field, & Cox, 2006) as well as how teachers become absorbed into these existing and evolving practices (Merchant, 2012).

2.2.2 Theoretical Frameworks of Technology Integration

Change in any type of instructional practice takes significant time to implement (Dwyer et al., 1990; Laborde, 2001) and the instructional practice using technology is no exception. There are also many facets of the education system that are impacted by the incorporation of technology into teaching. Although this study is focused on teachers' experience, it is important to put the teacher into the greater context in which they exist. In this section, I explore the literature relating to the way technology is incorporated overall into education, with the teachers' experience being a part of it.

A study by Ruthven (2008) examined three important facets of the incorporation of technologies into educational practice. Ruthven's (2008) study provides a good foundation for investigating the big picture of how technology is implemented in mathematics classrooms, as it looks at the overarching concepts of what should be considered in such implementations. In my study, I focus in on only one aspect of this framework as it relates to the teacher experience. To illustrate these concepts, Ruthven focuses on the implementation of the two software packages of computer algebra and dynamic geometry into a secondary school mathematics classroom. Although these are specific technologies being used, the sociocultural concepts employed have a wider application, and the insight offered by the implementation of each software package is valuable and transferable to other forms of technology in the mathematics classroom. Essentially, his framework offers a way of analysing the appropriation of new tools to teaching practices. I will use this framework to organise my discussion of the literature on how technology is used and implemented. I chose this framework because it provides distinctly different levels from which to look at the integration of technology, going from the design of the tool to the institutional adoption.

Using computer algebra and dynamic geometry software as examples, Ruthven (2008) examines the following three facets of the incorporation of new technological tools (software or hardware) into educational practice:

1. *Interpretive flexibility*: The variety of functionalities and modes of use of a tool both in the development of its design as well as in its appropriation as a practical tool.
2. *Instrumental evolution*: The process of integrating a tool at the level of a community as a whole.
3. *Institutional adoption*: The institutional frameworks and teaching resources that outline student curriculum and provide pedagogical guidance.

Although Ruthven (2008) demonstrated these facets using dynamic geometry and computer algebra software in secondary-school mathematics as examples, the sociocultural concepts that they employ are more widely applicable. Ruthven (2008) suggests that these concepts are valuable in analysing critical aspects of integration of all new digital tools used in teaching. However, as users become comfortable using a new tool, and it becomes a regular part of their work, they make adjustments to their practice, which develops into their regular practice. There are several studies demonstrating how dynamic geometry has been incorporated by teachers under everyday circumstances (e.g. Ruthven, Hennessy & Deaney, 2008), but Ruthven (2008) offers an overarching view of the important facets of such incorporation.

In the following paragraphs, I outline in more detail how Ruthven (2008) defines each of the three facets of incorporation of new technological tools and I use these categories to outline the literature in these areas. Although my study is situated within the level of *instrumental evolution*, it is important to recognise the larger domain in which the integration of technology is situated and the impact it may have on teachers' experience of using technology.

Interpretive Flexibility

Interpretive flexibility is a term used in the field of science and technology studies (STS) that "suggests technology design is an open process that can produce different outcomes depending on the social circumstances of development" (Klein & Kleinman, 2002, p. 29). This exists for all types of technology and it can be seen in the variety of its functionalities and also the variety of ways in which it is used. This is evident not only during its evolving design, but also in its creation and appropriation as a practical tool. Specifically, the process through which a technology becomes aligned with different user concerns and adapted to a variety of settings is the way in which it expands and grows beyond its originally intended purpose, continuing to evolve over time (Ruthven, 2008). In this sociocultural model, "design continues in usage" (Rabardel & Bourmaud, 2003, p. 666). Instruments, such as tools used by teachers, "contain components from artefacts themselves, and components from users' utilization schemes" (Rabardel & Waern, 2003, p. 643).

Teachers in particular, interpret educational resources and mediate how their students use them in their classroom (Haggarty & Pepin, 2002). For this reason, new tools do not determine classroom practice, rather the designs of their developers turn out to be only one component of it (Ball & Cohen, 1996). This has been demonstrated with the implementation of dynamic geometry, where advocates for innovation cast it as a means of supporting approaches to school mathematics based on relatively open student exploration, experimentation and investigation (Chazan & Yerushalmy, 1995; Hoyles & Noss, 2003). However, research has found that teachers find it challenging to conceive appropriate tasks, even though these studies often had teachers work alongside researchers, and to manage students' learning of the mathematics curriculum organised in such a way (Laborde, 2001). The challenge teachers face in using the full potential of these technologies is reiterated in a study by Ruthven, Hennessy and Deaney (2008) of the incorporation of dynamic geometry into mainstream practice. The findings indicated that teachers unintentionally use technology in counterproductive ways because they saw dynamic geometry as helping students through guided discovery in the classroom, however they used structured 'investigations' to establishing standard results. This same study also found interpretive flexibility among teacher users in that that they had significant variability in their approaches to the classroom use of dynamic geometry. These differences were linked with contrasting conceptions of the software and to general differences in teaching. The two main areas of divergence were:

1. The degree to which teachers planned for students to experience use of the software, which was influenced by the extent to which this was seen as involving students in mathematically disciplined interaction.

2. The way in which teachers handled apparent mathematical anomalies of software operation, which was influenced by the teacher's perception of whether such anomalies provide opportunities to develop students' mathematical understanding.

Such diversion may be even more pronounced when the technology being integrated into teaching has a wider scope of use, such as tablets used in this study. The variety of applications available, and the multitude of ways of using them in teaching mathematics, is likely to widen the gap in the way teachers appropriate them.

Ruthven (2008) recognised that there is a need to develop some apparatus to support collective development of mathematical activity through the medium of computer algebra. Similar to well established techniques for traditional paper and pencil tools, which had an official status and well-developed mathematical discourse for explaining and justifying them, new tools also needed to have such an apparatus to support collective development of mathematical activity. In my study the structure of teachers working together and learning from each other is intended to address this need. Since all the teachers were teaching the same topics, they were able to collectively establish techniques that were relevant to their teaching with tablets.

Instrumental Evolution

When a technology is introduced for the first time, it is likely to be treated similarly to the tools that are already established and familiar. When technology is incorporated in such a way, it functions as an ‘amplifier’ of existing forms of action rather than as a ‘reorganiser’ (Pea, 1985). Distinctive features and capabilities of the technology must be identified and recording of the tasks they make possible need to be developed. It is also important to understand how teachers develop their knowledge to use the technology in their teaching.

Ruthven (2009) developed a Structuring Features of Classroom Practice (SFCP) framework that assumed that over time experienced teachers develop practical knowledge about teaching with technology. Situating his work in the natural classroom setting, Ruthven developed the SFCP framework that identifies key structuring features of classroom practice and how they relate to technology integration. This framework highlights the knowledge teachers must develop to successfully incorporate new technologies. Bozkurt and Ruthven (2017) used the SFCP framework to further develop it in a classroom environments. The teachers in this study were experienced and also used GeoGebra software, which is specifically for mathematics teaching.

In my study, I am investigating the way teachers incorporate a technology that is not specific to mathematics, as they are given tablets with no particular software that they need to use. Although the knowledge they need to develop is important, I wanted to focus on how they would use the tablets when the possibility of the type of programs, and the ways in which to use the tablets, was left open for the teacher to decide. For this reason I was looking for a framework that would categorise the tasks in which technology was used to teach mathematics. Because of the extensive and diverse ways the teachers could use tablets in their lessons, I wanted to incorporate more opportunities to understand the teachers' experiences and also for them to learn from each other. Having the teachers meet regularly to reflect, discuss, and learn from each other about their use of tablets, is a way to help identify the distinctive features and capabilities of this technology. In addition to identifying these distinctive features, this forum is also meant to enable teachers to support each other in how to use tablets and co-develop pedagogy for the tool that works in their context.

Laborde (2001) offers an example of a study that sheds light on the instrumental evolution of dynamic geometry, by categorising the tasks that teachers develop to teach mathematics using technology. Over several years, teachers iteratively improved lesson ‘scenarios’ through classroom trials and discussion with a team of researchers and developers associated with the software. Laborde identified that the scenarios evolved through each iteration to incorporate increasing degrees of mathematical/pedagogical innovation. In the first degree, dynamic geometry provided a convenient parallel to paper and pencil for producing accurate static diagrams and generating measurement data. In the second degree, dragging the dynamic figure was used to illustrate characteristics in relation to the original shape. In the third degree, the tool modifies the solving strategies of the task because of the features of the dynamic geometry, possibly making the task more difficult. In the fourth degree of the scenario a genuine problem was created for students to solve. This problem involved a dynamic figure based on an unknown geometric transformation and accessible to the students only through the behaviour of the dynamic figure. Laborde reports that scenarios developed at this higher degree of innovation were developed only by experienced teachers who were very familiar with the use of technology in mathematics teaching and with research in mathematics education. These types of scenarios depended on establishing qualitatively new types of solutions to familiar problems. These four degrees focus on the purely mathematical aspects of using the tool, rather than any other characteristics that might enhance the learning in the classroom, such as ways of making the learning of mathematics more engaging or efficient. Although this may be because of the nature of the tool — dynamic geometry software is purely for mathematical tasks — in the broader context of technology in mathematics education, it is recognised that finding ways of making the learning more engaging and efficient does enhance the learning (Jones & Knezek, 1993; McCormick & Scrimshaw, 2001; Passey, 2011; Marks, 2000).

Laborde (2001) categorised the integration of technology (in her case the interactive geometry software called Cabri Geometre) in the design of geometry tasks into four categories, referred to as *instrumental evolution.* She classifies the tasks according to the role that the designer of the task, which is the teacher, attributes to the technology. I adapted this framework, as shown in Table 1, and used it as part of the preliminary framework guiding my study. As mentioned in the introduction, the framework that I develop in this thesis is called the Teacher Adoption of Digital Technology (TADT) framework. In this chapter I develop the preliminary version of the TADT, but this will be developed throughout the study. Since my study is not strictly focused on geometry tasks, as Laborde's (2001) study was, I adapted these categories to reflect how tablets were used more broadly in mathematics classes, independently of the mathematical content.

I use the four categories defined by Laborde as part of the preliminary TADT framework, but the names and the examples are changed to be more relevant to my study, as shown in Table 1. These categories are progressive steps, each moving closer towards an increased degree of technological integration. My interpretation of what Laborde means by the term *instrumental evolution* in the framework is the evolving uniqueness of representing or solving a mathematical task using the technology. As I understand it, and use it in my study, the idea of instrumental evolution is that progressively the technology is used to interact with mathematics in a way that is not possible without the aid of technology. As technology becomes more fundamental to the way in which a mathematical concept is represented or solved, the level of instrumental evolution also increases.

Table 1 Use of tablets for mathematical tasks portion of the TADT framework (Adapted from Laborde, 2001)

Features of tasks	Description of features
	Instrumental Evolution
Material	Definition: The task is different using a tablet than a paper/pencil task because of the tool being used, but not in the mathematical thinking required.
	Example: Worksheet on a tablet that provides the answer is the same as a textbook with answers in the back.
Connect	Definition: The task using a tablet helps students make connections in their mathematical thinking that would be more difficult to understand with a paper/pencil method.
	Example: Quickly graphing multiple equations using a graphing program on the tablet allows for visualisation of what changes in an equation mean to the graphical representation.
Enhance	Definition: The task using a tablet requires more mathematical knowledge than if it were solved using paper/pencil methods.
	Example: Constructing a square using a dynamic geometry software requires specific knowledge of the properties of the shape, such as the angles and properties of the sides, rather than simply drawing the shape.
Extend	Definition: The task is only possible using the tablet and not possible using paper/pencil.
	Example: 1. Using programing logic to solve a problem or create something. 2. Using the drag mode of a dynamic algebra software to understand the properties of shapes.

In my own study the mix of teachers included both highly experienced as well as more novice teachers. As Laborde (2001) found in her study, my hope is that such diversity will enrich the conversation and development of the teachers through the group meetings. I facilitated the meetings by asking questions to direct the conversation to increasingly more detailed uses of the tool. However, unlike Laborde (2001), the teachers in my study did not work on specific lesson plans together. In order to make the study as minimally disruptive to the regular working environment of the teachers, I did not insist on developing specific lesson plans that each teacher must use. The purpose of the meetings was to share and develop knowledge among the teachers. By me asking more directed questions of the teachers, I aimed to direct their discussions to facilitate the development of ways of using tablets that have characteristics of the fourth degree of innovation that Laborde (2001) describes using the technology. To aid this development, my study also gathered the teachers to work together and develop their use of the tool — iPad — in their lessons.

Institutional Adoption

Ruthven's (2008) analysis shows the complexity and challenge involved in integrating digital tools, such as dynamic geometry or computer algebra, into school mathematics. This illustrates the importance of central lines of mathematical development needing to be rethought if a coherent and effective integration is to be achieved. As these new technologies are quickly spreading beyond pilot projects and into ordinary classrooms, the institutional frameworks and teaching resources which lay out student curriculum and provide pedagogical guidance to teachers needs to be revised accordingly. This is illustrated in the study by Ruthven, Hennessy and Deaney (2008) where, as described earlier, many teachers saw dynamic geometry as helping to make forms of guided discovery viable in the classroom, usually through structured ‘investigations’ aimed at establishing standard results. This helped to explain the limited instrumental evolution, which presented itself in the teachers being cautious about investing time in having their students use (and learn to use) the technology. Therefore, the usage of dynamic geometry never went beyond the second degree of Laborde’s (2001) typology.

One of the reasons why the usage of dynamic geometry in Ruthven’s study (2008) did not reach its full potential is because the tools were treated in a very different way from more established manual tools. For example, the knowledge and skill required to make use of a protractor to measure angles by hand was carefully specified, whereas this kind of detail was not given to the distinctive knowledge required to measure angles with dynamic software. While the official guidance explicitly recognised and provided instructions for manual tools, it did not offer the same for dynamic geometry. Overall, the guidance showed little recognition of how dynamic geometry may open up unique mathematical strategies. The suggestions made assumed mathematical approaches already available with manual tools, or drew explicit parallels with established visual aids, missing the opportunity technology had to offer. This information provides some insight into how teachers may be using and developing their practice of teaching with tablets. Particularly as tablets are not specifically designed for mathematics, and there are multitudes of programs that can be used on them, the guidance that Ruthven found lacking with dynamic geometry software may be more pronounced with a tool as ambiguous as the tablet.

The implication of this for my study is that there is a need to develop more diverse ways of working with teachers to find new and beneficial ways of using educational technology. This is in line with Ruthven's (2013) statement that there is a need for more research in the concrete ways that teachers develop the use of technology in teaching. Although there are several frameworks in place to analyse the expertise that underpins the successful integration of digital technologies in teaching, more needs to be done to understand what teachers do with the technology (Ruthven, 2013), which brings into focus the role that teachers have in the implementation process.

2.2.3 Teachers' Reasons to Use Educational Technology

Frameworks providing theoretical perspective on how technology can, and should, be used to enhance the teaching of mathematics are very useful guides and provide one perspective on the role of technology. However, teachers often use technology for a variety of reasons. As professionals, they understand what impacts their students' learning, and understanding this is an important aspect to consider in the way technology is incorporated into education. Lagrange and Kynigos (2013) found that theoretical frameworks cannot be considered in isolation as implementing any experiment depended on merging the researcher's theoretical orientations with the teachers' views.

Although there are many different ways to use any technology, depending on what type of technology or program is used and for what purpose, there may be some key reasons why teachers may choose to use technology in teaching. Ertmer et al. (2012) found that teachers considered using technology in their classroom in terms of attractiveness, efficiency, and effectiveness. These are not related to a more complex way of understanding mathematics, which is what a lot of frameworks in mathematics education focus on, but they are some of the considerations that teachers have when deciding to use technology. Pegrum et al. (2013) also found that when looking at mobile devices, the most commonly mentioned benefit given by teachers was the level of motivation and engagement the devices had for students.

These different characteristics mentioned – attractiveness, efficiency, motivation, and engagement – may seem to have little to do with understanding mathematics more deeply or using technology to see mathematics in new ways, which is the focus of the frameworks previously outlined. However, as Ertmer et al. (2012) found, although teachers were seeking to make the learning process more attractive and more efficient to students, they indirectly assumed technology was contributing to effective student learning. It is important to consider the features that teachers value about the technology they use in their teaching. In addition to the frameworks that research has provided, I also want to incorporate the features that teachers value about technology in the framework developed in this study.

To understand what teachers value about technology, and their experiences overall, it is also important to understand is their views on using technology in teaching (Dogan, 2010), which is an important aspect of this study. Heitink et al. (2016) found that teachers' beliefs reflected their practice, which makes it important to understand what these beliefs are as the teachers are the ones that implement the use of technology in the classroom.

2.3 Teachers' Views of Educational Technology

Teachers are very important stakeholders in any initiative designed to integrate technology in schools, and their views must be thoroughly understood before any initiative takes place (Li, 2014). To define what teachers' views encapsulate is a complicated issue. The literature mainly refers to the way teachers view the integration of technology into schools as their *beliefs*. Beliefs, as a concept, has been studied in diverse fields, and have resulted in a variety of meanings. As a global construct, Pajares (1992) said that it does not lend itself easily to empirical investigation. The educational research community has been unable to adopt a specific working definition (Pajares, 1992). As Clandinin and Connelly (1987) found when reviewing studies about teacher theories and beliefs, many studies use different words, such as 'conceptions', 'perspectives, 'beliefs', and 'knowledge' to mean similar things. More specific to this study, there is also no consensus on teachers' beliefs relating to technology integration (Kim et al., 2013).

I do not intend to delve into and explore this debate about the meaning of 'belief', or the different interpretations of 'belief', in any detail. To move away from the debate around 'belief', in this study, I refer to the online Oxford Living Dictionary's definition of 'belief' – "An acceptance that something exists or is true, especially one without proof." (belief, n.d., para. 1). This definition is too strong for what the teachers are asked to express in this study, which is not an acceptance of what exists. Rather the teachers are asked how they regard educational technology and their attitude towards them. The online Oxford Living Dictionary defines 'view' as "a particular way of considering or regarding something; an attitude or opinion." (view, n.d., para. 6). This definition is more appropriate for my study and I will use it to define teachers views throughout this study.

Teachers' views about the role and effectiveness of technology in education are fundamental to the acceptance of new technologies in teaching (Kim et al., 2013). Views of the teachers, and other players in the system, have a large impact on the integration of technology throughout the education system. Li outlined the impact in the following way, in a study that investigated the views of secondary mathematics teachers and students in Canada (Li, 2014).

> Students' and teachers' beliefs about technology may affect their adoption of the tools which directly contributes to the establishment of a technology-enhanced environment. Further, administrators' understanding of technology-related issues may affect school policies. This, in turn, may influence the integration of technology in schools and reshape the environment. As a result of these factors, the establishment of a successful technology enhanced learning environment entails a solid understanding of each of its components in the context of its own culture. (p. 378)

Sugar, Crawley, and Fine (2004) suggest that teachers' views about the role of technology in education, and its value in that respect, is one of the most significant hurdles in fully integrating technology in a classroom setting. Similarly, Ertmer (2005) stated that conditions for successful technology integration – such as ready access to technology, increased training for teachers, and a favourable policy environment – seem to be in place, but high-level technology use is still low, which "suggests that additional barriers, specifically related to teachers' pedagogical beliefs, may be at work" (p. 25). Belland (2009) echoed this concern, reflecting that there is a second set of beliefs in addition to those underlying beliefs that influence how teachers use technology. These beliefs are related to the barriers teachers encounter in their attempts to interact with technology, such as the lack of training and scarcity of technological resources. Although this is not the focus of my study, I do capture the views teachers hold regarding the use of tablets in teaching mathematics, which might give some insight into their views on the subject. This insight may help educators understand why some teacher views are hard to change (Levin & Wadmany, 2006). Another important reason to consider teachers' views is that without this understanding other initiatives may not be successful. According to Cuban (1990), one reason why education reforms are so slow is because policy makers ignore teachers' views. These were found to be big factors in how and when change occurred in education.

In capturing teachers' *views* about having tablets in mathematics education I refer to the study by Chiu and Churchill (2016), and I adapt their framework to use in coding teachers' views in my thesis. In their study, Chiu and Churchill (2016) investigated the factors that influenced the beliefs, attitudes and anxiety levels of secondary teachers teaching different subjects. For the section of the preliminary TADT framework on teachers' views, I focused only on the beliefs portion of their framework (as I explained earlier in this section, the notion of *beliefs* is related to the notion of *views* that I use in this study). Chiu and Churchill (2016) built the framework on beliefs by combining the following three separate definitions of beliefs. They used Abbitt's (2011) reference to beliefs about technology as *self-efficacy* regarding computer use; Polly, McGee, and Sullivan's (2010) definition as the value of technology in learning and teaching; and Davis, Bagozzi, and Warshaw's (1989) suggestion that beliefs about the value of technology includes *perceived ease of use* and *perceived usefulness* of a new technology in teaching and learning. Chiu and Churchill (2016) described the positive or negative degrees on what teachers felt about each of the three scales of self-efficacy, perceived ease of use, and usefulness. I adapt this framework and incorporated it as part of the preliminary TADT framework, as shown in Table 2, which provides definitions and examples for each category.

Table 2 Teachers' views portion of the TADT framework

Tablet self-efficacy	Definition:	Teacher's views on her "capabilities to organise and execute the courses of action required to produce a given attainment" (Bandura, 1997, p.3)
	Positive Example:	I know how to use tablets to teach my mathematics class
	Negative Example:	I am not confident in using the tablets in my class
Perceived ease of use	Definition:	Teacher's views on the ease of use of tablets in teaching mathematics
	Positive Example:	I find it easy to teach with tablets
	Negative Example:	It is difficult to find the programs I want to use on the tablets
Perceived usefulness	Definition:	Teacher's views on how useful tablets are to teach mathematics
	Positive Example:	I think there is great potential for using tablets in my teaching
	Negative Example:	It is more trouble than it's worth to use tablets in my classroom

In a study investigating the views that prospective primary teachers had about using technology in mathematics education, Dogan (2010) found that the teachers were enthusiastic. Although these teachers were hesitant as they did not feel adequately prepared to use them. However, on reviewing previous literature about the views of mathematics and science teachers about the use of technology, Li (2014) concluded that there is a gap in understanding of their views. Pierce and Stacey (2013) observed that a lot of the research on learning to teach with new technology have had early adopters as the participants, which is not representative of most teachers. Addressing these observations, my study includes teachers with different levels of technology use and understanding their views on technology is an integral part the design. I want to understand if they had positive or negative views on the use of tablets in teaching mathematics. As an example, I want to explore if they viewed tablets as beneficial to the learning they hoped to instil. I also want to explore their view of their own ability to use tablets in teaching mathematics. Through individual interviews as well as the regular group meetings, I aim to understand each teacher's view, and how it may develop, over the course of the study. An important aspect of understanding the teachers is also to take into considerations the factors that might be impacting them.

2.4 Factors that Impact Teachers' Use of and Views on Technology

There are numerous factors that may impact the way teachers use and view technology. These factors may depend on the context in which the teacher works, as well as on their individual views and experiences. Perrotta (2013) argues that there is a need for greater understanding of how technologies are used between different schools and, more problematically, to explore the relationship between teachers' views and a range of individual and institutional factors. Kiraz and Ozdemir (2006) identified four main factors that enable technology acceptance: (1) the perceived ease of use of technology; (2) the perceived usefulness of technology; (3) the teachers' attitudes towards the use of technology; and (4) the frequency of use of technology. The first three of these factors relate to the teacher's perception and attitude, whereas the last factor touches on the use of technology. The fourth factor, being the frequency of use of technology, needs more unpacking, as it suggests that frequent use enables technology acceptance. However, the more a technology is used the more opportunities arise to uncover challenges both with the technology as well as how it is managed in a classroom setting.

Moersch (1995) discusses five distinct problem areas of computer usage in education: (1) staff development was usually insufficient and misdirected; (2) computers tended to be used for isolated activities unrelated to central instructional themes or concepts; (3) computer usage was one step removed from the classroom teacher; (4) technology usage sustained the existing curricula rather than being a catalyst for change; and (5) technology plans failed to establish a link between the need for technology and identifiable instructional priorities. In his 2007 study, Franklin indicated additional barriers to success. Even teachers who were well educated in the use of educational technologies and graduated from a university that won numerous awards for preparing teachers to teach with technology, those teachers did not always use their skills once they started teaching. The three key reasons given for their lack of technology use were: (1) too much curriculum to cover; (2) a lack of time in their daily schedule; and (3) the emphasis on high-stakes testing. However, there seems to be something missing, since these three reasons imply that it takes more time to prepare lessons that use technology than lessons without technology, and that high-stakes tests somehow do not work with technology. Possibly there is training needed beyond what the teachers were taught in their formal education.

Several authors have also written about the lack of effective teacher training on the use of classroom technologies (Guha 2003; Mentz & Mentz 2003; Tsitouridou & Vryzas 2004). In a global survey that involved input from schools nationwide, across 26 countries, Pelgrum (2001) found that the two most significant barriers to the use of technology by elementary and lower secondary school teachers were lack of technological knowledge and skills, and opportunities for adequate training. Thomas and Palmer (2014) also found that lack of opportunity for professional development was inhibiting teachers from using technology in their teaching. Taking these issues into consideration, my study organised teachers to meet as a group to discuss and learn from their diverse experiences and incorporated these discussions and reflections into their existing work-flow.

Ertmer (1999) looked at the factors impacting teachers from a different angle, by grouping potential barriers in two categories. The first-order barriers (ex. resources, training and support) and second-order barriers (internal to the teacher, such as confidence, beliefs about how students learned, as well as the perceived value of technology). In more recent years, Ertmer et al. (2012) found that the first-order barriers are being resolved by having more resources, training and general support for teachers. However, there appears to be mixed outcomes, as numerous studies have found that factors that would fit first-order barriers are still inhibiting teachers' use of technologies (Ditzler, et al., 2016; McKnight, et al., 2016). Regarding the second-order barriers, that relate to the teacher themselves, such as their confidence and beliefs, Ertmer et al. (2012) found they are still not being addressed. To better understand why the teachers' beliefs and confidence are barriers to their use of technology, it is important to dig deeper and understand their experience in more detail. Therefore my study is designed to get to know teachers closely over time and also understand their views, as was described in the previous section. At a time when technologies prevail in our lives, what is it about the technologies used in schools that impacts teachers' beliefs and confidence? This may also suggest that training and support is needed in schools to help teachers throughout their professional lives.

There are many ways of looking at factors that impact teachers, which can vary depending on any number of reasons — the training teachers received, the type of technology they are using, the school environment, or the teacher's personal experiences and beliefs. The research reviewed in the previous paragraphs often points to factors that are not necessarily ones given by teachers as impacting their choices, such as their beliefs about technology. Although all factors need to be understood, it is important that the factors teachers feel impact their decisions of if, and how, they use technology in the classroom, are also understood. As previously stated, Franklin (2007) outlined that time and the quantity of curriculum needing to be covered, were key factors given by teachers for not using technology. Lack of time was also found to be a key factor in a study investigating the integration of online learning in 26 Australian schools (Neyland, 2011). In this same study, teachers were found to be very frustrated by technical issues they encountered, both with the infrastructure and the network. Technical issues are not uncommon, in a US school that implemented 1:1 iPads (Ditzler, et al., 2016), the teachers were very frustrated by the Internet connection at the school as the system was frequently down. Support for teachers from the school has also been given as an important factor (McKnight, et al., 2016; Voogt, et al., 2011). Some studies have also found that tablets cause some classroom management concerns such as student behaviour issues and distractions (Ditzler, et al., 2016). Also, resources such as finding appropriate apps for tablets used in the classroom, can be challenging (Ditzler, et al., 2016; Neyland, 2011).

In my study I capture the factors the teachers raise as those impacting their use of tablets. Gathering this information will give insight into their experiences but can also be used to address their further development. Drawing on the literature summarised above, the initial

TADT framework includes the five factors – time, resources, technical issues, support, and classroom management – that are defined in Table 3 below.

Table 3 Factors portion of the TADT framework

		Definition
Factors	Time	Time available to prepare or learn to use tablets
	Resources	Resources, software or hardware, available to use tablets
	Technical issues	Issues concerning technical challenges with the hardware, software, or infrastructure
	Support	Support provided to the teachers from the leadership or technical team
	Classroom management	Classroom management concerns caused by the use of tablets

2.5 Developing Teachers' Use of Technology

There can be many reasons and factors contributing to why teachers may, or may not, develop their use and views on tablets over time. Even if they do develop in some way, research indicates that any change without some type of assistance takes a long time (Laborde, 2001). There are many ways that professionals can learn in the workplace, but they are not without challenges. Schools can be particularly challenging places as there are many different demands place on a teacher's time. In this section I first outline the literature on teachers' learning needs with regards to integrating technology into the classroom, followed by the role of professional development in schools. In the third section I explore the concept of Professional Learning Networks and how they can be helpful to teachers.

2.5.1 Teachers' Learning Needs

Both the success of integrating technology into the classroom, and the degree to which students can benefit from a technology-enriched environment, depends largely on what the teacher does with these tools. It is essential that teachers are willing to learn to use the technology in order to incorporate it successfully in their teaching (Kozma, 2003). This is well understood, and the development of teacher competencies for technology use has been the focus of current educational reforms worldwide (Chronaki & Matos, 2014). Tools are not neutral: they change the actions of the users as well as significantly affect their conceptualisation of reality (Vérillon & Rabardel, 1995). Central to the idea of integration of technology in teaching is the understanding and developing of teacher professional development (English, 2009). Several authors have written about the lack of effective teacher training on the use of classroom technologies (Guha, 2003; Mentz & Mentz, 2003; Tsitouridou & Vryzas, 2004). In a survey that involved input from schools across 26 countries, Pelgrum (2001) found that the two most significant barriers to the use of technology by elementary and lower secondary school teachers were lack of technological knowledge and skills, and opportunities for adequate training.

Increasingly, the importance of developing theoretical notions related to this is also getting recognised (Artigue, 2010; Goos, 2009; Goos, et al., 2010). As Goos (2009) explains: "Research that develops and validates a theory of mathematics teacher educator learning and development would lead to a better understanding of how expertise is developed in carrying out this professional task" (p. 215). To address this, I worked with the participating teachers over an extended period of time and observed how they developed their use of tablets in teaching mathematics. This was not purely an observation as I also facilitated the meetings in which the teachers were encouraged to develop their practice by learning from their peers. In addition, it is important to not only take into account the way that mathematical activity is shaped by technology, but also the ways that the activity shapes the technology (Jones, Mackrell, & Stevenson, 2010). How teachers develop their use of technology can have profound impact on the way technology is implemented in teaching.

In a 15-week study during which teachers collaboratively designed and developed an online course, Koehler, Mishra, and Yahya (2007) found that over the period of the study participating teachers moved from considering technology, pedagogy, and content as being independent constructs towards a richer conception that emphasised connections among these three constructs. The teams worked together and used design methods to learn by doing the actual task. Teachers were confronted with building a technological artifact while being sensitive to the specific subject matter requirements that were being taught. The group of educators worked collaboratively in small groups to develop technological solutions to authentic pedagogical problems. This is in line with my own work, where the teachers will not be learning out of context but will develop ways of using the tablets in their lessons.

Unlike the Koehler, Mishra, and Yahya's (2007) study, however, the teachers in my study will discuss ideas together, but will design the lessons outside of the group meetings. Some may assume that this type of learning is only needed for teachers who are unfamiliar with technology. However, Ma, Andersson, and Streith (2005) found that, although young teachers have grown up with computers, they may not automatically use technology effectively to improve the way students learn. It is unlikely that students, who have grown up with digital technologies, will learn to use computers in ways that benefit their learning as adults, unless their teachers have modelled effective technology use in schools (Fuller, 2000). This is important for my study, since some of the participating teachers were young enough to have had digital technologies in their school as students, however that does not mean they learned to teach with them. Like with any skill, guidance and training is needed for all teachers to know how to use technology in a way that will elevate their teaching and enable greater learning. Professional development plays an important role in this type development.

2.5.2 Role of Professional Development

As I mentioned above, the main audience for teacher training on how to use technology in the classroom is not limited to those who are unfamiliar with digital technologies. Even teachers who use technology in their existing instructional practices, some have found that they rarely take full advantage of its potential or use the technology to teach in new ways (Dawson, 2012). Even in cases where schools have successfully implemented a 1:1 programme, where every student has their own mobile device, some studies have found the programmme is not continuously positive. The second year of the 1:1 programme has been found to be a particular struggle (Alberta Education, 2010; Swallow, 2015).

With so many factors combined in the ecosystem of a school, there are many reasons why integration of mobile devices may not be fully utilised, as I outlined in Section 2.4. However, one factor may be the shortcomings of professional development for teachers, which is already well documented (Opfer & Pedder, 2011). In mathematics, as in other STEM (Science, Technology, Engineering, and Mathematics) subjects in the K–12 classroom, there have been found to be significant challenges for teachers. Steep learning curves and the challenge of gaining confidence and skill at guiding students through complex activities within the constraints of the K–12 classrooms all add to the difficulty of using mobile devices (Parker et al., 2015). These hurdles are not ameliorated by the fact that the sufficiency of teacher training and support has come into question (Ertmer & Ottenbreit-Leftwich, 2010). It is not that teachers are luddites, it is often likely that educational practitioners are already using 21st century methods and strategies in varying degrees and simply need additional support and professional development to ensure full application (Gunn & Hollingsworth, 2013).

Evidence suggests that teachers' views, and knowledge are crucial factors in technology integration. In addition, accounting for social and cultural influences on classroom environments is essential to be able to describe the complexity of their conceptions (Lavicza, 2010). These factors indicate that the traditional model of professional development needs to be reconsidered and modified to support teaching with mobile devices. Involving teachers in the development, either through teacher participatory efforts or through teacher education and professional development efforts, is essential. The cultures in which teachers learn and work must embrace and nurture this new model (Ertmer & Ottenbreit-Leftwich, 2010). Professional development needs to move away from the traditional model of sending teachers on an occasional course to develop their skills. Gunn & Hollingsworth (2013) have found that, "while sporadic professional development has been known to incite temporary adoption of new methods or innovations, widespread teacher change is only possible through thoughtful and systematic implementation of critical knowledge, skills, and strategies" (p. 204). There are many ways that such professional development may be achieved.

Heitink et al. (2016) stated that "[t]eachers' effective use of technology might be improved if they become better able to articulate the reasoning behind the use of technology in their teaching, share this reasoning with colleagues and confront their reasoning with findings from research." (p. 82) This suggests that one way in which professional development may be effective is by having teachers share knowledge and experience among themselves, through learning networks. Having such networks in the workplace may also be beneficial as Short (2014) found through a review of literature on learning in the workplace, that trust is extremely important and face-to-face connection with colleagues helps build this trust.

2.5.3 Professional Learning Networks for Teachers' Development

The notion of *Professional Learning Networks* (PLN), also referred to as Personal Learning Networks, was first coined by Tobin (1998). Tobin defined PLN as a "group of people who can guide your learning, point you to learning opportunities, answer your questions, and give you the benefit of their own knowledge and experience" (Tobin, 1998, para. 1). Such a network can take many different forms. These networks may include online chat rooms, conference gatherings, or formalised networks within an organisation. What they all include is an ongoing communication and exchanging of knowledge among the different members. Communication has been found to be an integral part of learning, and in a study by Swallow (2015) it was found that communication between and among teachers and students was a consistent critical component in the integrating mobile devices into the classroom. Ruthven's (2014) review of thirteen mathematics teacher networks found that most described some form of positive change in classroom practice.

It is recognised that discussion among teachers related to how technology tools can be used in their teaching is an effective way of incorporating technology (Clark-Wilson et al., 2015; Ertmer & Ottenbreit-Leftwich, 2010). The National Centre for Excellence in Teaching of Mathematics (NCETM) recognises this need for teachers to learn from each other, and while supporting a wide variety of mathematics education networks in the United Kingdom, it also encourages schools to learn from their own best practice through collaboration among staff and by sharing good practice locally, regionally, and nationally. These collaborations take place face-to-face at national and regional events across England and also virtually on the NCETM portal, and through webinars (Hoyles, 2012).

Both in England and around the world, teachers who have not found the support they needed have taken the initiative to take their own professional learning and development in their hands by developing online PLNs (Trust, 2012). Trust et al. (2016) found that "some teachers may have many of their needs supported within robust school communities and simply cultivate PLNs for lesson ideas and resources, others may turn to PLNs to nurture affective, social, cognitive, and identity aspects of their professional growth" (p. 28). These teachers were found to seek ways of improving their teaching and their PLNs offered a variety of ways of doing so (Trust et al. 2016). As teachers continue to develop their practice, Trust et al. (2016) found that they could benefit from "broad, holistic, and flexible networks as they navigate shifting professional landscapes" (p. 16). The flexibility of digital technologies to have anytime, anywhere availability of expansive PLNs, and their capacity to respond to educators' diverse interests and needs may have the ability to fulfil some of the professional growth requirements a teacher might have. The importance of these types of networks is seen as increasingly important. Jones (2011) went as far as to say that "while access to computing power may shortly no longer be a source of an unbridgeable 'digital divide', differential access to networks of people that provide support for, and nurturing of, educational innovation via ICT may be an emerging new form of 'digital divide'" (p. 43).

Although there are many benefits, joining online PLNs does require a certain level of being digitally savvy and having the time to initiate such involvement. Incorporating the essence of a PLN into a school setting would remove the barriers of entry that some teachers may face.

In addition, fostering a learning network among the teachers at a school has the added benefit that they share the challenges and opportunities of the context they are in. In addition, everyone would benefit from the knowledge members acquire outside of the school. As part of my study, I was influenced by the idea of learning networks, and I introduced and fostered a PLN among the participating teachers. This network was fostered through regular face-to-face group meetings among the participants, that I facilitated, which is outlined in detail in Chapter 3.

Capturing how the group meetings contribute to the teachers' development can be challenging. However, the essence of the group meetings is for the teachers to learn from each other. To have a quantitative representation of this learning, I will consider at the knowledge that they exchange with each other, which I will refer to as *knowledge exchange*. Specifically, knowledge exchange refers to the knowledge shared by the teachers during the group meetings in which they reflect, discuss, and learn about using the tablets to teach mathematics, which is hoped to contribute to their development addressed by the first research question. Knowledge exchange will be used as a code in the group meetings defining the occurrences when teachers share knowledge and ideas among themselves. The purpose of this code is to identify how working in a group influenced the development of each teacher's use of, and views on, tablets in their teaching. Exchanging knowledge among peers is important aspect of this study as it is very popular with teachers and it is an effective way of developing existing practice (Trust et al. 2016; Clark-Wilson et al., 2015; Ertmer & Ottenbreit-Leftwich, 2010). In this study I will not directly ask teachers to exchange knowledge. Rather, by asking them to reflect on their practice and discuss ways of using tablets in a group setting, I will observe instances when they organically exchanged knowledge with each other. In these instances of collaboration, I focus on understanding how knowledge and ideas are exchanged.

2.6 Summarising the Literature and Building the Framework

In the previous four sections of this chapter, I organised the literature in the four key elements of the research questions – use, views, factors, and development. Drawing on the literature in each of these four sections, I have outlined and defined the coding framework that I will use to code data captured throughout this study. I end this chapter by summarising these sections and presenting the initial TADT framework – combining the four coding frameworks – that I use, and develop, throughout this study.

The literature indicates that there are many ways technology is used in education and multiple ways to categorise the use of technology. The different frameworks available are mostly designed based on programs that are specifically mathematics programs. These frameworks are also designed in a way that the categories represent progressively more complex ways of using the technology, leading to categories where the user can engage with the mathematics in ways that is not possible without the technology. Of these different frameworks, Laborde's (2001) framework is the one that I chose to use in this study.

In the second section, reviewing the literature on the teachers' views on technology, indicates that many researchers find the views teachers hold about technology as important to the way they use technology in teaching. This is an important factor to consider in trying to understand how teachers experience integrating technology into their teaching. More broadly, there are many other factors that can impact the way teachers use technology, as reviewed in the third section. However, factors depend on individual teachers, the school, the technology used, and countless other elements. In order to deeply understand the experience of a few teachers, as this study intends to do, it is important to understand the factors that are important to the individual teachers.

In the fourth section, the literature on teachers' development is unpacked. The way teachers are trained and learn is widely acknowledged as being critical for how they teach. However, with the increasing change and complexity of the technology used in schools, it is important to have a continuous learning environment. The literature outlines the benefits that teachers have in professional learning networks, which is what I integrate in this study by having regular group meetings with the teachers. The aim of this is to leverage the benefits that teachers gain from interacting and learning from other teachers. The knowledge they exchange during these interactions can be a critical part of their continuous development in their own teaching.

Informed by the literature, I propose a framework to guide the understanding of teachers' experience in using tablets in teaching mathematics. As data is gathered and analysed, the framework will be modified and expanded. At this point, there are four main parts to this framework, which are defined in the following way:

1. **Use** is broken down into Laborde's (2001) framework of instrumental evolution. As this framework is progressive, with the tasks using technology in progressively more complex ways, the categories are represented in step format. This step format is to clearly indicate that the categories of tasks are progressive.
2. **Views** captures the ways teachers see tablets and their use of them.
3. **Factors** are a cumulative list of factors that teachers indicate as important in defining the way they use and view the tablets in teaching mathematics. Although the factors in the initial framework were drawn from the literature, additional factors emerged from the particular teachers in the study.
4. **Knowledge Exchange** captures the instances when teachers share exchange knowledge during the group meetings on how they use and manage tablets in their classroom.

The framework developed in this study is named the Teacher Adoption of Digital Technology framework, as it is designed to capture the teachers' experience of using, and developing their use, of digital technology, in this particular case tablet technology. The preliminary version is presented in Table 4. Throughout this study I will build upon this framework, which will develop and grow. More detail on each aspect of the framework is developed in Chapter 3, where the methodology of this study is outlined.

Table 4 Preliminary TADT framework

Use Instrumental Evolution	Material Connect Enhance Extend
Views	Tablet self-efficacy (positive/negative) Perceived ease of use (positive/negative) Perceived usefulness (positive/negative)
Factors	Time Resources Technical issues Support Classroom management
Knowledge Exchange	Conversations in which help was offered or knowledge was exchanged

3

METHODOLOGY

3.1 Introduction

In this chapter, I give an overview of the study, and discuss the selection criteria, data collection, and analysis procedures that I employed to address the two research questions. In Section 3.2 I situate my study by describing the selection criteria and profile of the school, the reasons why my study focuses on Year 8 mathematics teachers and their use of tablets, how I approached the school and gained access, and my personal background and experiences which might have influenced my approach. This study is comprised of two distinct phases that spanned over one academic year, as shown in the timeline in Table 5. In Sections 3.3 and 3.4 I describe in detail the methods used to collect, code, and analyse data in Phase 1 and Phase 2 respectively. There were three types of data collected in both phases, as outlined in Figure 1 below. The data gathered using the methodologies described in this chapter, builds towards answering the following two research questions:

1. How do teachers develop over time (if at all) their use of, and views on, tablets in the teaching of mathematics?

2. What factors contribute to teachers' decisions of how, and why, they use and view tablets in the teaching of mathematics?

Table 5 Study timeline

		Dates												
		2014						2015						
		July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July
Phase 1	School Visits													
Setting the	Classroom Observations													
Foundation	Individual Teacher Interviews													
Phase 2	Classroom Observations													
Evolution	Post Observation Interviews													
of Use	Group Meetings													

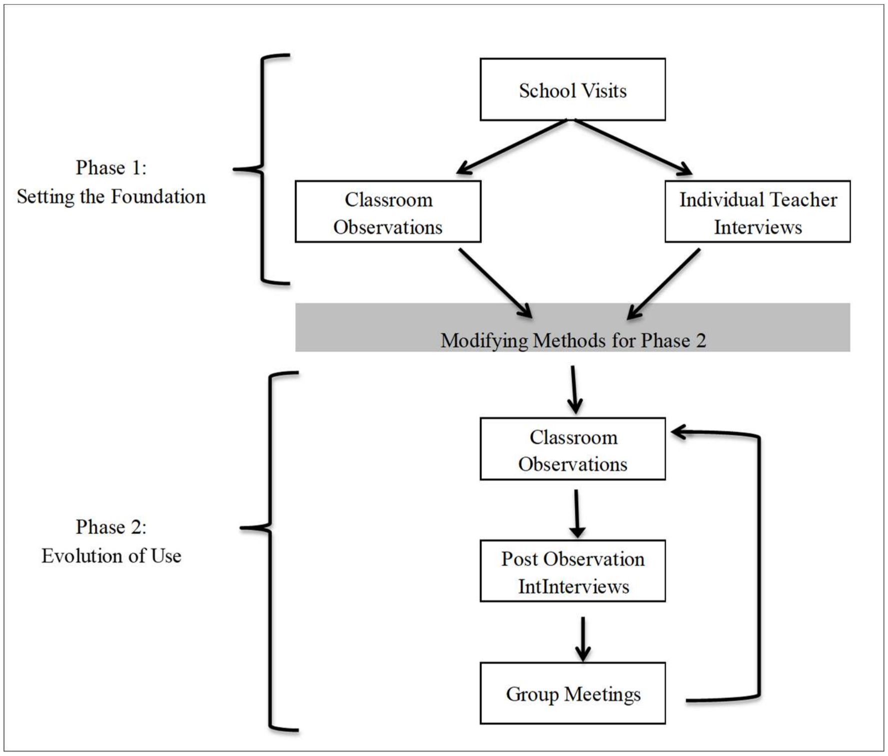

Figure 1 Flow of gathering data

Phase 1 (Section 3.2), referred to as *Setting the Foundation* phase, aimed to identify the context in which the study was run and define the baseline for how the teachers used tablets, and their views on, tablets at the early stage of the study. The following three methods were used to achieve this and help address the research questions:

- *School visits,* during which I had many casual conversations with teachers and saw some classes being taught, were important ways for me to become familiar with the school, teachers, and the boundaries imposed on my study. Building relationships with the teachers was also a key way of recruiting participants. Developing an understanding of the context within which this study was situated, set the foundation for the methods to be as minimally intrusive, and true to the regular daily school environment, as possible.

- *Classroom observations,* in Phase 1, were used to help me become familiar with the ways tablets were being used in the classroom at the early stages of the study. This also allowed me to trial the observation instrument and coding framework prior to using it in Phase 2.

- *Teacher interviews* were used to address both research questions, from the teachers' perspective, at an early stage of the study. Interviewing each teacher individually set a starting point from which any possible development in their use of and views about tablets might be seen over the course of the study.

The results of Phase 1 informed the final design of the methods used in Phase 2, as well as the creation of the revised TADT framework, which are outlined in Section 4.2. This enabled the methods of Phase 2 to be further embedded in the context of the regular daily setting of the school within which my study was situated. This was an important aspect of how I designed the study.

Phase 2 (Section 3.3), referred to as the *Evolution of Use* phase, aimed to identify how over the course of six months the teachers developed, or stayed the same, in their use of, and views on, tablets in the teaching of mathematics. The data from Phase 2 also informed the TADT framework which may further be developed. The following three methods were used to achieve this and help address the research questions.

- *Classroom observations* were one way of understanding how tablets were used in the teaching of mathematics. I, as the researcher, saw first-hand the way tablets were used in the classroom.

- *Post observation interviews* were used to dig deeper into what I observed in the classroom and understand the teachers' views on how tablets were used, the reasons they chose to do what they did, and the factors that contributed to their choices.

- *Group meetings* aimed to give the teachers an opportunity to reflect on, and develop, the way they used tablets in their mathematics teaching and learn from their peers. I facilitated the meetings by asking specific questions to guide the conversation.

3.2 Situating the Study

In this section I situate my study by giving the context in which it took place, the affordances and challenges of a naturalistic classroom setting, the characteristics of the school, why the study focused on tablets, and how I approached the school and recruited teachers. Finally, I give a brief overview of my background and professional experiences, which might have influenced the way I approached this study and the lens through which is see it.

3.2.1 Research in Classroom Settings

Conducting research in schools presents both challenges and opportunities (Alibali & Nathan, 2010). Considering the complex ecosystem of a school, I wanted my study to be immersed in that context and allow for all the factors that might impact the study, in the regular course of a school day, to do so. Allowing for the impact that the regular running of the school and classroom has on the study is what I refer to as the *naturalistic* setting. Some examples of factors that might have impacted the study in the naturalistic setting would include the teachers' schedules, the topics being taught during the study, interruptions in the classroom, and changes in the school's tablet policy. Although such a setting is unpredictable and messy, it also informs the study in ways that a controlled environment cannot.

Questions investigating how and why certain things happen in a school require the study to be situated in the naturalistic school setting. As an example, investigating the reasons why the second year of a one-to-one technology initiative seemed to be a vulnerable time for achieving programme goals, required Swallow (2015) to set the study in an actual school. The factors that may interfere with the study are too many to be accounted for in any controlled setting. For these reasons, I situate the study in an actual school setting and try to be sensitive to the day-to-day environment of the naturalistic setting as much as possible. In this effort, a significant part of the first phase of the study was for me, as the researcher, to set the foundation for the study by becoming familiar with the setting and the teachers, slowly integrating into the school, and familiarising the teachers with the study.

As there are opportunities, there are also challenges in situating research in a naturalistic school setting. Plummer et al. (2014) noted that a lesson learned in such research was to expect the unexpected. In their study, they were surprised by fire alarms, field trips, and all-school assemblies, among other events, which, in most cases, had been arranged by school administrators other than their primary contact. Some loss in accuracy, and deviating from the original research plan, is a price that must be paid. But some have found that the key to successfully conducting research in schools is to have positive relationships with teachers and administrators (Alibali & Nathan, 2010). Building these relationships is an extremely important part of this study and how I approach the research from the very start. Slowly and carefully I got to know the teachers and the school by first casually spending time in the school, having casual conversations about the way they used tablets in their teaching, and gradually becoming more involved. As part of this process, I slowly came to understand some of the challenges the school and teachers faced in integrating the technology into their teaching. This knowledge was an important first step in knowing what to look for and understanding the information that emerged over the course of the study.

In the rest of this document I use the terms *school* and *classroom* to refer to the naturalistic setting as I described above, in which the regular factors that might impacted my study could do so. I tried to minimise the disruption of my presence in the classroom and school, and design the study so that it integrated into the environment as much as possible. The only intentional interference I imposed on the normal day-to-day running of the school and classroom setting was interviewing each teacher in Phase 1, having short interviews with teachers after each class that I observed, and the group meetings. There likely were other ways in which my presence changed the setting, but I took great care to minimise this.

3.2.2 The School

The school was a large comprehensive British school, which has been open to innovation and research. The school has also been a training school for over a decade and has won several awards. The school is not situated in a large city and attracts students from its surrounding area. Regarding the student population, the proportion of students supported by pupil premium funding (additional funding for students known to be eligible for free school meals and those looked after by the local authority) was below the national average, but has risen significantly in the past few years. The proportion of disabled students, or those having special educational needs and are supported by school action, was also below the national average. The proportion of students supported at school action plus or with a statement of special educational needs is in line with the national average (OfSTED, 2014).

One year before I was introduced to the school, a programme was implemented that provided each Year 7 student with an iPad mini, which I will refer to more generically as tablets from this point forward. These students were meant to keep these tablets in their possession for the subsequent years of their schooling until they graduated. Each year the next group of Year 7 students were also planned to receive tablets until every student in the school had a tablet. However, after the first cohort of students was given tablets, the programme was paused and the new Year 7 students were not given tablets. I was introduced to the school the year after tablets were implemented. As there was only one year group, who was at that point in Year 8, those were the mathematics teaches I could recruit from. This timing provided the opportunity to avoid the initial turbulence that follows a significant change to the school structure, such as starting a one-to-one programme.

There are two main reasons why it was fortuitous for this study have started after the initial introduction of tablets in the school, and they each relate to the research questions respectively. The first reason is that I wanted to understand how teachers use, and their view about, tablets once they have been using them for some time and have become familiar with the reality of how tablets impact them and their students. The second reason is that to understand the second research question, which relates to the factors that impact teachers' use of and views about tablets, it is important that the teachers had some time to use tablets in their teaching so that they could identify the factors that support or inhibit their use of tablets.

3.2.2 Why Tablet Technology

In this study, I chose to focus on tablets because I wanted to study a digital technology that was relatively new as a teaching tool and currently being adopted by schools. The school in which this study is situated, implemented iPad mini tablets. The mobile aspect of the technology is important because it includes a lot of the technologies that are being introduced in schools at the time this study was taking place, such as tablets, laptops, and iPod touches. The characteristics of a mobile technology, and specifically tablets, offers opportunities for both the classroom orchestration and the teaching and learning of mathematics. As I mentioned in Section 1.2, in this thesis I use the term *mobile technology* to refer to a group of digital technologies that are characterised by their physical characteristic of being easily used in different locations, such as tablets or laptops, not to the concept of mobile learning which implies that learning can occur anytime and anywhere.

In terms of classroom orchestration, the mobile feature of tablets allows the teachers and students to use the technology in ways that are not possible with some other types of digital technologies, such as desktop computers, which are stationary, or interactive whiteboards, which cannot be used individually by each student and are only available at the front of the classroom. Each student having a tablet that they can use alone, or with other students, and they can carry anywhere in or out of the class, opens possibilities for how the teachers can orchestrate lessons. Students could work on different tasks on their own tablet, rather than everyone having to watch the same thing at the front of the class, and they could gather in groups with students working on similar tasks and easily change groups if needed, which is not possible with stationary computers. Tablets also allow for a different range of tools than laptops, in addition to online websites and tools, there are also many apps available with some making use of the increased mobility of tablets.

In terms of the teaching and learning of mathematics, tablets provide some different opportunities that other technologies, such as laptop computers, interactive white boards, or iPod touches, do not offer. The touch screen on tablets can make tasks more tactile than a laptop, potentially making activities such as numeracy games, that can be used to practice mathematical skills, more engaging. The camera feature of tablets could also be used to capture real world objects and use them in mathematical tasks. For example, because of the mobility of tablets, the camera could be used to take pictures of the different planes of an object, possibly helping students understand the relationship between the two-dimensional and three-dimensional representations of objects. Augmented reality, where the camera of on tablets is used to view the surrounding area on the screen and the program superimposes shapes, images, or text onto the real-world image, could also potentially help students make connections between mathematical concepts and real-world applications.

An important aspect of tablets in this study is that they are a new mobile technology used in the classroom, and teachers did not have an established understanding of how to use them in the teaching of mathematics. This is important because it provides insight into the use of new mobile technology in the classroom, which has had a history of being introduced into schools with little evidence to guide how they are being implement (Kiger, Herro, & Prunty, 2012). Not having an established understanding of the technology also allowed me to study how the teachers developed their use of, and views on, tablets in their teaching.

3.2.3 Recruiting the School and Teachers

I approached the school through one of my doctoral supervisors who already had professional contact with the school. As the profile of the school was an ideal fit for my study, my supervisors suggested that I start visiting the school and observe what the school was doing with tablets. Through these visits and informal conversations with teachers, I slowly gained their trust as they became familiar with me and the purpose and structure of the study. This gradual process of building trust was partially a way for me to gain access to the school and recruit teachers to participate in the study. I elaborate on these visits in Section 3.2.

The recruitment criteria for the teachers was to be from one school and all of them to teach mathematics in the same year group. These criteria allowed for the teachers the possibility to discuss specific lessons in the group meetings, and specific ways of using tablets in their teaching. The selection criterion was an opt-in criterion without imposing any pressure on who participates. The opt-in selection process has its drawbacks in that the teachers who decide to participate may not represent the general population. Presumably the teachers who volunteered to participate were motivated in some way to improve their practice of using tablets and to contribute to research in this field, which excludes teachers who were not motivated to change their practice, or those who felt that they were utilising tablets to their full capacity.

I do not presume to know how representative the group of teachers in my study was, but the fact that they chose to volunteer may have implications. One possibility is that these teachers were the most motivated to develop their use of tablets or were already the most comfortable teaching with tablets. In this case, their use of tablets, and their development over the course of the study, cannot be generalisable to the rest of the teachers in the school. Another aspect of this selection criterion is that the teachers who decided to participate were those who saw value in using tablets in teaching. This may imply that the results of the study would not be relevant to teachers who do not see value in using these technologies. However, engaging teachers who volunteer to take part may also imply that, because of their desire to develop their practice, they would enthusiastically champion the use of tablets and disseminate information to other teachers in the school.

The findings of this study are not generalisable, but the focus on a small group of teachers does have a purpose and several advantages. Having a small group, such as the four teachers in this study, allowed me to focus more closely on each individual teacher for a long period of time and understand their views and use of tablets more deeply. The small number also enabled the group meetings to be more productive, since the group was small enough to allow everyone to have their voice heard, but it was also big enough to have different points of views and experiences for a good conversation.

For anonymity, the names of the teachers were changed in this study and all the teachers are referred to in the feminine and given gender neutral names, regardless of their gender. The reason for not identifying the gender of the teachers, and arbitrarily assigning all teachers with the same gender, is to further shield the identity of the teachers and to minimise possible gender bias in the interpretation of the data.

3.2.4 My Background

My past experiences provide me with some familiarity and foundational knowledge about the environment in which I conducted this study. I am an electrical engineer with five years of work experience, which has made me comfortable to use and understand new technologies in my work. Following this career, I became a Canadian certified mathematics and physics teacher, and I have taught and conducted research in several schools in both

Canada and the USA. For many years throughout my career, I have volunteered at schools and tutored mathematics and physics to students.

Through the years, I have observed how some schools implemented technology in teaching. I experienced the way teachers used graphing calculators, laptops, tablets, iPod touches, and interactive whiteboards in their classes. I have seen how mathematics teaching can be enriched, and also watered down, with the use of expensive technology. Having these experiences, I came away both with criticism and praise for the devices and the ways in which they have been used.

Having this background, I came to this study with opinions on how a mathematics class could and should be taught, and the role technology can have, which likely had an impact on the way I approached and interpreted this study. My background in mathematics might have provided me with more understanding on what was being taught in the lessons I observed, and the kind of understanding the teachers were trying to achieve with their students. My background as a teacher might have also made me more sensitive to the teachers' experiences, which might have influenced my research design. It is difficult to know exactly how I would have approached this study differently if I had a different background, but it is likely that my past informed my approach and interpretation of this study in some way. However, I did try to minimise the possible biases that my background might have imposed. Some examples of this include the creation of a clear coding scheme for analysing the data as well as continuously questioning and challenging my interpretation of the results. Section 3.4 outlines in greater detail the ethical considerations that I had throughout this study.

3.3 Phase 1 – Setting the Foundation

Phase 1 spanned from July 2014 to February 2015. This phase set the foundation on which my study is built, and provided an understanding of the teachers' use of, and views on, using tablets in their teaching at an early stage of the study. In this section I outline the three methods of data collection used in this phase, which include visiting the school, observing classes, and individually interviewing each teacher.

3.3.1 School Visits

Purpose

The purpose of visiting the school was to develop an understanding of the regular daily school setting in which my study was situated and to build strong relationships with the mathematics teachers. The data gathered in this process was not formalised as it does not directly address the two research questions. However, this was a critical process to set the foundation, design, execute a successful study.

There were four main goals for visiting the school over several months. Firstly, building a strong relationship over an extended period helped develop trust. This was essential to enable the teachers to be open and honest with me throughout the study, providing accurate data. Secondly, by building relationships with the teachers, I gained an understanding about what was important to them and what their constraints were regards the design of the study.

This understanding was incorporated into the study to make it run as smoothly as possible. Thirdly, by visiting the school, I become a natural and comfortable part of classroom setting, enabling the teachers and students to behave more naturally when I went to observe lessons. Finally, building relationships with the teachers, allowed me to recruit teachers who were willing to commit to the study for several months. This kind of commitment was made possible by gaining their trust and addressing any concerns prior to asking them to participate in the study.

Process of school visits

The process of achieving the goals of the school visits was characterised in five key ways.

1. Building relationships with two key stakeholders of the tablet implementation who acted as advocates for my study. The two individuals were the director of information technology (IT) for the school as well as a mathematics teacher who has been identified as a technology champion for the mathematics department. The reason for selecting these individuals was that they were already advocates for using tablets in the school and were also well connected to the other teachers and staff. Building relationships with these individuals enables me to learn a lot about how tablets were used in the school. As these individuals were enthusiastic users of the technology, they were likely to be welcoming of my involvement and be champions of the study to the rest of the school. This relationship was

built through meetings and regular email correspondence. As both of my doctoral supervisors were connected to these individuals, they kindly offered to introduce me.

2. Frequent visits to the school helped me became familiar and comfortable with the school setting and how it was run. This allowed me to casually observe how students and teachers used tablets as they move around the school, and I could also pick up on casual conversations in the halls and staff room. These visits allowed me to observe and become familiar with the environment, without formally being the researcher, and see the school in its regular day-to-day functioning.

3. Attending events that were trainings or demonstrations for the use of tablets also provided a useful insight into how the school was intending to use tablets and how teachers were trained to use them. Dialogue at such events would likely be different from that observe in the daily school routine.

4. Casual conversations with teachers helped to slowly building relationships with them and gain some insight into their thoughts and experiences of using tablets. By having champions that introduced me to teachers, I can slowly and casually get to know them over a longer period, before officially asking them to participate in the study.

5. Casually observing mathematics classrooms helped me gradually become familiar with the classroom setting before entering as a researcher. These observations gave me a sense of how the mathematics classrooms were structured and how the teachers were using tablets in their teaching. Being a casual observer, and not taking any notes or pictures, allowed the teachers to also gradually get to know me before I went to take official observations. My approach was that of a learner, wanting to find out how the teachers used tablets in the class, rather than a researcher drawing conclusions.

These five aspects of my visits to the school were vital to the success of the study, and for gaining trust and commitment form the participating teachers.

Impact of the school visits

The school visits helped me immerse myself in the environment, become comfortable in it, and become a regular part of the school. Through this process, I learned about the environment, the people, and the regular functioning of mathematics classrooms. This helped to set the scene for the rest of the study, and what I learned about the school and teachers informed the modifications made to the methods of Phase 2 of my study. The outcomes will be summarised in Section 4.1.1 of the Results chapter outlining my experiences and how they impacted my study. A more descriptive chronology of stories describing key observations throughout this process can be found in Appendix 1.

3.3.2 Classroom Observations

Purpose

The aim of the classroom observations was to see how teachers used tablets in their teaching and how they asked the students to use tablets in the classroom. In addition, these observations were also intended to trial the observation instrument to ensure it easily captured the relevant information in the classroom. As a non-participant observer, I attended the lessons that were pre-approved by the teacher. I asked the teachers to allow me to observe lessons in which they intend to use tablets. The findings of these observations were meant to inform the way classroom observations would be conducted in Phase 2 of the study by: refining the observation tool; enabling me to be more sensitive to what was happening in the classroom; and familiarising myself with the way tablets were used in the classroom and what I should focus on.

Developing the classroom observation instrument

Several designs were explored in developing the observation instrument. I considered using a *systematic approach* (Wragg, 2012, p. 34) in which the observer puts a tally next to pre-set categories depending on when instances of these categories occur. I found this to be too categorical and it does not leave room to observe unexpected uses of tablets. Another approach is a *critical events* technique where the observer looks for specific instances of classroom behaviour, which illustrates some aspect of the teacher's style. The observer writes down what led to the event, what happened, and what the outcome was (Wragg, 2012, p. 64). This approach is relevant to this study in that I could write down a descriptive account of what the teacher and students do during each task in which the tablet is used. Wragg (2012) also states that a good approach to this type of observation is to interview the teacher after the class, which is something that is part of the design of this study. What is missing in this technique is the ability to capture when these incidents happen during the class. It also is less relevant for this study to describe the incidents that took place prior to using tablets, as it is more relevant to describe in detail what happened in the task that used tablets.

Having considered different approaches, I developed an observation instrument broadly adapted from Sears (2012). This instrument has some aspects of the previously mentioned techniques, but overall I found it to be better suited for this study. The observation protocol used by Sears (2012) was adapted from an instrument developed by Horizon Research, Inc. (2011) for the Cases of Reasoning and Proving in Secondary Mathematics Project that focused on proof-related activities. Sears (2012) used this tool to document how teachers use proof tasks during a lesson. Although this study is not specifically about proof tasks, it is about how teachers use mathematical tasks during a lesson where they had tablets as a possible tool.

I adapted Sears' (2012) instrument to document the type of mathematical tasks that tablets were used for by the teachers and students in the class. The instrument also captures the background information about the class, outline of the lesson, and classroom culture. This information was intended to capture as much of the environment as possible in case there was anything that might be relevant to the way tablets were used in the lesson. The observation instrument has designated space to write down detailed lesson observations looking for how the tablet is used, what software was used, frequency of use, and general notes on the use of tablets for mathematical tasks. Next to the observation notes, I also left a column to note when a picture was taken of a tablet or the board at the front of the class. Having a visual representation of what the program on the tablets looked like, or what the board looked like, is to assist with recollecting any details about the use of tablets that may be missed in the written observation. The observations are intended to be recorded objectively without making judgments or conclusions about the classroom interactions. For simplicity of managing data, the observation instrument was kept in an electronic format on my laptop, and each classroom observation was saved as a separate file. A sample of the observation instrument is in Appendix 2.

Conducting Classroom Observations

On arriving to each classroom observation, I met with the teacher prior to the class and ask where they would prefer me to sit and when it would be acceptable for me to walk around and see what students were working on. To capture the classroom setting, it was important for me to be sensitive and not cause any disturbance or discomfort to the teacher or students during my visits. Having spent time with the teachers and visited their classrooms during the school visits described in Section 3.2.1, my presence was hopefully a familiar one, further enhancing the ability to capture the regular flow of the classroom. In this vein, I always asked the teachers for their guidance and input on what to do in the classroom and offered my assistance as needed.

Developing the classroom observation coding scheme

The observation instruments were reviewed and incidents where tablets were used in the classroom were segmented into the separate tasks they were used for. *Tasks* are defined as single activities in which the tablets are being used for a purpose that is designed by the teacher. A task may include playing a mathematical game on tablets, graphing equations using the tablets, or teaching a lesson where the teacher controls the contents projected on the board from their tablet. Activities for which tablets are used only for administrative purposes were not coded in this study. Such activities may include taking attendance or sending emails to other staff. The reason for this exclusion is because only activities that are intended to help the students learn mathematics will be considered.

As I discussed in Section 2.2.2, the part of the preliminary TADT framework used to code the classroom observations was based on Laborde's (2001) framework. As I was applying the preliminary TADT framework in a larger context, not specifically to a mathematics software as Laborde (2001) did, I widened the scope of the framework. I took every use of the tablets and categorised them in this framework, even if they were not specifically used to solve a mathematics problem. I saw every task for which the table was used in the mathematics classroom as potentially having some impact on the way students learned the subject. Possibly the tablets were making it easier to access more mathematics knowledge, such as by using a video tutorial, or it was fundamentally changing how mathematics was understood, such as by using programming to solve problems. The categorisation of instrumental evolution of the task was higher if the tablets were used in ways that the mathematics was either represented or needed to be solved differently because of using a.

3.3.3 Individual Teacher Interviews

Purpose

The aim of the individual teacher interviews was to help understand teachers' use of, and views on, tablets in the teaching of mathematics at an early stage of the study, and the factors they identified as having influenced them. These interviews were an important way of setting a baseline at the early stage of the study in order understand if they developed over time. This also allowed each teacher to express their thoughts privately to me, which may have revealed more information, and possibly different kind of information, than what they expressed in group meetings or post observation interviews.

The interviews with each teacher were conducted after the first group meeting. This caused a slight overlap of the two phases, however it provided an opportunity to have each teacher to give their thoughts on having group meetings. This was intended to help identify any concerns teachers might have had about the group meetings, which was important in minimising intrusions on teachers and for the meetings to be as useful as possible. These were important considerations as the meetings were intended to help teachers develop their practice, and as with the entire design of the study, all aspects were intended to be as minimally intrusive as possible.

These interviews were also meant to contribute to building the context for the rest of the study by helping me become more familiar with each teacher and gain greater understanding of their use of, and views on, tablets and the factors impacting this at the beginning of the study. This data was triangulated with data from the group meetings and post observation interviews, but also captures broader ideas on the topic.

Developing the individual interview questions

The individual teacher interview questions are open-ended and act as guides, as outlined in Table 6. The sub-questions were not meant to all be asked during the interview, rather they constitute possible prompts related to the question in case they were needed. The interview questions were developed in such a way that they address the research questions as much as possible. Question 1 is directly related to the first research question by identifying the teacher's views on using tablets at the start of the project, providing a baseline. Similarly, question 2 relates to the same research question but focuses on the use of tablets. Question 3 is intended to elaborate on the first two questions and provide some clear examples of teacher's use of and views about tablets. Question 4 is intended to gain feedback on the group meeting aspect of the study that allows for some peer collaboration, which is intended for the teachers to share experiences and knowledge of using tablets. Question 5 relates to the second research question in that it aims to identify factors that influence the teacher's views and use of tablets. Combined the questions provide a baseline on teachers' use of and views on tablets at the start of the project, and also allow the teacher to open up about the factors that that inhibit or enable their use of tablets.

Table 6 Individual teacher interview questions

Number	Question
1	How do you feel about using an iPad in teaching mathematics?
1a	Why do you feel that way?
1b	What/who makes you feel that way?
2	How do you use the iPad in your teaching?
2a	What kind of things do you consider when deciding if and/or how to use the iPad in your mathematics lessons?
2b	Why is this a consideration?
3	Have you had any successes and/or challenges in using the tablets in your teaching?
3a	What?
3b	What did that look like?
4	How are you finding the group meetings?
4a	What do you think about them? Why?
4b	Has your teaching or preparation for using an iPad in your teaching
5	Is there anything that you wish you had that might help in the way you use the iPad in your teaching?
5a	What?
5b	Why?
5c	How would it make a difference?
5d	Why do you think you don't have this now?
5e	What would need to change to enable you to have this?

Conducting individual interviews

The interviews were approximately 30 to 40 minutes in length and took place at a time and location in the school chosen by each teacher. Having already met each teacher on several occasions during the school visits described in Section 3.2.1, there was an element of familiarity, and I hope also trust, between the teacher and myself, enabling a more open and honest discussion. The familiarity and comfort that this preparation instilled was also important for the teachers to understand what I was trying to find, which I hope enabled them to reply in a more direct way to my questions. Prior to the interview, teachers were told that I would ask some guiding questions, but that they should also talk about whatever they felt was relevant and important. This was to allow teachers to raise any points related to having tablets in the school, which otherwise the might have been missed. The interviews were audio recorded and transcribed.

Developing the individual interview coding scheme

The coding scheme for the individual teacher interviews are directly aligned to the three key elements of the research questions. The two key elements of research question one are teachers' use of, and views on, tablets. And the third key element is from the second research question, which are the factors that impact teachers' use of, and views on, tablets. These three key elements – *use, views, and factors* – form the basis of the coding scheme used.

Coding teachers' *use* of tablets in teaching mathematics was based on the same framework used to code classroom observations, given in Table 2, the preliminary TADT framework. This framework was revisited after Phase 1 of the study. This revised framework was used to re-code the individual teacher interviews to align the *observed* way teachers use tablets to the way they *report* using tablets in the interviews.

The codes for teachers' *views* about having tablets in mathematics education was adapted from the framework used by Chiu and Churchill (2016), as I described in Section 2.3. Chiu and Churchill (2016) used a Likert-type scale on questionnaires to describe the positive or negative degrees on what teachers felt about each of the three scales of self-efficacy, perceived ease of use, and usefulness. In my study, the teachers were not asked in such direct ways to identify their stance on these scales, rather it was revealed through more organic, but directed, interviews. I identified teachers' replies on each of these three aspects as either a positive or negative view. I make the decision based on the descriptive words and phrases the teachers used to identify their views, whether these words were describing positive or negative views.

The codes for the *factors,* that teachers reported as having an impact on the way they use tablets in their teaching, are outlined in Section 2.4. Although, as outlined in Section 2.3, the literature indicates that there are many different factors that impact teachers' ability and choices of using technology. Some of these factors include the type of curriculum they need to cover, the time they have to prepare the lesson, their level of comfort using the technology, and the training they have received. However, I believe that in order to understand the particular teachers in this study, I need to understand the factors they feel impacts them, and their decisions in using tablets, as they vary greatly from person to person and place to place. Classroom life is synergistic and the many different aspects that impact on the classroom as a whole are interconnected (Brown, 1992). For this reason, I do not presume to identify all factors that may have an impact on the way teachers use tablets. I use the codes that have been outlined in Section 2.4 as part of the preliminary TADT framework, and they act as a starting point. Throughout the study I added a code for *factors* at any point that a teacher mentioned something that had an impact on the way they used tablets in their teaching. These codes were updated after Phase 1 and Phase 2, along with the entire framework. No distinction was made between inhibiting or debilitating factors in the table summarising these codes.

After transcribing the audio recording of each interview, these codes were identified in the transcripts and categorised accordingly. Within each code, the transcript segments were reviewed several times to see if any patterns emerged. Further subcategories were developed as needed to capture greater details relating to the research questions, which was incorporated into the framework after Phase one was complete.

The preliminary analytic framework used for Phase 1 is outlined in Section 2.6. As Knowledge Exchange is only used in the group meetings, that category is not used in this Phase. As this framework is developed throughout the study, the results of Phase 1 will contribute alterations made to the framework used for Phase 2. The evolved coding scheme table is presented in Section 4.2 where the implications of Phase 1 are discussed and the final methods for Phase 2 are described.

3.4 Phase 2 – Evolution of Use

In this section I discuss the three data collection methods used in Phase 2 – classroom observations, post classroom observation interviews, and group meetings – and the way they addressed the research questions. This phase spanned from February to July 2015. Although the methods for Phase 1 and 2 were designed prior to data collection, part of the design was to analyse the results of Phase 1 and use that information to make any needed modifications to Phase 2 prior to collecting the data. This section describes the original design of Phase 2, and the changes that were ultimately made to the final design are outlined in Section 4.2.

3.4.1 Classroom Observations

During the original design of Phase 2, the classroom observations followed the same format as the classroom observations in Phase 1, outlined in Section 3.2.3.

Purpose

As in the classroom observations in Phase 1, the aim was to see how the teachers used tablets in their classroom teaching and how they ask the students to use tablets in the classroom. This data source directly addresses part of research question one by answering the question regarding how, if at all, teachers develop their use of tablets as a teaching tool in their mathematics classroom. The data from these observations was triangulated with individual teacher interviews to understand more deeply what the teachers described as their use of tablets.

Developing the classroom observation instrument

The classroom observation instrument originally intended to be used for this part of the study was the same as the one described in Section 3.2.2. Changes to this instrument were made once the results of Phase 1 were analysed.

Conducting Classroom Observation

As in the classroom observations of Phase 1, I met with the teacher prior to each class and asked where I should sit. In addition to what was described for Phase 1 of the classroom observations in Section 3.2.2, in Phase 2 I also took pictures during the observations. Prior to each class, I confirmed with the teacher that I could take photographs during the lesson. These pictures helped me remember the programs used, and the way they were used, without having to fully rely on my written description. The pictures also allowed me to later see aspects of the programs, or the way they were used, that I may not have noticed and described during the classroom observation. These pictures only focused on the board and tablets, to maintain the anonymity of the people and the school. People were only included when their physical interaction with a tablet or board was relevant to the activity the technology was used for, but in such cases their head and any identifying features of the uniform and school, were covered by a shape. At the end of every class I also showed the teacher the pictures taken to ensure they verbal approval of the images.

Developing the classroom observation coding scheme

The preliminary TADT framework described in Section 3.3.2, was the intended coding scheme. However, the results of Phase 1 observations were considered in order to make any possible alterations to the revised TADT framework and coding of classroom observation data in Phase 2. I will discuss these alterations in Section 4.2.

3.4.2 Post Observation Interviews

Purpose

Directly following every classroom observation, I interviewed the teacher and audio recorded the conversation for transcription. The purpose of these interviews was to gain insight into the teachers' thoughts on their lesson, to both clarify what was observed during the class and understand the teachers' experience and thinking on what, how, and why tablets were used in the way they were during the class. These interviews also allowing the teachers to reflect on the lesson they taught.

These interviews were guided by the following three overarching objectives. First, to capture the immediate feelings that the teachers had about the lesson and what she thought was successful and/or challenging about using tablets. Second, to understand the role and purpose of using tablets in the lesson, and whether that was the way tablets were used. If the intended use differed for the actual use, the teachers were asked to elaborate on what those differences were. Third, to find out what the teachers would change about the way tablets were used in the lesson and what factors could help them make that change.

Prompting the teachers to reflect on their teaching, and use of tablets in their lessons, was an important part of the post observation interviews. Reflection is generally seen as a key way of improving practice (Steeg, 2016) and it may often not be incorporated in many teacher's schedules. Providing teachers with time, and encouraging them, to reflect on their practice was part of the design of this study to help instigating further use and innovation in the way the teachers used the tablets to teach mathematics.

Developing the post-observation interview questions

The questions for the post-observation interview were designed to be short, approximately ten minutes in length, and open-ended. It was important to have short interviews to be as minimally intrusive on teachers' time as possible, and because teachers had limited time following a class. These interviews were not scheduled separately from the classroom observations, when teachers might have spent more time calmly answering the questions, because the raw reaction teachers had about the lesson would have been lost. Also, it would have been difficult for teachers to find time to schedule these interviews.

Table 7 outlines the post-observation interview questions that were used, in the order that they were intended to be asked. I was willing to forgo some of the questions if a teacher wanted to elaborate more on one point or felt that other issues were more important, as long as the conversation was about using tablets in their lesson.

Question 1 was an opening question intending to get the raw reaction of how the teacher felt about the class. In addition to this being a launching pad for the discussion, it was intended to address their views, which is related to research question one. The decision to use the world ‘feel’ rather than ‘view’ was to make the interviews as natural and close to the context of the teacher’s experience as possible, however in describing their feelings their views were likely to be exposed. Questions 2 to 6 all directly refer to teacher’s use of tablets, which is addressing research question one. However, the ways in which the questions were asked were likely to also reveal some of their views. Question 2 focuses on what they see as a successful and question 3 on the challenges of the way tablets were used in the lesson. Question 4 investigates if the way tablets were used was any different from the way the teacher intended them to be used. This question intends to link the difference between what was observed using the observation instrument, and what the teacher actually intended but could not be observed in their class. This was important since the teacher may know how to use tablets in very different ways than what other factors influencing the class dynamic allow. This question also addresses research question two regarding the influencing factors that impact the use of tablets. Question 6 looks to the future, having experienced and possibly learned from the way the tablets ended up being used in the class, what the teacher may consider doing with tablets in the future. This question intends to prompt the teacher to think of new ways to use the tablets and help develop their use. The second part of question 6 asks the teacher what would help them achieve this, which is intended to also push the teachers' thinking about how to develop their use, but also addresses the research question two about the factors influencing teachers use.

Table 7 Post-observation questions

Number	Question
1	How do you feel about the lesson?
2	What was the intended role/purpose of the iPad in this lesson?
3	What was a successful outcome of using the iPad in this lesson?
4	What was challenging about using the tablets in this lesson?
5	How was the use of the iPad different from what you had planned? Why did you change your plan?
6	What would you do differently next time? What would help you do that?

Developing the post-observation interview coding scheme

The post-observation interviews were coded to address the research questions in the same way as the individual teacher interviews, described in Section 3.2.3. These codes for both types of interviews were aligned to enable comparison and triangulation of the data.

The one difference is that in the coding of post-observation interviews, the codes relating to the use of tablets differentiate between *desired use* and *actual use.* This difference is made when a teacher referred to wanting to use tablets in a particular way, but did not do so for some reason.

3.4.3 Group Meetings

Purpose

As outlined in Section 2.5, teachers' development is a critical part of integrating technology into their teaching. Basing it on the literature on Professional Learning Networks, the group meetings are aimed to create a similar environment in which teachers can learn from each other and share their experiences of using tablets to teach mathematics. The following paragraphs outline the three main reasons for having group meetings:

1. The meetings served as group interviews, which have the benefit of allowing participants to elaborate on each other's ideas and experiences, giving depth to the individual interviews.

2. The meetings served as a dedicated time in which teachers could develop their use of tablets in their teaching. Other studies have shown (Dwyer et al., 1990; Laborde, 2001; Ertmer & Ottenbreit-Leftwich, 2010) that without any training or guidance, it takes years for teachers to change and develop their use of new technology in

their teaching. A major aspect of my study is to situate it in a school setting in such a way that would be sustainable for any school to adopt the framework that emerges. For this reason, rather than having specific external training for teachers, the group meetings served as peer training. There are three main reasons for this approach. First, the cost-effective nature of this approach would enable other schools to use this model. Second, it allows schools to tap into the diverse knowledge and experience that teachers already have, and share it among each other. Third, it ensures that the training takes into account the specific context of the school and the specific circumstances and challenges that the teachers face, which is likely to impact the way they use tablets in their teaching.

3. The meetings provide added value to the participating teachers. In the initial informal conversations teachers expressed a desire to learn and develop their use of tablets in their teaching, which is why having time to train was something that they found valuable.

Developing the structure and questions for group meetings

The original plan for the group meetings was to have two one-hour group meetings every half term. The first meeting of the half term would be to discuss the topics being taught that term and learn about the best ways in which the tablets may be helpful in some of those topics. The second meeting of the half term was to reflect as a group on the successes and challenges of using tablets in the previous lessons, and to discuss any lessons learned. In addition to facilitating these meetings, my intention was to look for ideas raised by teachers on how they might use tablets in future lessons and observe how they develop these ideas in the group. One way they may develop ideas is by having one teacher mention a way they would like to use tablets, and other teachers sharing their knowledge of programs that may be useful to that teacher. This type of knowledge sharing would be evidence that the teachers are using the meetings to learn and develop their use of tablets.

During the final negotiation with the teachers and the school regarding their commitment to the study, the school expressed a concern about the time commitment required for these meetings. For this reason, the meetings were reduced to five in total, approximately one every half term, and the lengths were extended to ninety minutes each.

The group meetings each had open-ended questions and a goal, which progressed from general to more specific targets. I developed the questions for the first two meetings at the start of the study, but the questions for subsequent meetings were to be influenced by the progression of the previous meeting. The reason for this was to incorporate information that I gathered from previous group meetings, classroom observations, and interviews. Overall, each meeting incorporated some aspects of reflection on practice and planning for future lessons. The meetings were semi-structured to allow the teachers to expand on aspects that were most important to their own teaching and development.

I expected to see some evolution in the teachers' development and in their practice, which may have occurred in a few different ways. One possibility may have been for the teachers to discuss the use of tablets in ways that increasingly allows students to interact with mathematics in new ways, as defined by the Laborde framework (2001). Another possibility of how the group meetings may have shown evidence of evolution of teachers' practice is if the teachers discussed using a greater variety of programs on the tablets and in ways that they have not used them before in their teaching. Teachers may present these changes to the group and share their knowledge with other teachers in a form of knowledge exchange, or the teachers may develop these ideas together. This was not something that I specified; rather I observed how the possible evolution in practice developed in the meetings.

Conducting the group meetings

The teachers arranged the meeting dates at a time and place in the school that was most convenient for them. I emailed the teachers the goal for each meeting and some points that I would like them to think about before the meeting. Each meeting was audio recorded and later transcribed.

My role as facilitator of the meetings was to set goals, ask questions, allow the conversation to develop, and pick at important points that were raised to understand the teachers as much as possible. I also tried to ensure that all teachers had a voice in the conversation and could express their thoughts. I stated the goals at the start of each meeting, and possibly gently nudged the conversation while it was taking place, which was the extent of my intended interference. I am not suggesting that my presence as the organiser and facilitator of the meeting did not influence the teachers at all. It is possible that the information they provided was influenced by my presence, but I took care to minimise my involvement. If the conversations were about the use of tablets in their teaching I allow conversations to develop. I assumed that the teachers expressed what was most important to them. To capture the most honest data possible, it was important to allow the group meetings to be organic and allow teachers to express their thoughts and feelings.

In the following paragraphs, I outline the guiding questions for each meeting. I did not intend to ask each question, as they would have taken longer than the intended ninety minutes, but they served as guides for the meeting. I was flexible to alter the questions for the meetings following the second meeting based on the outcomes of the previous meeting.

Group Meeting 1

The goal of the meeting was to establish a benchmark of how the teachers were using and thinking about the use of tablets in their teaching.

1. What do you think about the use of iPad in the teaching of mathematics?
2. How do you currently use the iPad in your teaching?

    a. What is typical?
    b. What is the impact on how your students learn mathematics?
3. How do/would you like to use the iPad in your teaching? What are the reasons why you do/do not is the iPad in that way?
4. What are you expecting or anticipating from the group meetings?

Group Meeting 2

The goal of this meeting was to think about concepts that will be taught in the upcoming lessons, which could benefit from the use of tablets. Question 1 was used as a way of reflecting on how tablets were being used and exchanging ideas on what each teacher was doing in the classroom. Question 2 opened the conversation to the challenging topics that the teachers will be teaching in the future and how the iPad could be helpful in teaching those subjects. Question 3 aimed to identify the topics that teacher know to be difficult for students to understand in the upcoming lesson, and questions 4 was intended to nudge the teachers to think about ways in which tablets might be useful in addressing these difficult mathematics topics. Question 5 was intended to push further the conversation by challenging the teachers to think about differentiation and how tablets can be used to address not only difficult mathematical concepts but also how they may address different type of students learning needs.

1. How has your teaching with the iPad been since our last meeting?
    a. Did you have any discussions or new information about using tablets?

   b. Have you made any changes with the way you use tablets in your teaching?
   c. How, if at all, are you using tablets defiantly?
2. What concepts will you be teaching this half term?
3. Which of these mathematical concepts are usually difficult for students to understand and learn?
   a. Why?
   b. What type of students?
4. Could this topic/concept benefit from using an iPad? Why?
5. How could the iPad be most useful to different type of students in understanding mathematics? How could the iPad be used?

Group Meeting 3

This meeting was aimed at continuing to push everyone's thinking about ways in which the tablets could be used in the classroom. Teachers were encouraged to think about ways in which tablets could be used in ways that could characterise the tasks as more complex, as described in Table 2 in Section 3.2.2. For example, if teachers were using tablets mainly for tasks that are categorised as *material* the aim is to discuss ways in which tablets could be used for tasks that have characteristics of *connect* or *enhance*, as described on table 2.

Question 1 was reflecting on recent practice and the question 2 aimed to push for new ideas. Because the previous meeting did not stay on the intended track of questions (more details are given in the Chapter 4 where I present the results) the intention of this meeting was to revisit ideas on how to use the iPad in new ways.

1. Recap last term (success and challenge of using tablets).
2. What might be your next step in developing the way you use the iPad in your teaching and student learning? (If teachers give a new way of using iPad ask following questions)
    a. What is the benefit of doing this?
    b. What may be a drawback to doing this?
    c. How might it help students learn?
    d. How is it different from existing methods you use? ex paper-pencil
    e. What kind of iPad resources is available to do this? What is required of the school network/IT support?
    f. Is there some way that using the iPad would have helped students make conjectures about the mathematics concepts they were learning? Something that would not have been possible using paper pencil methods?
    g. The way iPad had been used was greatly facilitated by the prepared teacher use of the software for interactive presentations and student work. Is there some way you may be able to structure the way students use the iPad program to investigate mathematical concepts?
    h. What topics will you teach this term that might benefit from using the iPad in the way you have described?
    i. What topics/lessons this term would you like to focus on using the iPad?

j. What might the use of the iPad look like in these types of lessons?

Group Meeting 4

The goal of the final meeting was to reflect on the journey taken by each teacher during the study and to discuss ideas for future use. Questions 1 and 2 focused on how the teachers might have changed their use of tablets in their teaching, and discussed whether they saw any impact on the students. This study does not aim to verify if there was an impact on students, rather I refer to the teachers' professional judgment and their expertise on how their students were impacted. Question 3 intended to capture their professional opinion about how tablets could enhance mathematical understanding. Question 4 addressed the upcoming change in the school's policy of tablets. Question 5 and 6 are aimed at what the teachers see as valuable about tablets and the impact they can have on their teaching.

1. What has been the main change in the way you see tablets in teaching maths?
2. Has your students' understanding of maths been enhanced by the use of tablets?
3. What math tasks would be best suited to use the iPad
    a. How would the math task be changed/enhanced by the use of tablets?
4. How will class sets change the way you teach? What will it enable?
5. How would you like to use tablets in the future?
6. What impact did participating in this project have on your teaching?

Developing the group meeting coding scheme

The coding scheme was aligned to the individual teacher interview and post-interview coding scheme described in Sections 3.2.2 and 3.3.2. There is one additional coding category for the group meetings, which is referred to as *Knowledge Exchange*, as outlined in Section 2.4.

The criteria for coding something as a knowledge exchange was when one teacher makes a statement about the way they use, or wish they could use, tablets in their teaching and another teacher added to the conversation either by providing ideas, sharing experiences, or giving instruction on how to use the tables in similar situations. This type of exchange relates to the second research question in that it identifies how the factor of working with colleagues can influence the teachers' considerations in how they use the tables.

3.4.4 Data Analysis

Using the coding schemes that were described in the previous sections for Phase 1 and 2, all the different data sources were analysed individually and across data sets. As stated by Miles and Huberman (1994), "good qualitative data are more likely to lead to serendipitous findings and to new integrations; they help researchers to get beyond initial conceptions and to generate or revise conceptual frameworks" (p. 1) – this is exactly what the iterative process of the two phases in this study are intended to do.

Through this process, the analysis of the data allows for findings to emerge from one set of data that may inform other data sets. As an example, through the individual interviews in Phase 1, teachers may mention qualities they look for in the tasks they design for tablets, that may not be captured in the observation data. These developments are then incorporated in the coding scheme for Phase 2 data. Through this process, the initial TADT framework that emerged from the literature was refined following the analysis of Phase 1 data, and then again following Phase 2 analysis.

In the following paragraphs, I describe the mechanics of how the data was analysed using the coding schemes. I demonstrate this by using an example of an extract from one of the teacher interviews to show how the data coding sheet was constructed. As the TADT framework and the coding was an iterative process, with the framework expanding with each iteration, the example below is one that represents the final analysis process, however the mechanics are the same throughout.

The data was all analysed using Microsoft Excel spreadsheets. In the case of interviews and group meetings, when audio recording was used to gather data, the transcripts of the audio were recorded in Microsoft Word. I chose to use Excel as the software to organise and analyse my data, because I wanted to have the control of a manual system that I can clearly see what code each segment of data has been assigned to. Although some software might be used to code qualitative data, I wanted to keep the data visible and easily controlled for reflection and exploration of data (Morse & Richards, 2002). There are several different types of data used throughout the study, but in the management and analysis I decided to follow time-ordered displays of the data. This method helps in "preserving the historical chronological flow and permitting a good look at what let to what, and when (Miles & Huberman, 1994, p. 110). Along with this time-ordered display, I also managed the data by situating it into the coding structure of the TADT framework.

There are two distinct types of data that I systematically analysed, which are dialogue data and observation data. The dialogue data includes the audio recordings of the individual teacher interviews, the post observation interviews, and the conversation from the group meetings. The observation data includes the spreadsheets on which I wrote my observations of the classroom teaching. The main difference between these data types is that the observation data are my own words that describe how I saw the tablets being used and the dialogue data are what the teachers said about their use of tablets. In both cases, the relevant passages were coded to the TADT framework. I will provide a brief overview of how data was coded for analysis by using an example of an audio extract from a teacher interview.

I transcribed audio recordings into a Word document, as shown in Figure 2, that numbered each line and indicated the time point at which each section was on the recorder. Since both the individual teacher interview and all the post observation interviews were separate for each teacher, I transcribed each teacher's interviews in one running Word document, starting with their individual interview at the start of the study, followed by each of the post observation interviews in chronological order. Group meetings were transcribed separately for each meeting. As I read over the dialogue several times, I highlighted sentences that fit a component of the TADT framework. Figure 2 is an example from one of the individual teacher interviews where the teacher discusses her use of tablets. I present the key questions that I asked in bolded blue text, and the clarifying questions that I ask are enclosed in square brackets.

looking at worksheets there is a greater cognitive demand in the digital worksheets because it uses for example negative numbers where you weren't going to and that becomes a sticking point for certain students, so sometimes I don't. but if I can **I will use a digital worksheet as one example, because they are brilliant for giving students confidence. [why?] They can check them their and then.** Because it gives feedback and some of the better ones allows for partial feedback by which I mean, if you haven't done a question it doesn't mark it as wrong, it only marks the question you've tried. You have two questions in, they are not sure if they are doing it right, they check, brilliant they are right, or I don't know what I'm doing, and I need to ask for help. As opposed to not starting an exercise, which is what they do on a paper exercise, or doing the whole thing and not seeing if they have it right. So potentially a misconception they had at the start continues.

[25:15min] What do you think you would really like to have to improve the use of iPads? This could be anything.

I really just think that it's probably nothing that I can't find myself if I did have the time. It's nothing that anyone could give me, **it's just the time, or for someone to go away and do the research, or just give me thinking time.** Often with my lessons, this works well with a traditional class, but not so well with iPads, a lot of my lessons are plans for short and medium term, but very little long-term

Figure 2 Transcript extract

Taking the qualitative data of the dialogue, I wanted to quantify the aspects related to the TADT framework in order to show the generality of the observations and as a way of "verifying or casting new light on qualitative findings" (Miles & Huberman, 1994, p. 41). To this end, I coded the sentences that corresponded to elements of the TADT framework by highlighting the sentence in the transcript, as shown in Figure 2, and transferred it to the TADT framework in an Excel worksheet as shown in Figure 3 below. I recorded the page and line number for each quote next to it. If more quotes fit into one code, I added lines under the code and expanded the table.

				Page # / Line #	Quote
Use of Tablets (Values in brackets Indicate Desired Use of Tablets)	Instrumental Evolution	Material		4/10	I will use a digital worksheet as one example, because they are brilliant for giving students confidence [why?] They can check them their and then.
		Connect			
		Enhance			
		Extend			
	Characteristics	Efficiency	Resources	4/10	
			Classroom management		
			Instant formative		
			Teacher focus		
			Increased exposure to		
			Speedy access		
		Engagement	Instant feedback	4/10	
			Creative		
			Student as teacher		
			Visually enticing		
		Focus	Individualised learning		
			Customisable		
			Teacher multiplied		
			Visualisation		
			Skills focus		
	Views		Tablet self-efficacy		
			(positive/negative)		
			Perceived ease of use		
			(positive/negative)		
			Perceived usefulness		
			(positive/negative)		
	Factors		Time	4/21	it's just the time, or for someone to go away and do the research, or just give me thinking time.
			Resources		
			Technical issues		
			Mathematics		
			Support		
			Management		
			Classroom management		
	Knowledge Exchange		Conversations in which help was offered or knowledge was exchanged		

Figure 3 Coding transcript extracts

In this example, I highlighted two quotes to demonstrate the different coding used for the use of tablets and other aspects of the framework. The first quote highlighted with yellow in Figure 3 is from the teacher describing how she uses tablets for digital worksheets. This type of use corelates to a material aspect of the Instrumental Evaluation because the only difference between a paper worksheet and a digital worksheet is the material aspect of it being on a tablet. Once I identified how to code the quote in terms of Instrumental

Evaluation, I also needed to consider what characteristics this task has. As described in more detail in Section 4.3.3, each task for which tablets are used can be identified in one category of Instrumental Evolution but that task fits one or more codes under Characteristics. The teacher mentioned in the quote that she likes the digital worksheets because students can check their answer instantly. This corresponds to a code of Instant Feedback under Engagement. Because the digital worksheet also saves the resource of either printing worksheets with the answers, or providing textbooks, which teachers have said earlier that they are not available at this school, the other characteristic that this task has can be categorised as Resources under the Efficiency category.

The second quote highlighted in green in Figures 3 captures the teacher discussing how the lack of time inhibits her ability to use tablets as she would have liked. She talks about not having sufficient time to find the right resources and have the time to plan ahead. This quote speaks to time being a factor in the way she is able to use tablets, and for this reason was coded under the Time code within the Factors portion of the framework.

Extracting quotes in this way allowed me to code them in the framework and track where they came from. After all the data was coded, with the table expanding as I placed more quotes under each code, I counted the number of occurrences under each quote. These occurrences corresponded to the frequencies reported in the tables shown in the Results of the thesis. The process was the same for the post observation interviews, however in those interviews, since I already observed how the tablets were used, I filled in the Views and

Factors portion of the framework. In this way, as excerpts of the transcripts, and notes form the observations, were extracted and slotted into the framework, the framework expanded. Reading over the quotes that were assigned to each code allowed for easy reflection. In time, these excerpts were simply counted and collapsed into numerical representation of how many were in each code.

3.5 Ethical Considerations

According to Sieber (1992), "[t]he ethical researcher creates a mutually respectful, win-win relationship with the research population; this is a relationship in which subjects are pleased to participate candidly, and the community at large regards the conclusions as constructive" (p. 3). In this study, I took great care in creating such a win-win situation as described by Sieber. I first carefully gained some understanding of the working environment, constraints, and desires of the teachers in how they used tablets in their teaching by visiting the school, observing lessons and having conversations with teachers. I designed the research to incorporate their existing workflows and address the questions they hoped to answer through this study. I aimed to align the objectives and methods with those of the teachers' as well as the school's. This is not to say that my presence did not burden the school and teachers in some way. As much as I tried to be flexible and accommodating, participating in the study did take time away from the teachers. The time and effort required to participate in the study, regardless how small, was adding to the teachers' already extremely busy work schedule.

Tickle (2002, p. 44) indicates that conventionally in qualitative research the conditions under which consent is negotiated for access are those of openness, anonymity or confidentiality. My approach was one of cautious observer and progressively building a relationship with the teachers and administration of the school. In addition, I was cautious to gain informed consent from the participants, which are the teachers, and avoid first going through what Homan (2002, p. 24) describes as the gatekeepers, in this case the principle or head of department, who might assume the entitlement to give consent on behalf of the teachers. To avoid having teachers feeling the pressure of authority giving consent for this project, I first approached the teachers and built a relationship with them. Throughout the recruitment process and the span of the study, I regularly reminded the teachers about my role, the way I will use their information, and how I intended to protect their identity. I was also clear about the limits of what I would be able to do, particularly as the sample size was small and the characteristics of the school may identify who the teachers are. Although I made every effort to have full disclosure and clear lines of communication to ensure compliance with ethical guidelines, there are still limits to this process. I recognise that, because I spent a significant amount of time with the teachers over one year, the bond that formed among us may have stopped the teachers from considering the possible consequences of providing certain type of information. This is also the strength of building strong relationship, to get in-depth data, but I did take care to always be transparent.

Pring (2002, p. 122) outlines the following four rules that the researcher should follow for honorably conducting research, which are further explained below:

1. Set out clearly the kinds of knowledge that is required;
2. Give access both to the data and to the conclusions drawn from that data;
3. Provided for the right to reply from those who have participated in the research;
4. Consider the possible ways in which research findings may be used.

First, the researcher should set out clearly the kinds of knowledge that is required. Those being researched have the right to know beforehand the general terms of what the researchers will be looking for and for what purpose. I did this by gradually building a relationship with the school and teachers, explained my intentions for the study and asked for their input. These conversations were not only to clarify what I was looking for, but also to understand what should be incorporated in the research.

Second, the researcher should give access both to the data and to the conclusions drawn from that data, enabling the possibility of both being questioned. Throughout the study, I asked teachers for their consent in recording the interviews and asked them to tell me at any point when they would like me to stop recording. I also showed the teachers any pictures I took during the class and deleted any that the teacher did not want me to have.

Third, Pring outlines that opportunity should be provided for the right to reply from those who have participated in the research but who may believe that alternative conclusions could be supported by the data. On completing my thesis, I will provide a copy to the teachers involved and will welcome feedback.

Fourth, the researcher should take into account the possible ways in which research findings may be used. My aim is to have my research used by other schools to incorporate a peer networked learning environment for their teachers, or for teachers to be inspired by possible ways of using tablets in the teaching of mathematics. I also hope that the framework developed in this study will be useful to other researchers in the field and policy makers who intend to introduce mobile technologies in schools. However, I am aware that the study may also be used by the administration, of the school in which it is situated, to make judgments on the way the teachers use tablets. This is not my intention and I informed the school that I would not share any data with them. The possibility of negative action being taken on the teachers is relatively low as the time from their participation to the final thesis being published is quite long. I am also cautious to not write the thesis so that it may be interpreted as making any judgments about teachers in this study. This is neither the intention nor purpose of this study.

Having spent a considerable amount of time with the teachers in this study, it was inevitable that I developed relationships with each of them. Getting to know them as people and colleagues, it is possibly that I developed biases that could impact the way I interpret my data. Throughout this study, and the writing of the thesis, I try to always be aware of my possible biases and to be critical of all aspects of my analysis and presentation of the data.

I recognise that regardless how careful I was ensuring that I treated the teachers ethically, their involvement in the study may have impacted them in ways that I could not anticipate or prevent. For example, through their participation they may have formed new relationships with their colleagues and prompted experimentation of how they used their tablets in their teaching, which may have changed their teaching in unexpected ways. Their participation might have also singled them out among other teachers, who did not participate in the study. These other teachers may have developed bias (positive or negative) about them because they chose to take part in this study. These biases may change the working relationship among the teachers in some way.

Throughout the collection of data in this study I was guided by the ideas that the relationship between the teachers and myself must be a win-win for the research, the teachers, the school, and ultimately the students. I hope that this was achieved to the best of my ability and to the satisfaction of the school and teachers involved. My Central University Research Ethics Committee (CUREC) form (see Appendix 5) was approved on 6^{th} November 2014.

4

RESULTS & DISCUSSION

4.1 Introduction

In this chapter, I discuss the results of the data analysed in my study. In the Section 4.2 I discuss the results of each of the methods used in Phase 1 of the study. In Section 4.3 I discuss the implications that Phase 1 results had on Phase 2 of my study and the changes that I made to the original methods. In Section 4.4, I discuss the results of each of the methods used to collect data in Phase 2. In Section 4.5 I discuss the implications of Phase 2 and present the final TADT framework. In Section 4.6 I write a portrait of one of the teachers in this study to give depth of understanding of what the teacher experience is like. Finally, in Section 4.7 I present all of the data gathered in the study on the final TADT framework and analyse the results across the methods, as well as reflecting on the tablet program overall.

4.2 Phase 1 – Setting the Foundation

As in the Methodology chapter, this section is organised into the following three sub-sections that align with the three distinct aspects of Phase 1: school visits, classroom observations, and individual teacher interviews.

4.2.1 Schools Visits

Visits to the school and the teachers took place between July 2014 and February 2015. Intentionally, this was a slow and gradual process of visiting the schools and gradually getting to know the teachers better over the months. As the purpose of this aspect of Phase 1 was to understand the setting in which the study was situated, and to build strong relationships with the mathematics teachers, the goal was to take the time to immerse myself in the environment and become familiar with the school and the teachers. As explained previously, this was important to situate my study in a naturalistic school setting. Table 8 summarises the key outcomes of visiting the school and how they assisted my study. To get a more descriptive sense for the environment and the process of visiting the school, a chronological account of this time, and my experiences, are detailed in Appendix 1.

Table 8 Key outcomes of school visits

Process of building relationships	Key outcomes that contributed to shaping study
Ongoing discussions with two key stakeholders (director of digital technology and the mathematics teacher identified as a technology champion)	Gained insight into history of how the tablets were implemented into the school
	Gained insight into key successes and challenges that tablets have posed
	Received feedback on ideas relating to how I was developing my study
	Introduced to other teachers in mathematics department
	Met the teachers and observe their classes - these meetings were organised by the stakeholders
Visiting school	Gained familiarity with the environment, which helped me to integrate and feel comfortable in the school
	Saw how teachers informally shared information about tablets in the staffroom
	Saw how students used tablets in the halls between classes
Attending school event designed to demonstrate the use of the tablets to the parents	Heard the way the Head Teacher described the tablet program to parents
	Heard the questions, comments, and concerns raised by parents regarding the tablet program
	Saw demonstrations by different subject teachers on how they used tablets in class
Talking to teachers	Gained insight into personal experiences, views and use of tablets from a variety of mathematics teachers
	Discussed my study with the teachers and gained feedback on the design, enabling me to design the study in a way that fit more naturally into the setting and also provided participating teachers added value for taking part in the study
	Built relationships gradually with teachers, which was a key recruitment strategy in the study
Observing classes	Gained familiarity with the classroom environment and the flow of mathematics lessons
	Gained a general understanding of some of the ways tablets were being used in the mathematics classroom
	Became a familiar presence to the students and teachers, reducing some of the disruptive element my presence may have posed in future classroom observations
	Became comfortable with where I should sit and how I should interact in the classroom to minimise the intrusion I may have posed

In discussions with the two key stakeholders, as shown in Table 8, I came to understand the many technical challenges that had to be overcome at the start of the tablet programme. The overload on the school networked initially made it impossible for two classes to use the internet on the tablets, causing significant frustration among the teachers. However, many of these challenges were getting solved and a lot of the work these two stakeholders had was helping teachers use the tablets in their classes and find resources for them.

When I attended the school event held to demonstrate to parents how the tablets were used in the classrooms, I heard parents both praising what their children were doing with the tablets at home but also questioning how useful they were for learning. These conversations showed the bigger environment in which the teachers were situated, demonstrating some of the pressures and influences on the way teachers incorporate tablets into their teaching.

As I talked to many teachers throughout these visits, I started to get a glimpse of how they described their use of, and views on, tablets in teaching. I also heard some of the factors influencing them. This meant that by the time I interviewed the teachers participating in this study, many of the things they said were not a complete surprise to me. Having this foundation allowed me to easily ask follow-up questions that helped to add depth to the interviews.

My visits in mathematics classroom gave me a similar foundation in having a glimpse at how the tablets were being used, preparing me for the classroom observations that I conducted later. I saw that the tablets were generally used for short periods in the class for specific activities. It also appeared that some teachers had already developed a routine with their students where they knew by one or two words when it was acceptable to use tablets and when it was time to put them away. These visits also gave me a sense for how the atmosphere in a class changed when students were able to use tablets. The noise level and excitement usually escalated and teachers had a variety of ways of manging this.

My slow assimilation through the school visits enabled me to capture information in my study that minimised any obstructions that may have been caused by my presence, allowing me to obtain data that was as close to the reality of the school as possible.

4.2.2 Classroom Observations

As I described in Section 3.2.2 of the Methodology chapter, the aim of the classroom observations in Phase 1 was to gain a general understanding of the way tablets were used in the classroom, providing a foundation for more detailed classroom observations conducted in Phase 2 of the study. Part of this process was testing the observation instrument and becoming comfortable observing lessons, as well as for the teachers and students to be comfortable with my presence. The following are the results of these observations.

A few minutes prior to each lesson, I met the teacher outside of the classroom and asked them where I should be seated. All the teachers were very flexible and happy to have me sit anywhere I liked. I usually chose a spot towards the back of the classroom, but close enough to some of the students so that I could overhear their conversations. The classrooms were mostly setup with rows of desk and a white board at the front of the classroom with a projector suspended from the ceiling and directed towards the board. There were posters and artwork limiting the walls, with boxes of supplies on the shelves around the room. I was told that the school was no longer using textbooks, so there were many handouts and notebooks that were occasionally passed out to the students.

The teacher usually gave me a quick idea of what would be taking place during that lesson, and I always offered to help in whatever way I could throughout the lesson. Occasionally I did help by handing out notebooks or walking around the class to assist students who were having difficulty with the work. As the students arrived they generally were quick to take their seats. As I stood at the back of the class I felt almost invisible. I thought that the pilot classes would also serve as a way for students to get to know me and get used to my presence in their class. As I learned, the school had a culture of having administration observe classes, which is likely why it was hardly noticed that I was in the classroom. I was not introduced by the teacher, nor were any of the students questioning why I was there.

Having my computer in my lap, I sat and observed the mathematics class. I took notes on my computer using the observation instrument outlined in Appendix 2. The observation instrument captured a lot of information about the classroom atmosphere and what was taking place during the class. It was quite challenging to focus on all these different aspects of the classroom and capture all the information. As I was trying to do this, I noticed that it was hard to immerse myself in the lessons, which prevented me from observing the details of how the tablets were being used. Much of the detailed information being captured by the observation instrument did not directly relate to the research questions, which is one of the reasons why the instrument had to be modified, as I outline in Section 4.2. I found it would have been more useful to capture free hand notes on what was happening in the classroom when tablets were being used, and not have to organise these experiences into set categories outlined in the observation instrument. I also found that it was challenging to describe the program being used with tablets and the way in which tablets were held by the students. Pictures of tablets would be more useful to instantly capture the visual aspects of the program and how tablets were physically held. These shortcomings were addressed in Phase 2.

I found that tablets were used in a variety of ways. This included tasks such as starter games at the beginning of class that helped students practice their arithmetic. They were also used to project information and pictures on the whiteboard that the teacher prepared in advance, this included such things as instructions for the lesson or notes for the students write down. Quick Response (QR) codes were also projected on the whiteboard, which the students scanned with the camera on their tablet, as shown in Figure 2, and that instantly retrieved worksheets on their tablet, or brought up a website, that was being used in the lesson. Tablets were also used for quick formative evaluations of what was being taught in the lesson, using programs such as Socrative. This program allowed teachers to create a short quiz that students could access on their tablets and the results were instantly available to the teacher. By posting two or three questions in a Socrative quiz that each student answered on their tablet, the teacher was instantly able to see who understood the problems and who did not. This seemed to allow the teacher to decide whether to review the concept to the entire class or approach individual students who needed help. This was also later confirmed in what the teachers described in post observation interviews, which will be synthesised in Section 4.4 once all of the analysis is completed. If only a few students got the questions wrong the teacher would decide to go to those students directly and help them understand the concepts. These are a few examples, but they demonstrate the diverse ways in which teachers used tablets.

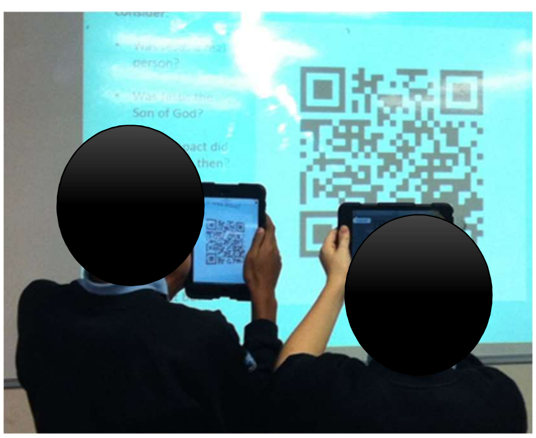

Figure 4 Using QR codes in class

When I considered how these tasks would fit into the preliminary TADT framework, where the categories of the use of tablets is referred to as instrument evolution (influenced by the Laborde (2001) framework) as outlined in Section 2.6, I did not see tasks that went beyond the first or second level of categorisation. I was focused on understanding how these tasks enabled mathematical understanding and which category of the framework did they fit into, but I did not see any indication that went beyond the first, or at most the second level of categorisation. However, as I observed the role that the tasks had in the classroom, I started to see something else. It seemed that the tasks for which the teachers used the tablets served different purposes that aided the mathematical learning. The teachers were using tablets to organise the lessons in ways that to me seemed like they allowed for more time to learn the mathematics and to engage students and focus their attention. This reasoning was later also given by the teachers when they were interviewed. One example of this was the use of quick response (QR) codes as shown in Figure 2. Several teachers expressed that they valued the quick and easy access these codes offered for students to open electronic resources. Without the use of these codes, the teachers would have either had to email the link or provide the web address for students to type in. Although these may seem equally easy, as professionals who are in the classroom every day, the teachers said that according to their experience, any additional step such as opening email, or typing in the name of a link, provides hurdles for students where several minutes of classroom time would be lost due to the disruptions caused by having an extra step for the students. This is valuable time that is taken out of a lesson that could be better spent on learning. This information helped me realise that there was something missing in the codes when I intended to categorise the tasks. Instrumental evolution categories are increasingly more complex way of using technology, however I saw that the teachers found the use of the tablets valuable even when they were used in ways that Laborde saw as the most basic use of technology. Although there is great value in viewing tasks in terms of Instrumental Evolution categories in the preliminary TADT framework, it is not a full picture of what is considered by the professional teachers are valuable in teaching and learning. In Section 4.2 I will discuss further how I incorporated these observations in Phase 2 of the project.

4.2.3 Individual teacher interviews

The individual teacher interview data is summarised in Table 9, and to provide more context to the values on the table, each teacher's interview is summarised in the subsections below. As stated earlier, an individual task that the teacher mentions using the tablet for can only be categorised once under Instrumental Evolution in Table 9. However, teacher's views and factors they discus may be categorised under several categories of views and factors. Each teacher summary first identifies the ways the teacher described their use of tablets at the start of this project, then the teacher's initial views about using tablets in teaching, and finally the factors the teacher mentioned as influencing their use of, and views on, tablets. As the interviews are the teachers' reflections on the tablets which were introduced a year prior to this interview, the references to the way they are used also spans over that time. For this reason, these interviews provide a glimpse into the journey the teacher took with the tablets since they were introduced in the school until the start of the project, and it is not simply a reflection of where the teachers are at the start of the project.

Table 9 Individual teacher interview data frequencies

			Jordan	Sam	Alex	Charlie
Use of Tablets	Instrumental Evolution	Material	5	5	4	1
		Connect				
		Enhance				
		Extend				
	Views	Tablet self-efficacy (positive/negative)	1		1/3	2
		Perceived ease of use (positive/negative)		1	1	
		Perceived usefulness (positive/negative)	1	1 / 1	1 / 2	1
	Factors	Time	1	1	2	3
		Resources	1	2	1	2
		Technical issues		1	1	
		Support				
		Classroom management	4	3	3	1

The individual teacher interviews provided the first insight into how each teacher self-reported using tablets in their teaching, how they viewed the use of tablets in teaching mathematics, and the factors that impacted their practice. Although the teachers vary in age, experience, and comfort in using tablets in teaching mathematics, they do share some similarities on their use of, and view on, tablets in their teaching and the factors that influence them.

Regarding the initial use of tablets mentioned by the teachers, it was Jordan and Sam who described the most number of tasks, at five each, as can be seen in Table 9 above. While all the teachers only described tasks that could be categorised as material in nature, the tasks they described did have other elements that they seemed to value. They valued ways could mainly be categorised as having characteristics of efficiency or engagement. The majority were related to efficiency in that they minimised resources needed.

In terms of the teachers' views, there were more negative views expressed than positive, although no teacher expressed only positive or only negative views. The teachers expressed that they joined the project because they hoped to improve their use of tablets, as they imagined that they could be very useful. However, in their actual use of the tablets they were mostly negative regarding the usefulness of tablets. Perceived ease of use of the tablets also only had negative views, although it is possible that people did not talk about what was easy about using tablets, only what they found difficult. The teachers were particularly critical of the challenges they faced when trying to find programs that would enhance the way they taught mathematics. They were particularly frustrated at the lack of curated quality mathematics resources.

In terms of factors, each teacher mentioned many different factors that impacts their use of and views on tablets. Classroom management was the most cited factor that impacts use of tablets. Teachers lamented about the challenges they faced in managing the distractions and disruptions caused by the tablets during the lesson. This is a great concern for the teachers and managing the behaviour of students is a big issue. Teachers talked about students feeling like they have too much ownership of the device and they like to use it to take pictures, play games, or needed to constantly be touching their tablet during class. Time was the second most mentioned factor, with every teacher mentioning the extremely minimal time they had to develop lessons that use the tablet and find the right resources to use. The way their teaching schedules were organised, and the demands of the job, meant that finding and creating lessons using the tablets had to be done in addition to their workload and often on their own time.

Teacher #1 - Jordan

Jordan had less than five years of experience as a mathematics teacher and was very enthusiastic about the use of technology both in her personal life as well as in teaching. In such a short career, Jordan become involved in supporting the mathematics teachers in using their tablets for teaching and developing resources for them. Although Jordan said she enjoys using technology, and saw the potential in teaching mathematics, Jordan reported finding it challenging to find useful resources and have the opportunity to learn from colleagues about successful pedagogical approaches. Jordan said that she saw the opportunity of participating in this study as a chance to learn to use tablets more frequently and effectively in teaching mathematics.

Initial Use of Tablets in Teaching Practice

There were many changes in the way Jordan reported using tablets in her classroom since they were first introduced to the school. In Table 9 it can be seen that Jordan discussed five different ways of using tablets. All the ways in which she used tablets would be considered material form of instrumental evolution, but there were diverse programs and methods in which she used them. It appeared to me that Jordan was not using the tablets for the sake of just using the technology, she seemed to have specific intentions for learning that she wanted to achieve. Jordan said that her judgement for how and when to use tablets was "the same initial thoughts as with any other resource, which is whether the task is achieving what I want the students to be achieving."

At the start of this project Jordan recalled that when tablets were first introduced to the school, she used them mainly as a culminating task. She would ask students to create videos, iBooks or presentation summarising their learning. Before having tablets, Jordan said she would have had the students do similar activities by creating a postcard or a poster. At the start of this project Jordan said she was using tablets in several different ways. Wherever possible she tried to replace paper worksheets by electronic worksheets, provided they achieve the same learning objectives. She believed the electronic worksheets were an excellent way of giving students confidence because they provided instant feedback to the students about their work, allowing them to proceed to the next question knowing that they are correct. Another benefit Jordan saw was that some electronic worksheets, such as Mangahigh, changed the level of difficulty of the next question depending on how previous questions were answered, making the learning process individual to each student's ability. Jordan felt that this individualised worksheet, as it was adjusting the following mathematics questions depending on the students' earlier performance, was an effective was of differentiating the lesson for each student. This was certainly different from what could be offered by a textbook with answers in the back.

> One of the ways that iPads can be useful in teaching is that they can massively increase effective differentiation. You can actually meet the needs of the child and challenge the child in a suitable way, and they can also check if they are getting it right, they get a confidence boost.

Jordan mentioned one of the main barriers to mathematics was when a student did not know if they were doing the work correctly and then they stopped. If they have the capacity to check their work as they go along, Jordan said that she found the students to be more engaged. This was one way she saw tablets helping students progress in their understanding of mathematics. Jordan acknowledged that this could certainly be replaced by having an answer sheet or a book with answers in them, however the school does not use textbooks and photocopying answer sheets for everyone is something Jordan sees as an unreasonable amount of photocopies.

Overall, Jordan enjoyed using tablets and was enthusiastically looking for new ways of incorporating them into her teaching. She had ideas and plans on what she could do next, as well some ideas on how to initiate more collaboration among her colleagues.

Initial Views of Tablets in Teaching Practice

Jordan was a young and enthusiastic user of technology, readily trying out new tools. As can be seen on Table 7 she has a positive tablet self-efficacy, although she only once made a comment relating to self-efficacy, which was the following.

> In terms of proficiency I'm not really concerned. I can do everything that I want to do and I don't have a lot of the hang-ups that some staff have about being worried that it would work. Usually I will give it a go and usually I will find a second way of achieving something, even if I can't achieve it one-way.

This ease with technology did not necessarily instantly transfer to the use of technology in her classroom. Technical challenges were a significant problem and factor that has been raised on many occasions during this project. Jordan indicated that although these technical issues did put her off slightly from wanting to use tablets when they were first introduced, and this resulted in a negative view about the usefulness of the technology.

Initial Factors Impacting the Views and Use of Tablets

During this initial interview, Jordan talked about three key factors that inhibited her use of tablets in the classroom. These were time, resources and classroom management, each of which prevented Jordan from using the tablets as she would have liked.

As outlined above, Jordan wanted saw great value in tablets providing individualised learning. Although she was incorporating some individualised learning with digital worksheets, but it was not to the extent she could imagine. However, it was the lack to time that she said really prevented her from implementing that, as she described.

> I can happily create traditional resources that are read on an iPad, such as a PDF, so that is still a step up from just giving a worksheet, but it's still not interactive. So, in terms of creating resources, that is something that would be useful, but I don't have the capacity at the moment to create an interactive resource that is built for an iPad.

Jordan discussed the distraction that tablets presented. She reported that "there is a surprising propensity for students to be constantly on. There is a temptation to be constantly fiddling with it and if someone is talking to just be looking at the screen." She said that she did not see this distraction easing over the year that the students have had tablets. However, she feels that if the school had a common policy on how to use tablets, it would be more helpful. She mentioned that it would be important for all classes to use tablets, so that it was not a novelty when the students come to mathematics class. She tried to manage these distractions by clearly telling students to put tablets face down when they are not being used, but this wasn't always effective.

Jordan also outlined the challenges that the management of the school creates by not having a unified policy for the use of tablets across all subjects. She said that this lack of unity created classroom management concerns because the student were not used to always using the table. up her reasons for this frustration in the following way.

> In maths they use it all the time, but then if they go to other subjects where it's not used, or they go to other subjects where it is used and it's not used in Maths, they get fidgety because well 'I'm using it in this but not in this', there is no common approach in how to use it or not use iPads.

Jordan feels confident that she will be able to improve her use of tablets as a learning tool, where she can use the tablets in new ways that help students better understand and learn mathematics. However, she said that she needed time to plan, find resources, and just time to think about her own practice.

Teacher #2 - Sam

Sam had less than five years of mathematics teaching experience and was enthusiastic to be involved in this project. She saw this as a way of learning more about how to use tablets in teaching and as a way of finding time to collaborate with colleagues on this topic. Sam used technology with ease and saw the potential for the impact that it could have in the classroom. Although she did not have as much time as she would have liked to developing ways to use it, she still used tablets regularly in her teaching and has even given ideas and resources to other teachers. The following are some of the key points that Sam talked about during the individual interview.

Initial Use of Tablets in Teaching Practice

Like Jordan, Sam described five different ways of using tablets in her classes, all of which can be categorised as being material in terms of instrumental evolution. She used tablets for quizzes to get instant feedback, as a way of plotting graphs, and she found some good websites that she used as a starter exercise. She said that the students enjoyed these activities as well as the Quick Response (QR) codes she used to direct them to the site. Sam said that even the QR codes provided an element of excitement, as students were curious to see where it would lead them, as well as efficiency since the students could quickly access the digital resource it led to. Overall, Sam felt that using tablets engaged her students, as they did not seem to notice how long quizzes and worksheets were, possibly because they can be more colourful and interactive than paper versions.

Sam said that her goal for participating in this project was to do a bit more with the tablets after every group meeting and further build her skills. In developing her practice Sam had a vision of what she would like to see tablets achieve, but has not yet found a program to accomplish that.

> In an ideal world it would be nice to teach them a new concept and have the program prompt them in some way that they would want to explore concepts further on their own.

Sam could visualise what she wanted the program to do and the impact she wanted this to have on her students, which was for them to explore concepts on their own. Sam seemed to not only believe that there were ways of using tablets that she was not aware of, but she also had ideas of what she wanted to accomplish with the tablets. However, in the year that the tablets had already been introduced to the school, she has not been able to find a way to use the tablets to help students explore concepts further on their own. As described earlier, the way she described using the tablets could only be categorised as material in nature, and the ways in which she would like to use the tablets, but is unable to, could possibly materialise in tasks that could be categorised as more complex. After a year of using the tablet, receiving the training and support that the school offered, and having the interest to improve her teaching with tablets, as indicated by her desire to participate in this study, there may be other factors preventing her to use tablets as she would like.

In terms of what Sam considered when planning the tablet resources for her class, it was mainly about how easy it was for the children to access. Some resources need to be downloaded or used a password, which makes the logistics challenging. Also, Sam makes sure that the program will be useful, so that she can see that her students' understanding of mathematics is progressing.

Initial Views of Tablets in Teaching Practice

Sam sees tablets as being useful in the mathematics classroom, but not easy to use, as they can cause difficulties. At the start of this project she saw the role of technology as a way to eliminate a lot of the physical tools, such as protractors and calculators, needed in the mathematics classroom, but she didn't find any program to do that. Although she could imagine it being much more useful, she has not found anything specifically mathematics related other than plotting graphs. This reflects the negative perception she has of the usefulness of tablets on the Table 7.

A big success that Sam recalled early on when tablets were introduced to the school, was that it created a smooth routine where students knew what they had to do at the start of the class. There was also the ease of not having to unpack and repack resources such as colour pens, paper, and manipulatives when they were incorporated in the tablets. This ease of not having to handle physical resources, such as paper and pens, helps with classroom management concerns, however it does not acknowledge the value of using physical. There are important motor and special skills that are developed by using physical manipulatives or tools like pens and protractors. However, in these reflections Sam seemed to be focused on her most pressing concerns in the use of tablets to teach mathematics, and one of these concerns was classroom management.

Initial Factors Impacting the Views and Use of Tablets

Like the other teachers, Sam listed many factors that impacted her use of tablets in her teaching, having a total of seven different factors. The three main factors that Sam said contribute to the challenges of using tablets in her teaching was the technical failure, students being distracted, and the lack of resources for teaching mathematics. Sam said that, although she taught high achieving students who are well behaved, the students still got distracted by wanting to touch and play with tablets. However, at the same time Sam said that she also found the students were more engaged when tablets were used in the lesson, which she has not seen diminish since they were introduced.

One of the things that Sam said would help her improve her practice was the opportunity to share and learn from her colleagues. Sam felt that it would be useful to learn how her colleagues dealt with difficult classroom management situations caused by the tablets as well as to get tips on the tools they found useful in their lessons. Unfortunately, she said that the nature of the school schedule does not give teachers the opportunity to share their learning, which she hopes the group meetings will provide.

One frustration that Sam expressed was that lack of mathematics apps that she can use. “There is nothing specifically maths related that would help. It would be nice to have an app that would be really great in doing these things maths, but we as a school we haven’t found those things.” It sounded like a feeling of isolation, that mathematics was somehow different from other subjects and needed particular type of apps.

Teacher #3 – Alex

Alex had less than five years of teaching experience. Alex was an enthusiastic user of technology and has actually experienced first-hand the power it can have on learning. She said that she was diagnosed with dyslexia as a child and was given a laptop in elementary school as a way of helping overcome her learning challenges. This was enormously helpful and therefore Alex hoped to leverage the power that tablets may have in helping students learn mathematics. Although Alex was very enthusiastic, she had expressed frustration at not being able to research and find good resources because of the challenge that dyslexia posed on her research skills. Alex hoped that this project would help to find the right resources and also collaborate with colleagues.

Initial Use of Tablets in Teaching Practice

Before the start of this project Alex said she really was designing very traditional lessons, which did not involve any technology. Once the lesson was designed, she would quickly consider if there was any part of the lessons she could use the tablets for. The four ways Alex described using tablets was for having students send work through email, as a white board for students to raise in class and show answers, and for students to take pictures. She said that because the information on the Internet was not well curated, it was particularly difficult for her to research good ways of using tablets. Alex recognised that there was much greater potential for tablets but was not sure how to use them and quickly lost confidence.

> I had the view that there were other people in this department doing amazing things and because I had stopped using it, because there was just too much else going on, I lost confidence and felt that I was so behind these other people that I'll never catch up with them.

Although Alex was hardly using tablets at this point, she said that she saw the potential power of using them to make differentiation easier and increase engagement, as students could be in control of their learning. She did not see tablets as replacing the teacher but rather as a multiplication factor on the teacher, as she might be able to more effectively direct her energy. Using tablets in such ways was what Alex aspired to do in the future.

Initial Views of Tablets in Teaching Practice

Although Alex has grown up with technology and experienced the benefits that a computer can have on her learning, she had significant frustrations about the use of technology as a teacher. She had great difficulty using the tablets with her own students and finding good resources. This conflict of not realising the benefits of technology as a teacher, that she experienced as a student, possibly contributed to the fact that Alex was the teacher with the most negative views, by discussing six separate negative views during the interview.

> I feel frustrated in some ways, because I feel the way the iPad is designed is very close ended. It is designed by someone else and not necessarily for your purpose or it is used very simplistically more for communication. I think there is a lot of potential, but teachers need a way of controlling that potential, like being able to design things.

Alex seemed to feel strongly that the key to being able to use the tablets is to have teachers involved in the design, as a way of ensuring that the program would be useful to their teaching. This seems to imply that Alex has many ideas about the way she would like to use the tablets in her teaching, but somehow, she is not able to find the program she needs. There is evidence that co-designing lessons and technologies used in the classroom with teachers, is important for successful design (Fishman et al., 2004). However, with thousands of mathematics applications that are available for use on the tablets, it may be that there are other factors that are also impacting Alex's ability to find the programs that would enable her to use the tablets in the way she would like.

At the start of this project, Alex said that she hardly used tablets in her teaching. She saw the potential for them and felt that they could be a powerful way of diagnosing the type of problems that students needed to practice and scaffolding the work for them. She saw the potential for individualised support and differentiation. However, Alex emphasised the need for teachers to be well trained and proficient in this process. She saw the teachers as the weak link, that if they are not able to harness the power of these personal computers by developing and extracting the right material, the benefits to the students will simply not exist. Alex hoped to build her skills and find a way to customise the technology for her need.

Initial Factors Impacting the Views and Use of Tablets

Like Sam, Alex also described seven different factors that are impacting her use of tablets. One of the main factors that Alex reported as inhibiting her use of tablets was the inability to customise programs for tablets. This was important because she said most of the programs she finds lack some aspect that would make it useful for her lessons. Having the ability to customise programs would make it much easier for her to incorporate tablets into her lessons. Her own lack of confidence using tablets was another major factor for Alex.

She said that she was frustrated and that as the teacher she felt "like the weak link and you can't harness the potential to get it all to work, because you have no idea where to start." She said that through the group meetings she hoped to improve her practice by learning from other teachers.

Another factor was the lack of specific mathematics related training. Alex was frustrated that the trainings that were offered on using tablets, did not address the needs of mathematics teachers.

> I sat in a training session and have not found any way I can use it in maths. I think maths rows its own little boat and it's not about writing stuff and designing and creating, you don't answer questions in word form.

Teacher #4 – Charlie

Charlie had over twenty years of teaching experience and was also a leader in several initiatives at the school. Working with students with severe learning difficulties, Charlie hoped that tablets could serve as an aid in their learning. Charlie said that she was not particularly an avid user of technology, but did see the possible potential that tablets may have in the classroom. However, lack of skill and lack of time prevented Charlie from using tablets at all. Charlie hopes that this project will be an opportunity to learn skills and collaborate with colleagues to learn from them. Because of the scheduling of the school, Charlie never had the chance to talk to her colleagues.

Initial Use of Tablets in Teaching Practice

The one time that Charlie used tablets prior to the start of this project was to show a video in her class. She said that she saw the tablets as a valuable resource that could help her students visualise basic numeracy concepts, that most of her students struggled with. Charlie often used manipulatives in her teaching, such as clocks, blocks, or number lines, which she said were not very accurate or recruited fine motor skills. Possibly because of the importance of manipulatives in her teacher, she saw the potential of tablets being that of an accurate, personal, and interactive manipulative. Charlie used a lot of tactile resources in her class, such as clocks, food, and a variety of different manipulatives. Because her students lack basic numeracy skills, Charlie was always searching for ways that she could help her students visualise mathematical concepts and practice them using tactile methods.

Initial Views of Tablets in Teaching Practice

Although Charlie was using tablets significantly less than anyone else, almost not at all, and she mentioned having negative self-efficacy twice, she still said that she thought tablets could be useful. Charlie said that she was open-minded and wanted to progress in the way she used tablets in her teaching. Although she uses a tablet for her own use, she has not been able to use it at all in her teaching. She was working with students who have significant learning difficulties and Charlie sees a great potential in the tablets helping them develop concepts.

> I think it has great potential. I would like to give it a go, but currently I am not using them at all. This is something I would like to do, but it’s not high priority considering the many other demands on my time.

Initial Factors Impacting the Views and Use of Tablets

As can be seen in the Table 9, lack of time was the most cited factor, which she said impacted her ability to research tools and resources to use on tablets. However, she said that having the first group meeting was extremely beneficial and it did start the ball rolling towards more integrated use of tablets in her mathematics class.

> The biggest positive for me is that I have seen it work. I’m enthused enough to know that I would like to do some more. If I could cut down the amount of time, or find a shorter way to get really good resources, I would use it more often. It’s the sort of think you feel that actually, you can have someone go through and give a list of resources.

Although Charlie was enthusiastic about the possibility of using tablets in her teaching, the barrier of entry was too high for her at the start of the project. The lack of time to explore the resources, lack of knowledge and experience in using tablets, and the lack of opportunity to receive guidance prevented Charlie from adopting the tablet in her teaching.

Summary of Individual Teacher Interviews

These initial interviews provide insight into the teachers' use of, and view on, tablets in their teaching and the factors that influence them at the start of the study. Table 10 highlights some of the key quotes from the teachers that reflect their thinking. It can be seen that the teachers have a high expectation of the tablets. Jordan refers to the possibility of differentiating the lesson for students and Sam hopes to find a program that can help students understand new concepts by gradually prompting them. Even Charlie, who does not use the tablets, sees potential. However the teachers also face frustration, with Alex saying that the tablets do not offer what she needs in her lesson and Joran lamenting the distraction that it causes in class.

Table 10 Key quotes from initial teacher interviews

Teacher	Quote
Jordan	One of the ways that iPads can be useful in teaching is that they can massively increase effective differentiation. You can actually meet the needs of the child and challenge the child in a suitable way, and they can also check if they are getting it right, they get a confidence boost.
	There is a surprising propensity for students to be constantly on. There is a temptation to be constantly fiddling with it and if someone is talking to just be looking at the screen.
Sam	In an ideal world it would be nice to teach them a new concept and have the program prompt them in some way that they would want to explore concepts further on their own.
Alex	I had the view that there were other people in this department doing amazing things and because I had stopped using it, because there was just too much else going on, I lost confidence and felt that I was so behind these other people that I'll never catch up with them.
	I feel frustrated in some ways, because I feel the way the iPad is designed is very close ended. It is designed by someone else and not necessarily for your purpose or it is used very simplistically more for communication. I think there is a lot of potential, but teachers need a way of controlling that potential, like being able to design things.
Charlie	I think it has great potential. I would like to give it a go, but currently I am not using them at all. This is something I would like to do, but it's not high priority considering the many other demands on my time.

What is not obvious from Table 10 summarising this data, is the span of time that the teachers cover with their remarks. Notably, Alex mentions four ways tasks for which she has used the tablets, but it is important to note that this use was mostly a year prior to the start of the study, when the tablets were first introduced. Her increasing frustrations with the tablets diminished that use. In contrast, Jordan and Alex have gradually increased their use of tablets in teaching and the five tasks they refer to are more in line with the way they use the tablets at the time of the interview. This difference might be reflected in their general views, where Alex has significantly more negative views than Jordan or Sam. Interestingly the number and nature of the factors that Alex mentions, having an impact on her, are quite similar to those mentioned by Jordan and Sam.

It was striking that every teacher mentioned ways of using the tablets that could be described as providing some form of engagement or form of efficiency to the learning process. This is not captured by the preliminary TADT framework, but it is something that came up on several occasions. Jordan mentions that electronic worksheets gave students confidence in their work, which engages them in the activity for longer. Sam referred to QR codes as both being engaging to students, because it gave an element of surprise as to what they would need to work on, as well as efficient since the digital resource (worksheet or program) was quickly accessed by all students. Alex also referred to the possibility of tablets being engaging, in that students could be in control of their own learning. Although she did not know how this is possible, she imagined this would be a very beneficial use for the tablets.

These interviews provide the base for how each teacher reported their use of, and views on, using tablets in their teaching, and the factors that influence that. This base allowed the possible changes that may occur over the course of the project to be compared to where the project began. A synthesis and deeper analysis of the main themes will be conducted after all the data has been analysed and triangulated.

4.3 Implications of Phase 1 Results on Phase 2

As described in Section 3.2, the purpose of Phase 1 was to establish the foundation in which this study was situated. In addition to me assimilating into the school environment, there were three outcomes of this phase that influenced the second phase of the study. These outcomes relate to the constraints of the school context, changes to the observation instrument, and a change to the understanding of how tablets were being used in the classroom. The changes to the study that resulted because of these outcomes are described in the following sections.

4.3.1 Constraints

Through the process of ongoing visits to the school over the course of six months in Phase 1, I became familiar with the environment and the constraints within which this study must be situated. The school visits allowed me to understand the constraints and build them into the design of the study. There were a variety of constraints, starting with the fact that since the teachers need to follow the curriculum, it is possible that the topics they had to teach at the time when I was conducting my study, may not have been the most optimal for using tablets. This was not discussed, but the constraint of not being able to choose what topics to teach in mathematics can limit the potential for using tablets. Other constraints included the availability of time, which limited the number of group meetings. Although the teachers seemed to enjoy the group meetings, in the initial negotiations with the school, I was told to cut the number of meetings I was intending to have from eight to five, as the school schedule did not allow for more time for the teachers to spend more time on this project. However, those also needed to be further restricted to four since in June 2015 the school made a change to their tablet policy and tablets were not available from that point onwards. This change resulted in me having to cancel one of the group meetings and also having fewer classroom observations and post observation interviews as the teachers stopped using tablets.

4.3.2 Observation Instrument

Using the observation instrument in Phase 1 helped me realise that there were several changes that needed to be made. As described in Section 4.1.2, the complexity of the observation instrument inhibited me from seeing the classroom interactions more holistically and focusing intently on the tasks that used tablets. I also found that a lot of the information captured by the instrument did not directly relate to the research questions of this study. To accommodate these outcomes, I significantly simplified the observation instrument for Phase 2, as shown in Appendix 3. The instrument was changed to focus on generating detailed notes when tasks involve the use of tablets. By having the lines of the sheet dedicated to every minute of the class, it is possible to see how frequently and for how long the tablets were used.

In addition to the detailed notes, there was also a column to capture a brief description of photographs taken of the board and the tablets. To capture the detail of the programs used, and the way it was being used, photographs were found to be the best complement to the notes. I did take great care that no faces or identifying material of the school or person was captured in the pictures.

4.3.3 Use of Tablets in the Classroom

As I described in Section 4.1.2, through the classroom observations, I began to realise that tablets were used to teach mathematics in ways that I had not fully anticipated. I expected tablets to be used in the classroom in ways that helped students understand mathematical concepts better than would be possible from traditional notes or textbooks, such as using dynamic geometry software to demonstrate the properties of shapes (Ruthven et. al., 2008), or to use Internet resources to explain mathematical concepts, such as with the use of video tutorials. Although, as outlined in Section 4.2.3, the teachers did talk about ways they would like to use tablets, which included ways that were not possible with traditional paper and pencil, these were not the way the teachers actually used them. I also anticipated tablets to be used for activities other than to teach mathematics, such as to take attendance. What

I did not anticipate was that the tablets would be greatly valued by the teachers when used for tasks that did not directly relate to new ways of explaining mathematical concepts, but rather facilitated students to learn more mathematics during their lesson. The teachers seemed to value these ways of using tablets, even though they were frustrated that they could not implement some uses for tablets that they imagined would be beneficial, and that may be categorised as more complex. However, as professionals who saw value in using tablets in the ways they were being used, I believe it is important to explore what that use is and why they find it valuable in their classroom teaching.

Tasks that I initially observed as simply using tablets for the sake of using tablets, turned out to be seen by teachers as facilitating student learning in different ways. I observed tablets being used for quick formative evaluations that allowed teachers to instantly see which students did not understand a concept, allowing them to go directly to those students and help them individually. I also saw tablets used for short numeracy games at the start of a class that helped students practice mathematics skills and seemed to engage them and focus their attention prior to the start of the lesson. Using tablets in this way seemed to make the classroom more *efficient*, and the activities more *engaging*, so that students could interact more with mathematics during the class. I am not suggesting that it would not have been more beneficial to also have tasks that conceptualised mathematics in new ways for the students, as the preliminary TADT framework demonstrates. But what I began to understand was that these tasks added value to the lesson that was not being captured by Instrumental Evolution portion of the preliminary TADT framework.

These observations helped me understand that tablets were being used to teach mathematics in broader ways than what the framework allowed me to capture. I decided to write down on the observation instrument every activity for which tablets were used in greater detail. As a certified mathematics teacher, I am familiar with what was being taught and I have experience in teaching these topics myself. Using this professional judgment, I observed how the tasks were possibly adding value to the mathematics classroom and what the teacher's intentions might be. By interviewing the teacher after every observed class, I was also able to get their view on how these tasks were contributing and adding value to the teaching and learning. I began to realise that there were additional categories that should be added to the Instrumental Evolution section outlined in the preliminary TADT framework in order to capture a more holistic view of the ways technology is used to help students learn mathematics in the classroom. Although this framework showed valuable information, it did not represent the full picture of what teachers valued about using tablets to teach mathematics. Although the teachers expressed many frustrations in how they could use the tablets, I believe it is important to create a framework that also captures the aspects of using tablets that the teachers, as professionals, value.

In education, it is often believed that technologies can enhance learning, however it is often difficult to find explicit statements on what that means (Kirkwood & Price, 2014). Although there are other frameworks and measures by which the use of technology is evaluated in the classroom, there is often a level of increasing complexity that makes the use of technology more valuable. McCormick and Scrimshaw (2001) describe different levels of change in the pedagogy of using ICT, going from ICT as efficiency aid, to ICT as extension of devise, and finally the most valuable being ICT as transformative device where the creation of knowledge is the goal. While teachers did mention in their individual interviews that they wanted to use the tablets in ways that could be described as transformative ways, such as to see mathematics in new ways and to provide individualised learning, but the they were not using them in these ways. The teachers did talk about different barriers that stood in their way, such as not knowing what apps to use or not having the confidence to try to use tablets in such ways.

By observing the classes, interviewing teachers, and talking to them casually in Phase 1, I realised that there were many reasons why the teachers valued the use of tablets in teaching mathematics. Although the use of tablets did not seem complex in the way that the preliminary TADT framework describes, they did serve important roles that gave students the possibility to further develop their mathematical understanding. An example of this might be that using digital manipulatives on the tablets that eliminated the time spent on handing out, and collecting, physical manipulatives to the class. This valuable time saved could add to the time students spend on using the manipulatives and learning mathematical concepts. The use of tablets in such ways did appear to be useful, and the teachers felt that they were useful. However, tablets could potentially have been more beneficial if in addition to this use they would have integrated tasks with characteristics that the framework outlined as more complex. Observing these tasks throughout Phase 1, I realised that they could be described in terms of contributing towards the *efficiency* and/or *engagement* in the mathematics lesson. Even further, after analysing the results of Phase 2, I realised that some of the tasks for which the tablets were used could also be described in terms of contributing towards helping students to *focus* on the mathematics lesson. These revelations following Phase 1 and Phase 2, prompted me to circle back to the data several times to recode the results with an expanding framework. In the end, I expanded the preliminary TADT framework, by adding three new categories for uses of tablets. Which are collectively called *Characteristics* of tablet use. The categories of *Efficiency*, *Engagement*, and *Focus* were developed, each with several subcategories of the characteristics that tasks might hold.

Efficiency is considered by Jones and Knezek (1993) to be the purpose of technology in the educational process. In a study by Kirkwood and Price (2014) where they review how technology enhanced learning is interpreted in higher education literature, they use the Higher Education Funding Council of England's definition of efficiency as "existing processes carried out in a more cost-effective, time-effective, sustainable or scalable manner" (p 8). This relates more to the organisational aspect of using technology in their study, but I was beginning to see efficiencies in the classroom that allowed for more mathematics to be learned. I use the term *efficiency* in this study as a categorisation for tasks that help make the class proceed more smoothly, allowing more time and resources for the learning of mathematics. Using tablets in such a way may not seem to be particularly innovative, however, pedagogically it reduces distractions and can enable more learning.

The forms in which tasks can facilitate efficiency varies from saving time to saving resources. In the case of resources, one aspect may be providing PDF answer sheets on tablets. Although this may appear to be identical to providing printed paper answer sheets, the reality of the school was that it would not have been possible to provide those copies for every student. It is important to consider that simply because some things are possible in other schools, such as printing answer sheets for every student, those are not necessarily possible in some schools without the technology. It is certainly debatable whether the cost of tablets would not outweigh the investment into resources such as photocopies or textbooks. However, this is not what I am trying to understand in this study. I take the reality that the teachers were working in and try to understand what they were doing with tablets and why. Considering the context, utilising tablets to solve such problems seems to have exposed students to more mathematics. Although this is not suggesting that the teachers fully utilised the benefits tablets could provide to mathematics learning, it was still a positive contribution. In total I identified six subcategories of tasks that all have the characteristics of increasing efficiency. These are individually outlined in Table 11, with examples of tasks in each subcategory.

Table 11 Tablet tasks coding framework

Features of tasks	Description of features
	Instrumental Evolution
Material	Definition: The task is different using a tablet than a paper/pencil task in the tool being used, but not in the mathematical thinking required.
	Example: Worksheet on a tablet that provides the answer is the same as a textbook with answers in the back.
Connect	Definition: The task using a tablet helps students make connections in their mathematical thinking that would be more difficult to understand with a paper/pencil method.
	Example: Quickly graphing multiple equations using a graphing program on the tablet allows for visualisation of what changes in an equation mean to the graphical representation.
Enhance	Definition: The task using a tablet requires more mathematical knowledge than if it were solved using paper/pencil methods.
	Example: Constructing a square using a dynamic geometry software requires specific knowledge of the properties of the shape, such as the angles and properties of the dies, rather than simply drawing the shape.
Extend	Definition: The task is only possible using the tablet and not possible using paper/pencil.
	Example: 1. Using programing logic to solve a problem or create something. 2. Using the drag mode mode of a dynamic algebra software to understand the properties of shapes.
	Efficiency
Resources	Definition: The task uses the tablet to reduce the need for additional supplies such as paper, manipulative, and other physical objects.
	Example: PDF version of test solutions eliminates the need to make photocopies for every student.
Classroom management	Definition: The task reduces disruption in the classroom and enables the teacher to orchestrate the classroom as intended.
	Example: 1. Students not having to go to board to write solution for entire class. 2. Reduced need for physical resources that are limited and need to be collected and stored.
Instant formative	Definition: The task allows the teacher to instantly receive answers from students to a set of questions.
	Example: An electronic mathematics quiz that helps the teacher to identify the level of mathematical ability of each student or polling the class on how confident they feel about the lesson.
Teacher multiplied	Definition: The task alows the role of the teacher to be replicated sevearl times, alleviating the teacher from having to repeate information.
	Example: Having a video of an instructor explaining a concept, allwos the student to return to the instruction part of the lesson and not have to ask the teacher to repeat parts of the lessons.
Increased exposure to subject	Definition: The task enables students to interact with more mathematics than would otherwise be possible.
	Example: Graphing multiple equations using a tablet allows students to see the relationship between a graph and an equation as they do not need the lengthy time to draw each graph by hand.
Speedy access	Definition: The task increases the speed to access resources.
	Example: Accessing electronic worksheets or websites using a link or scaning quick response (QR) code.
	Engagement
Instant feedback	Definition: The task provides students with immediate answers to mathematical problemse they complete.
	Example: Electronic worksheets indicate if an answer is wrong, or provdie answer, allowing students to proceed in their work with a sense for of their abilities.
Creative	Definition: The task allows students artistic freedom in building or representing their mathematical thinking.
	Example: Students take pictures of shapes they build with blocks and create presentations of the 2D images they take of the front and side views of the shape.
Student as teacher	Definition: The task facilitates students presenting and explaining work to the other students.
	Example: Taking a picutre of student work to project on the board, or using a program that projects individual student's tablet screen on the board, allowing students to demonstrait their work to the class.
Visually enticing	Definition: The tasks esthetic and/or interactie nature makes it pleasing to the use for the students
	Example: Games that require students to practice mathematical skills such as numeracy.

Engagement is described by Ruthven (2009) as it "relates to securing the participation of students in classroom activity" (p 3). Although the research on the impact of technology, and particularly mobile technology, on students' engagement in mathematics is limited (Fabian, Topping & Barron, 2016), there are some studies that suggest that tablets have a positive influence on students' engagement in mathematics (Hilton, 2016). It is difficult to make such broad statements particularly as tablets can run many different programs and can be orchestrated in the classroom in a variety of ways. It is really teachers' pedagogical approaches that define how engaged students will be using the technology (Attard & Northcote, 2011) and also how well they will learn. In this study *engagement* serves as a categorisation for tasks that help to capture and sustain the attention of students so that they focus more intently on learning mathematics. The term *engagement* is not used synonymously with *entertainment*.

I identified four characteristics in which tablets were being used to engage students, two of those subcategories did not provide any form of entertainment in order to capture students' attention. For example, using electronic worksheets that indicate correct answers, captivated students' by providing them confidence in knowing whether their work was correct or not. This seems similar to what a textbook could provide, but again the context is such that the school did not have textbooks. I identified four subcategories of tasks that all have the characteristics of increasing *engagement*. These are individually outlined in Table 10, with examples of tasks in each subcategory.

Tasks for which the tablets are used, that have characteristics that fit the subcategories under Efficiency and/or Engagement, can provide opportunities for students to increase their exposure to mathematics and possibly furthering their mathematical understanding. Although in these categories tablets may not be transforming the way the students understand the mathematics, teachers noted that the tablets did seem to be allowing greater access to the mathematics material and learning in a way that opened doors to further mathematical understanding.

Having developed the subcategories describing features of tasks under Efficiency and Engagement, I went back to the data from Phase 1 and recoded the individual teacher interviews (reported in Section 4.1.3), classroom observations (reported in Section 4.3.1) and group meetings (reported in Section 4.3.3) in Phase 2. In coding the tasks, a task can fit only **one** of the four subcategories under Instrumental Evolution, however the task can have characteristics that fit **several** subcategories under Efficiency and Engagement. For this reason, the total number of tasks observed in a classroom are identified by the total number of tasks categorised under instrumental evolution, but not the total number of tasks identified in all the three main categories.

4.3.4 Factors Impacting Teachers' Use of Tablets

Over the course of the initial teacher interviews many factors were mentioned as having impact on teachers' use of tablets. Two factors that were not part of the framework started to emerge.

One factor I will categorise as *mathematics misunderstood*, which refers to factors that have the characteristic of not fully understanding the needs of mathematics subject teachers. One example given in Section 4.2.3 by Alex, was that the training provided for teachers did not address the teaching needs of mathematics subject teachers. The apps that were being taught to be used on the tablets were not relevant to mathematics teachers. Sam also mentioned that she, or the school overall, have not found really mathematics specific applications to use.

Another factor that emerged I will categorise as *management*, which refers to decisions made by school leadership that impact teachers' use of tablets. In Section 4.2.3 Jordan describes the schools lack of a united policy on using tablets across all subjects. She saw this inconsistency as contributing to students being distracted by the tablets.

As these two factors emerged from the individual interview data, I want to be able to account for them throughout the study. In the modified TADT framework I add these two factors of as *mathematics misunderstood* and *management* to the list of factors that I will code for.

4.4 Phase 2 – Evolution of Use

In this section, I discuss the results of the data gathered in Phase 2 of this study. As in Section 3.3 that outlines the methods for Phase 2, this section is also organised into sub-sections that align with the distinct data sources of Phase 2 – classroom observations, post observation interviews, and group meetings. The data collection spanned over seven months, from January to July 2015, with specific dates for each data source collected given in Table 12.

Table 12 Data collection dates

Half Terms (2014/2015)	Dates	Group Meetings	Classroom Observations (by teacher)			
			Jordan	Sam	Alex	Charlie
Half Term 3	07-Jan-15 to 13-Feb-15	22-Jan-15				
Half Term 4	23-Feb-15 to 26-Mar-15	23-Feb-15	10-Mar-15 24-Mar-15	19-Mar-15 26-Mar-15	13-Mar-15	18-Mar-15
Half Term 5	13-Apr-15 to 22-May-15	14-Apr-15	07-May-15 21-May-15	01-May-15 14-May-15	15-Apr-15 08-May-15	13-May-15
Half Term 6	01-Jun-15 to 22-Jun-15	03-Jun-15	11-Jun-15		17-Jun-15	

4.4.1 Classroom Observations

The results of the fifteen classroom observations are outlined in Table 13. The number of observations were less than I hoped for, but there were a variety of reasons why this occurred. It was partially due to a hectic school schedule, but as I was also later told, the teachers were cautiously only wanting to invite me to classes where they were going to use tablets frequently and in innovative ways. Although I did often say that I would like to see the regular ways they used tablets. However, the main reason for the reduced classroom observations, was because in the middle of June the school abruptly recalled all tablets for the remainder of the year. This recall also cancelled one of the group meetings. I will discuss the details of this situation in more detail in Section 4.3.3.

Table 13 Frequency of tasks for which tablets were used during each observed lesson

		Classroom Lesson															
		Jordan					Sam				Alex				Charlie		Total
Features of mathematical tasks		1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	frequencies
Instrumental Evolution	Material	3	2	1	1	2	1	6	5	4	5	4	7	2			43
	Connect			1			1			1						1	4
	Enhance																0
	Extend																0
Efficiency	Resources	2	2	1	1	2	1	3	2	2	3	1	4	1		1	26
	Classroom management	2	1					3	4	2	4	2	5	1			24
	Instant formative					1	1	1	1	1		2	1				8
	Teacher multipied	1															1
	Increased exposure to subject						1			1						1	3
	Speedy access	1						2	2	3	4		2	1			15
Engagement	Instant feedback	1	1		1			2					3			1	9
	Creative			1								2					3
	Student as teacher								1		2						3
	Visually enticing								1		1					1	3

The first key finding from the observation data was that over time I did not see a recognisable change in the number of tasks for which tablets were used, or a shift in the Instrumental Evolution of the tasks. I was hoping to see an increased use of the tablets and for some teachers to be assigning tasks that could be categorised as Enhanced or Extend, particularly in the classes towards the end of Phase 2. This did not occur, and there is no detectable pattern of teachers progressively using more complex levels of Instrumental Evolution (I will explore the possible reasons for this when I triangulate the different sources of data in Section 4.4, drawing a more complete picture of how the teachers used the tablets in the classroom, what they individually said during the post observation interviews, and what they said during the group meetings).

The lack of change in the Instrumental Evolution of tasks may not be a surprise, as I outlined in Chapter 2 that training is needed for the use of technology to change quickly, which was my aim in designing the group meetings. However, having my intended number of meetings reduced by the school may have been a contributing factor. If more group meetings would have been possible, my intention was to focus the conversation specifically on ways that the tablets could be used in ways that could be categorised as more complex in terms of Instrumental Evolution. However, it may be that for teachers to move to those type of tasks in a relatively short time there would be a need for direct examples or instruction of how to design such tasks. This is something that would be valuable to explore in further studies. However, the predictability of how long, or how much training, it would take to move to the higher levels of Instrumental Evolution is difficult to predict.

What is especially striking, and an outlier from the other teachers, was Charlie. She described herself as having very little experience using tablets and being nervous about using them in her class, which makes it particularly significant that she created a task that fits the Connected category. Although I was invited to observe her class on two occasions, she only used tablets in this one class. This might lead someone looking at the data to assume that she made a significant jump in how she used tablets in her teaching and if more classes were observed she may be more innovative than the other teachers. However, this may be misleading, and rather the example of Charlie may highlight the ways Instrumental Evolution in the framework possibly only gives a limited perspective on the way technology can be used in a mathematics classroom.

In addition to Charlie, both Jordan and Sam also created tasks that were coded as Connected, there was no distinct pattern that would suggest that more practice using tablets encouraged this shift. Similarly, the frequency of tasks using tablets incorporated into a lesson also did not change over time. Although teachers did not appear to be using the tablets more over time, this is not necessarily the case since the actual time that each task required in the classroom was not recorded. The reason for this omission is that the length of time tablets are used in the lessons does not address the research questions, which focus on the characteristic of how tablets are used. However, it is interesting to note that Sam and Alex had the same number of tasks over the same number of lessons. This may seem surprising as Alex stated many times that she has almost completely stopped using the tablets prior to the start of this study, while Sam indicated in the individual teacher interview and group meetings that she has gradually increased her use of tablets for a variety of tasks and feels comfortable using them. This unexpected outcome might be due to the fact that the first observed lesson for Alex occurred after the first group meeting, in which Alex gained a lot of confidence, motivation and ideas on how to start using tablets again.

In the Efficiency category the two most common feature of tasks were Teacher Focus and Speedy Access. Teacher Focus mainly included tasks that allowed the teacher to direct their attention to particular students who needed their help. This was valued by teachers because it allowed them to focus their attention on the students who need it the most. One example is when students could not check their work, they would bombard the teacher with questions to check if their work was correct. This depleted so much of a teacher's time that it deprived students who really needed help with the work. Speedy Access was the second most common way of tablets being efficient. Having students access material quickly not only saved time, but it also helped avoid distractions when students would quickly go off task. An example of tasks that would be considered in this category would be the use of Quick Response (QR) codes, which are similar to a barcode and can be scanned with the camera of a tablet to instantly bring up on the tablet the webpage that the QR code represents. QR codes can be projected onto the screen at the front of the class for students to capture it, using the camera on their tablet, instantly accessing a worksheet or websites. Teachers indicated that students not having to type in website addresses saved a lot of time, and helped to manage the classroom by causing fewer barriers between tasks. Teachers often mentioned that the smallest distraction, such as having to type in a password or website, causes students to get distracted and start talking to their classmates.

In the Engagement category, the most frequent feature of tasks was Instant Feedback, which had three times as many tasks with that feature than any other subcategory under Engagement. Teachers indicated that the fact students could find out instantly if their work was right or wrong, allowed them to move on in their work and solve more problems than they would have otherwise. I observed students saying out loud that they got a certain answer correct and they proceeded in their work, rather than having to wait for the teacher to confirm that they were doing the questions well. In the classroom, the teacher made a comment that without the tablets, students who were getting the answers correct, but were not confident, would wait until the teacher came to check their work before moving forward. Having this confirmation allowed them to stay on task and stay engaged in their work.

In the Focus category the most commonly observed feature of tasks was that of Teacher Focus. All the other observed tasks had either features of Individualised Learning or Visualisation but were only observed once or twice. Alex had the most tasks that incorporated Teacher Focus, with five in total, but all teachers had this feature in at least one of their tasks. In the interviews and group meetings, the teachers often referred to the benefit of having tasks that allowed them to sharpen their focus on students who needed them the most.

Looking vertically across Table 10 indicates that all the teachers used the tablets for tasks that incorporated a great variety of features. Alex had the most diverse features of her tasks, followed by Sam. This is again interesting, as Alex only started to use the tablets again after the first group meeting, having almost entirely abandoned them in her teaching. More detail about Alex's interesting journey in integrating tablets into her teaching is outlined in detail in Section 4.6.

4.4.2 Post Observation Interviews

As described in Section 3.3.2, I conducted a short interview with each teacher following every classroom observation. As previously explained, these interviews had the dual purpose of giving time to the teachers to reflect on their practice, as well as for me to gain a greater understanding for how the teacher experienced the class and what their thought processes were. In this section, I summarise key aspects of each interview individually, and connect them to the classroom observations. In the interviews the teachers may not refer to each task for which the tablets were used, rather they highlight the main ways the tablets were a success in the lesson, how they were challenging, and what they might change next time. However, the open-ended nature of the interviews allows each teacher to focus on the aspects of the lesson they feel was most important regarding the use of tablets.

Teacher - Jordan

The post observation interviews with Jordan following each of the five lessons I observed, are summarised in Table 14 using the framework developed in Section 3.3.2. After each lesson we went to the mathematics office, which was shared by approximately five mathematics teachers, and we sat down to discuss the lesson. Often Jordan had very little time before her next class, therefore she often had to put away papers from one class and gather supplies she needed for another class. Occasionally other teachers came in and out of the room, but these interruptions did not seem to bother Jordan, who seemed to be keen to share her thoughts about the class.

Table 14 Post observation interviews for Jordan

		Classroom Lesson				
		1	2	3	4	5
Views	Tablet self-efficacy (positive/negative)	2			1	1
	Perceived ease of use (positive/negative)	1		1/1	1	
	Perceived usefulness (positive/negative)	1	1	2	3/1	4
Factors	Time	1	1			
	Resources			1		
	Techical issues	1	1		1	
	Mathematics missunderstood					
	Support					
	Management	1				
	Classroom management	2	1			1

Classroom Lesson #1

As can be seen in Table 14, Jordan has positive self-efficacy regarding her use of the tablets and also the usefulness of the tablet in this lesson. The negativity of the ease of use is connected to the technical issues that emerged throughout the class, causing classroom management concerns and frustrations with management. The severity of the technical issues is not immediately apparent in Table 14, as the code represents the number of times an issues was raised, not the length of time it was discussed. However, the qualitative data described below, sheds more light on what the concern was.

As we arrived in the mathematics office and I asked Jordan how she thought the class went, raw emotion and frustration was evident in her voice as she explained.

> Really really frustrating as a teacher, the technology issues. We have to discuss that. In a previous lesson a few of the students couldn't get Showbie (software for the tablet) to work and this time a majority couldn't get it to work. With enough working around it, by getting students to work in pairs, which had to be facilitated by me, they couldn't do it independently, I think I got it to where at least a pair had access to it.

Jordan was using a program called Showbie which she could load a PDF document on and have all the students access the document on their tablets. This document was the detailed solutions to a big test that the students completed in an earlier class. Jordan pointed out that this was not an innovative way of using tablets, but without it she could not have justified the cost of photocopying a copy of the test solutions for every student to check their own work, since the solution booklet was several pages long. Having tablets gave every student the ability of focusing on the problems they got wrong on the test and needed to improve, rather than have Jordan go through all the solutions on the board.

Jordan explained that having Showbie program not work on many of tablets being used was only part of the technical problem in this class. Jordan tried to upload the PDF to the school website for the students to access, but because of some other technical difficulty she could not access the website. These technical challenges caused a lot of inconvenience and frustration during the class.

As can be seen in Table 14 above, Jordan had two tasks that used the tablets and both of them had characteristics of being Material in nature. The tasks also made the class more efficient by saving resources, by not having to photocopy test results for each student, and managing the classroom by allowing every student to focus on the test results they were most interested in, rather than having to watch the teacher solve each problem on the board. The students would have to sit and wait for the teacher to get to the test question that they got wrong, before they would be interested in seeing how it is solved. This waiting period is not only a waste of time for the students, but it also allows for distractions and possible disruptive class behaviour such as talking with friends. Having the solution booklet on the tablets, allows each student to focus on the questions they need to learn how to solve. Jordan would have been completely happy and satisfied with the way tablets were used in the lesson, but as can be seen in Table 14 technical issues and classroom management were the factors that were her greatest concern. It was the technical issues that really damaged the effectiveness and flow of the lesson she had planned.

Classroom Lesson #2

During this class, Jordan used an electronic worksheet that had mathematic problems on it for students to solve. Students had to write the solution of each problem in their notebook as a way of showing their recording and demonstrating the strategy they used to solve each problem. Once they reached the answer they were to type the answer in the program. The program would let the student know if their answer was right by indicating with a checkmark a correct answer and an X for a wrong answer. Figure 5 below shows what the tablet looked like while one student was working on the electronic worksheet. Jordan said that the topic in the lesson was a difficult concept for students and therefore it was particularly important for students to be able to check their own work before asking for help. She explained this in the following way.

> The program takes them away from self-assessment to a concrete assessment. There is a difference in how you perceive you are doing and how you are actually doing. With a middle set like that, there is a perception that they are doing far worse than they actually are.

She particularly focused her comment on middle set students because she said they are often the ones who get answers right, but their confidence is not strong enough to be sure their work is correct. Having these students constantly asking the teacher to check their answers, when in fact they were correct, wastes a lot of time that the teacher could have been helping students in need. Waiting for the teacher to confirm a correct solution also causes the student to waste time that could have been spent working and possibly causing distractions as they wait for the teacher.

These tasks can be categorised as Material in characteristics, but as can be seen in Table 14 the tasks that Jordan used tablets covered four different features in Efficiency and Engagement. These were more diverse range of features than was covered in any other lesson that I observed.

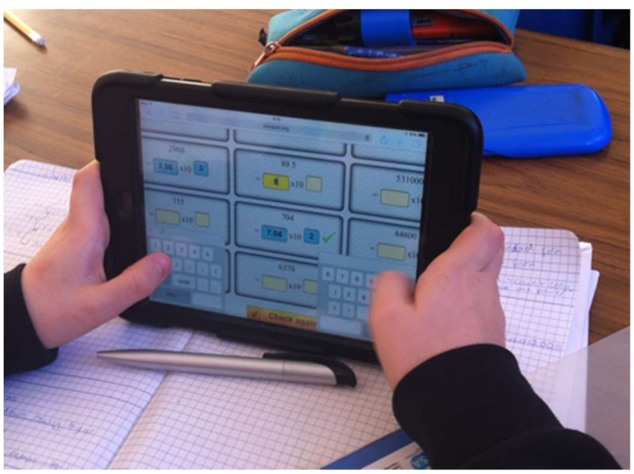

Figure 5 Electronic worksheet

She said that lack of time is a big factor inhibiting her from using tablets more effectively. “I don’t stop to think about the longer term. This is one of those things where I need to put more emphasis on my practice". The reason Jordan wanted to use the games was to engage her students. She explained that by engaging them they would do more mathematics, which in turn would improve their skills. Lack of time was inhibiting this from taking place.

Classroom Lesson #3

Jordan was happy with the lesson, which focused on planes and elevation. The aim was for students to understand the different views of a three-dimensional object. They achieved this by taking pictures of the three faces of blocks in such a way that the pictures were two-dimensional. Other students in the class had to create the three-dimensional blocks using the pictures created by their classmates. Figure 6 below is a picture of a student doing this activity.

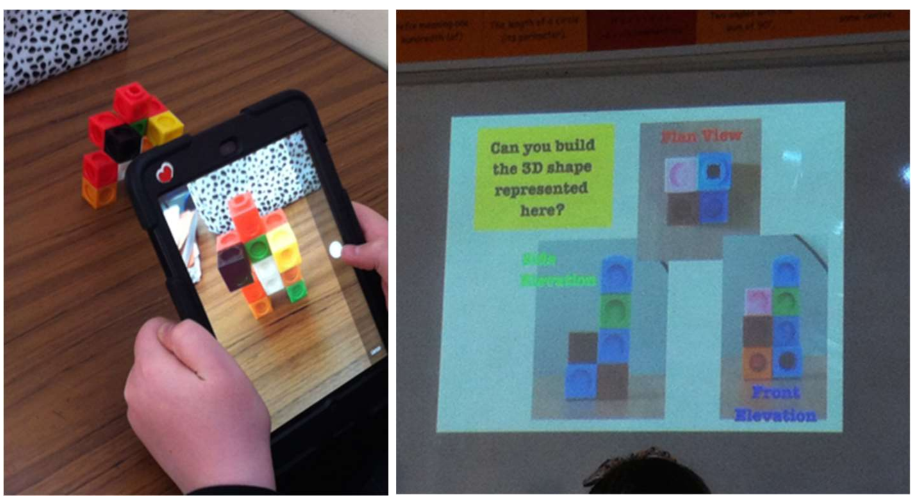

Figure 6 Dimensions of 3D figures activity

This was the only lesson in which Jordan designed a task that can be considered as Connect in the Instrumental Evolution category as can be seen in table 10. Jordan commented on the fact that moving the tablet to get a clear plan of the figure was helping to make connections for students that often struggle to go between 2D and 3D figures. It is an important skill in mathematics to mentally move between 2D and 3D representations of figures. By moving the camera in capture 2D representations of a 3D figure, the students practise seeing the two representations of the figure. However, Jordan spoke mostly of the way she found this engaged the students who otherwise were not very good at manipulating three-dimensional shapes and they were learning the necessary skills. Jordan also highlighted that she would have liked to find a program that could use virtual blocks to build shapes and view from different angles, but she could not find such a program. She thought that this would be very beneficial because it would not be limited by the resources of the number of blocks available in the class.

Although Jordan would have liked to have students take pictures of the different sides of objects they found, like a mug or pencil case, there was no time left at the end of the class. The lack of time was not due to any particular issues with the activity, as the students were very quick at taking pictures and putting together a slide of the pictures. Overall, Jordan was happy with the results and how the students progressed in the lesson.

Classroom Lesson #4

Jordan was relatively happy with the class, which was focused on transformations of shapes. She was happy with the website she found, called Transum.com, that she used to introduce the topic. It was an interactive worksheet where the students needed to insert the coordinates of the transformation and the program would tell them if they were correct. This was a useful way for students to self-check their work. However, Jordan said that tablets could be used in a more complex way, if the program could allow the student to draw a shape and manipulate it in a variety of ways. Jordan knew of the perfect program to do this, a website called CIMT, but unfortunately they had recently upgraded to flash players, which could not be viewed on tablets. Jordan found this change rather alarming, as she used to use this resource, but as she was preparing these lessons she realised that it no longer works.

In preparing for the lesson Jordan found the resource she used in the class by searching on the Internet. She also had some leads on what to search for from a conversation she had with another mathematics teacher in the mathematics office. She talked about the way these conversations, although rare, provide excellent tips on finding useful resources.

Apart from some minor timing issues in the way the class was run, there was nothing that Jordan would choose to do differently in this class. Although she knows there could have been better programs for the tablet, the class was a success. Even though when looking at

Table 14 there does not seem to be anything fascinating happening in the class since there was only one task for which the tablets were used and it was a task that has characteristics of Material Instrumental Evolution. There are also only two other features of this task, which was to provide teacher focus and give students instant feedback on their work. The only factor inhibiting her use was a technical one, which related to her trying to find a program in preparation for this class, but the program was discontinued.

Classroom Lesson #5

The class focused on volume and Jordan was very happy with the way the lesson went. She commented that the only time the class was slightly disrupted, was when the students had to use their tablets for a Socrative quiz. This is a program on the tablet that allows teachers to create short quizzes for the class. The teacher sees instantly the responses each student gave, allowing her to address any errors that the class, or individuals, are making. Jordan described the value of this feedback when she said the following.

> It was useful because it meant that I knew who I needed to see right away. I needed to see Tom because interestingly he got the three easiest questions wrong and the two hardest questions right. Sally, who got the first three questions wrong and another student also got some of the questions wrong. Apart from that the only time students got it wrong was on the last question, which was quite challenging. But it meant that I knew who I needed to go and see right away when they started to work on the worksheet.

Jordan was using this as a formative assessment for what the students understood of the lesson. This type of instant feedback allowed Jordan to see who understands the questions and she could directly approach the students who did not understand. The program instantly provides a teacher with a summary of how many students got each question correct and a summary of every individual student's results. This allowed Jordan to focus her attention on students who did not understand the question, or review a question on the board that most of the class got wrong. However, the short steps needed for the students to log in created a pause that opened conversation among the students and distracted the class. There was a short technical difficulty when Jordan accidently set up the Socrative quiz in the teacher view, but that did not create much disturbance.

Following the quiz, the students spent much of the class working on an electronic worksheet. This has become a routine in Jordan's class and she describes the benefits of these worksheets in the following way.

> They are really starting to get the hang of these. I do the work in my book, I check it with the iPad and I ask the questions as I need. And actually that meant that there was a solid half an hour or forty-five minutes of them just working through questions. They were on task, which really aided their learning. The reasons we talked about before, that they are able to gain confidence.

Overall Jordan was happy about her lesson and could not think of anything that she would have done differently. She felt that the learning was achieved. Again, from Table 10 it may appear that tablets were under-utilised as in this final lesson the tasks only had Material characteristics and covered two features of the Efficiency categorisation. However, in this study I am not measuring effectiveness, rather I am taking the professional knowledge of each teacher to let me know if tablets served an important role in helping the students learn mathematics. In this case Jordan said that they had and she was happy with the results.

Summary of Jordan's Post Observation Interviews

Over the five post-observation interviews with Jordan, there were a few key points that came up on several occasions. One such point was the failure of technology, which was a major issue that disrupted the class on several occasions. Although Jordan was comfortable using technology and feels confident that she can manoeuvre around technological challenges in the classroom, it was still a source of great frustration. She needed to prepare backups for lessons that involve the use of technology, but the increased amount of time needed to prepare the backups was often unfeasible.

Jordan recognises that some of the ways in which she used tablets was not particularly innovative, such as providing static PDF documents to students, or electronic worksheets, that indicate correct answers. However, Jordan was quick to point out that because of limited physical resources, such as printing allowance and textbooks, these programs were invaluable. They provided individualised learning and freed up teachers' time so that they could focus on helping students who most needed their guidance.

Time was a constant factor that Jordan identified as a key reason for not being able to advance her use of tablets. She said that simply reflecting on her practice and having the time to plan the term in advance, would greatly enhance the way she could use tablets. Finding necessary resources and planning lessons that involve more complexity were squeezed into busy schedules and she often fell back on what she has done in the past. As Jordan expressed in her individual interview in Section 4.2.3, she thought that the greatest value of having tablets was to individualise learning, providing an opportunity for each student to advance at their own pace and work on the skills they needed to focus on. However, the most that she could find would be digital worksheets that provided the answer to the question. Finding the time to find the resources she would like, was challenging for her. Lack of time is a persistent concern in busy schools, which is challenging to remedy. Possibly if these concerns were clearly communicated to leaders of the school, or to technology companies, a teacher could be pointed into the direction where appropriate resources could be found, but this was not happening in this case.

Teacher - Sam

I observed a total of four lessons that were taught by Sam, which is summarised in Table 15 using the framework developed in Section 3.3.2. After every lesson, we either stayed in the classroom where Sam taught or we went to the mathematics office, which was shared by approximately five mathematics teachers, and we sat down to discuss the lesson. Usually after Sam's lessons the students had recess, which meant that there was a lot of noise throughout the interview and occasionally interruptions. However, Sam was not distracted by the surroundings and was fully devoted to the interviews.

Table 15 Post observation interviews for Sam

		Classroom Lesson 1	2	3	4
Views	Tablet self-efficacy (positive/negative)				1
	Perceived ease of use (positive/negative)	2			
	Perceived usefulness (positive/negative)	4	3	1	2
Factors	Time	1			
	Resources	2		1	3
	Techical issues	1	1	2	
	Mathematics missunderstood				
	Support				
	Management				
	Classroom management	3	3	2	1

Classroom Lesson #1

Sam was happy about the outcome of this class and how the students progressed. The purpose of the tablets was to have students graph equations quickly, to be able to see the connections between the equation and its graph. Figure 7 shows what the program looked like on the tablet and the notes students took to keep a record of what they did on the tablet. This task is categorised as having features that make it a Connect task in terms of Instrumental Evolution, since the task allows the students to make connections about the relationship of equations and their graphical representations. Because it would take a long time to draw a single graph, this connection could not be made using paper and pencil.

Another aspect that Sam said she really valued was the elimination of drawing skills from this activity, allowing students to focus on the skill of understanding how changes in an equation relate to the graphical representation. As can be seen in Table 15, Sam's view of how useful the tablets are in this type of task is very positive, as she describes four positive outcomes of using tablets.

> The fact that they could plot graphs and they could all do it. They could all load it up on the website and I can assess them all. The things that I've said, the fact that I can do both of those things made it more successful than it otherwise would have been.

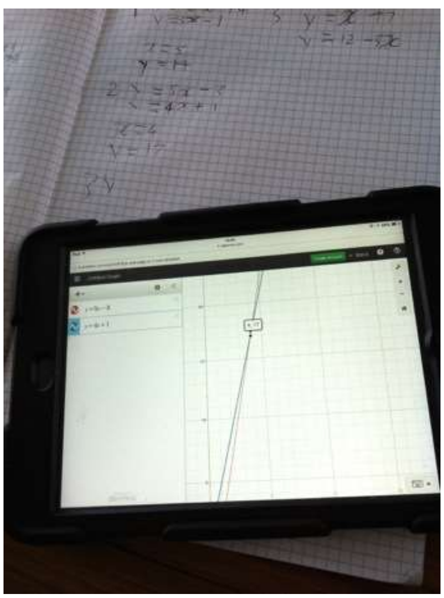

Figure 7 Graphing activity

One very important aspect of using tablets, was that she could easily differentiate the task and allow students to progress at their own pace, providing an element of individualised learning. In the following quote, Sam describes a gifted student she could help progress in his mathematical understanding, because she was able to give him more complicated equations to work with. The speed of graphing equations enabled this student to learn about the relationship between more complicated equations and their corresponding graphs.

> A student in the class sits at the back and is really really clever. I had been able to give him equations that are squares and cubes and although he could probably tell me just about what they looked like, but if I asked him to plot them it would have taken him ages and he wouldn't really have gotten the point that there is more than one solution. But the fact that he could do that there, he has a much better understanding of how simultaneous equations work. That was a really positive thing for him to do that he couldn't have done if he didn't have an iPad in front of him. I also wouldn't have been able to give him random ones. I gave him three extra ones that I just wrote down for him and he could use the iPad to see what the graphs were doing.

Throughout the interview, Sam did not mention any added value of having a tablet for this task that could not have been replicated by a graphing calculator. None of the features that were described were unique to tablets. However, I am not aware if the school had graphing calculators available, which could have been used for this task.

Even though Sam sees tablets as a great resource in this lesson, she still noted some difficulties in terms of the factors that impact her use of the tablets in her lessons. One factor is the time it took Sam to find a software that would graph equations in the way she needed them for her lesson. In terms of resources, she was limited by the lack of a budget to pay for apps, which she found frustrating as she quickly found a program that would have worked, but it was not free. In the classroom, technical issues and classroom management were also noted concerns. She found that the program loaded quite slowly for some students which caused some frustration. In terms of classroom management there were both benefits and drawbacks as tablets offered a way for students to easily check if they were correct when solving equations, but also having the tablets in the classroom required Sam to strictly tell students when tablets were to be used and other times it had to be face down on the desk to avoid any distractions.

Overall, Sam felt that without the tablets the students would have not gained as much understanding of mathematical concepts and they would have needed more time to graph the equations by hand.

Classroom Lesson #2

Sam was happy with this lesson although she felt that it was a bit less fun than some of her other lessons as the main activity was for the students to solve problems in their books and use tablets to check the answer. As seen in Figure 8, Sam used a Quick Response (QR) code to allow students to easily access the electronic worksheet shown in Figure 9 that she wanted them to use. The electronic worksheet served as a checking tool, it had equations they had to solve and putting in the answer into the program indicated if it was right or wrong. To show their work, the students had to write their full solutions in their notebook.

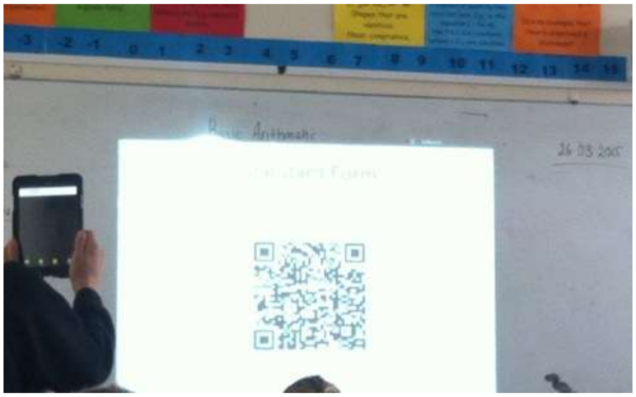

Figure 8 QR code used to access digital resource

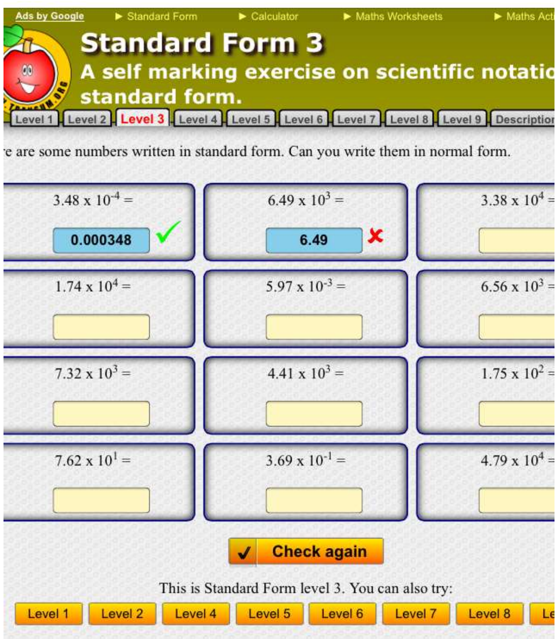

Figure 9 Interactive worksheet activity

Both these uses for tablets are categorised as Material in nature, but they still provided benefits that Sam valued. The QR code allowed for easy access to the worksheet, avoiding the time required to type in a web address or having to access a link through email. Sam also mentioned that making processes as simple as possible also helps to avoid disruptive behaviour in the classroom. In the following quote Same describes why she likes these worksheets and how she uses them in her class.

> Today I knew that they would struggle answering those questions so it was really nice to have a digital worksheet that told them if they were wrong. I wanted all the evidence in their books, so it wasn't speeding them up in any way, because they still had to copy questions and work out the answer. But the fact that I didn't have a bunch of hands up asking if this is right, was really helpful because you can see right away if they were right or wrong.

Although Sam saw many benefits for using the electronic worksheet, it does seem that the benefits would have been the same as if the students were given an answer sheet, or could find the answers at the back of a book. Sam did not refer to these possibilities, but in other conversations, I was told that the school does not have textbooks and they want to save on photocopies. It may be, that the benefit of tablets is that they bundle together many resources, but it is worth noting that the aim of the class could have been achieved without the use of tablets.

As students solved the worksheet, writing full solutions in their notebooks and checking the answer by putting it into the electronic worksheet on their tablet, Sam walked around the class and took pictures of some of the students' work. She projected these pictures on the board to demonstrate some of the ways the problems could be solved. Sam initiated a class discussion about the methods used to solve the equation. Although this could have been achieved by having students write their solutions on the board, the advantage of the pictures was that it did not require the time needed for students to rewrite their work and also it eliminated the disruption of students coming to the board. The tablet served as a way of saving time and managing classroom behaviour, which is something that is a frequent concern to Sam and the other teachers. The one thing Sam said she would modify the next time she uses this activity, is to ask the students to write their solutions with felt pens, as the pencil they used in their notebooks was difficult to read when the picture of their work was projected on the board.

At the end of the lesson the students wrote a small quiz on their tablet using a program called Socrative. This quiz had five questions, four of them tested them on using standard form, which was the focus of the lesson, and the last one asked if they thought they understood the lesson. The results of this quiz allowed Sam to have a snapshot of what the class, as a whole, and individual students, understood from the lesson and also their own confidence in how well they grasp the lesson. Although this quiz could have been a paper and pencil quiz, the program on the tablet saved Sam a lot of time as it gathered all the answers in one place, marked the answers, and summarised the results for the teacher. This allowed Sam to instantly see which students successfully learned the lesson and which still needed help on particular concepts.

The factor that caused most of the concern in using the tablets was that some students did not have their tablets with them. Some forgot to bring them and one student had her tablet confiscated by the school because of bad behaviour. This made it difficult the manage the class, as Sam had to arrange for these students to share tablets with other students and they were not able to fully benefit from the lesson as they often relied on their partner's solution for the problem. These issues emerge from having every student own their tablets.

The benefits of owning the device are that the student have this resource at home, however when I asked Sam if she ever assigns work that requires the use of tablets at home, she said she does not. Sam said that the students know they can log onto the Transum sight, which is the one that has the electronic worksheets they use, or they can access numeracy games, but she does not require them to do any of this for homework since she cannot verify if they did the work or not. This barrier could be lifted if the technology were designed differently or if homework was structured differently. Not using the tablets at home does diminish the value of having every student own their own tablet.

As in the previous lesson, the factor that Sam mentioned most often as having an impact on her using the tablets, was classroom management, which, as can be seen in Table 15, she mentioned three times in this short interview. Sam talked about concerns that tablets pose in classroom management when some students do not bring them to class, but also the benefits that the tablets help manage the class by not needing to have students leave their desk to write on the board, rather their work can be projected from the tablet, and also easily navigating them to online resources, by having a QR code and not needing to write in long website names. As can be seen in this lesson, tablets pose classroom management problems but they also help alleviate other traditional classroom management issues that teachers often face.

Classroom Lesson #3

This was a busy lesson, during which Sam wanted to achieve a few different things. The focus of the lesson was to hand back a recent test that the students wrote and review the questions. At the start of the lesson Sam had to return the test papers to the students as well as some other papers she wanted to give them. To help manage the class during this time, she gave the students a colourful numeracy game to play on their tablets, as can be seen in Figure 10. To access the game, students had to scan the QR code that Sam projected on the board. Scanning the QR code ensured simple and quick access to the game without the students having to type web addresses that could be misspelled and cause distractions.

Figure 10 Starter game

Once the tests were handed out, Sam wanted the students to review the questions they got wrong on the test, but having peer-to-peer tutoring. To avoid all the students going to the one or two students recognised for being the most successful in the class, Sam wanted every student to have the possibility of helping another. As the test was written in such a way that the questions got progressively more difficult, Sam asked the students to record the last three questions that they got correct on the test. To record this information, and share it with the rest of the class, Sam decided to use a shared electronic spreadsheet that every student could write on and view. Figure 11 shows two students looking at this spreadsheet on their tablets. Sam started the spreadsheet by having a header row with the number of each question on the test. In the rows underneath the students were meant to put their name and mark the last three questions that they got correct on the test. An example of the table is in Figure 12 below.

Figure 11 Shared spreadsheet assigning peer-to-peer tutoring

	Test Question							
Student Name	1	2	3	4	5	6	7	8
Kim						1	1	1
Robert			1		1	1		
Dave					1		1	1

Figure 12 Example of shared spreadsheet assigning peer-to-peer tutoring

Once all the students had recorded their names, they were asked to find on the spreadsheet which of their peers got correct questions that they got wrong on the test. Once they saw who got the questions, they were asked to pick one of the students they wanted to ask for help and go to them to learn how to solve the problem. This type of peer-to-peer tutoring has many advantages. Partly it demonstrates that every student was successful at some parts of the test and it gives an opportunity for every student to be an expert and tutor someone else, providing a boost in self-esteem and alleviating the congestion of everyone bombarding the one or two students recognised as exceling in the class. Sam described the many advantages of doing this activity in the following way.

> Someone like Tim, at the back, is really good at everything, but some of the quieter girls don't want to go and ask him because they are nervous, but they can see who else answered that question well and go to them and ask instead. Also, because I asked them to choose their last three, meant that everyone had an opportunity to say something they were good at. For example, this girl, she didn't get the best mark in the class and she got many wrong, but she answered one of the questions really well and there were people in the room who didn't realise she could do that. This gave her the opportunity to be an expert in that particular question, which is a nice feeling, and not always to be the person having to ask everyone. It also stops people like the boy who is really good in the class, from just talking all the time, because they do know all the answers. Saying that you can only pick two or three you are good at, gives them the opportunity to realise that other people in the class are good at something they aren't good at.

I categorised this activity as Material in terms of the Instrumental Evolution, as it could be accomplished using a paper and pencil method, or by having a similar spreadsheet on the board that students can fill in with their names. At first, I saw limited advantages for using the tablets for this task. I did recognise that this activity engaged students, as they could act as teachers and demonstrate their knowledge, and the tablets make the task more efficient, as students did not need to move around the class to fill in and read the spreadsheet. Talking to Sam, it became clear that although this task is possible without the use of tablets, the logistics and the classroom management issues that would otherwise arise, would make it unlikely for her to ever use.

> That would have been harder to do just on the board. I would have had to have pens to write their name, but then they wouldn't have all seen the names. Or, I could have given them all posted notes, which I did before, but it's not quite as clear. This way they could all sit down and just think about what they wanted and look for it in their own space.

Even with the efficiency of using the tablets to accomplish this task, Sam still had some technical difficulties to overcome. She did not realise that there was a small delay from the time students put their name on the sheet, and the information became visible to every other student. This caused some students to inadvertently overwrite each other and caused a bit of frustration.

Although Sam was generally happy with the way the activity flowed, she would have liked something more from the program. She was initially trying to see if a collaboration software such as Padlet, would be able to offer what she wanted. She was looking for a structured way of creating a table, like a spreadsheet, but she was hoping to have the ability for students to also take pictures of their solutions and put them next to their name. Sam wanted students to be able to not only see who got some questions right, but also what their correct test solution looked like. It is possible to attach pictures next to the text in Padlet, but since it did not provide the structure of a spreadsheet, Sam decided the activity would have become quite chaotic with every student writing freely in an empty space. This desire for the teacher to slightly change features of programs they found, was not uncommon. Throughout these interviews I did not hear from teachers that they wanted a fundamentally different program for the tablets that they could not find, something that might change a task from Material to Connect, or from Connect to Enhanced, in nature. What was often noted by teachers was the desire to slightly modify features that already existed.

The final activity in the class was using the poling software Socrative. Sam asked the students to open the Socrative app on their tablet and she wrote the code they needed to enter to access the quiz she had designed. Usually this tool was used to evaluate students' understanding of the lesson, but Sam used it as a way to capture and organise student goals, enabling her to use this information to motivate their learning later on in the term. Sam describes her intentions for this activity as follows.

> Sam: At the end, I just used it to record what they are good at, or not good at, as a way of keeping a record. Most of the time they just write it on a piece of paper that goes into their folder and in reality, I never look at it. Whereas now I have a record of all the things that they said they can do and I can ask them about it.

> Me: What you asked them on Socrative was ‘how will you improve your understanding’?
>
> Sam: Yes. First of all, weather they were pleased or disappointed with their results and then what topics they wanted to work on. I will keep this for now, but in two weeks I will take it out and ask Jackson ‘have you done this?’ or Emma ‘have you done that?’. I will do that individually because I have their individual data. When you do it as a whole class, they will either lie or it’s something they won’t often do.

This activity is another example of a task that is categorised as Material, as defined in Table 10, since it would be identical to a paper and pencil version, but it still significantly changes the teaching of the class. Because the Socrative program organises and summerises the responses in one easy to find file, the teacher saves a lot of time by not having to organise every student’s paper response. This organisation makes it possible for the teacher to easily look back in a few weeks and remind the students about the plans they made to improve their knowledge of the topics they got incorety on the test. As in other situations, the technology facilitated the learning of mathematics becaues of the organisation and efficiency it provides.

Classroom Lesson #4

Sam thought this class went well and very quickly. She said that she enjoyed teaching isometric shapes and giving the students an opportunity to draw, which is something a bit different from what they usually do in their class. Throughout the lesson the students used the tablets for five different type of tasks, although only one of the tasks could be categorised as Connect in term of Instrumental Evolution, all the tasks were valued by the teacher for different reasons.

Starting the class, Sam projected on the board a few multiple-choice questions that quizzed the students on previous mathematics knowledge. She instructed the students to open the Whiteboard app on their tablet, which is a simple whiteboard on which students can write with their fingers. The students were instructed to give their multiple-choice answer and hold up their tablet for everyone to see which letter they chose. This seemed to engage the class as all the students looked around to see what answer other students held up. This task was not different in any way from having a piece of paper and writing a letter on it to hold up. Possibly the only difference was, that there was no need for pieces of paper with a letter on it floating around.

The main goal for the class was for the students to use isometric paper to draw three-dimensional diagrams and draw their corresponding planes and elevations. Sam said that she did not know initially how she would use the tablets or what program she wanted to use, but she did want to use the tablets for this lesson. When I asked her why she felt it was important to use the tablets for this class, this was her answer.

> Because it’s a lesson the requires something more than just pen and paper, always. Either it requires having lots of isometric paper, or lots of cubes. These are things that are hard to come by because the department doesn’t have many left. There isn’t lots of physical resources around, so I wanted that iPad to be that physical resource and provide the things that I need.

It is not only the resources that Sam wanted combined into one easy use, but what she meant when saying that the lesson “required something more than just pen and paper”. Sam wanted the students to have freedom to draw whatever structures they could imagine and view them from different angles. Sam also did not want them to be limited by their ability to draw on isometric paper. She describes these important features in the following way.

> To allow them to draw lots and lots of things. Typically, they are not very good at drawing on isometric paper, and it almost wasn’t really the purpose to learn how to draw on isometric paper, it was for them to planes and elevations and for them to know what that shape was. Usually in the past, that was only possible if you had multilink cubes and then again they make them into cubes and you have no evidence that they have been able to do what you asked them to do. What’s really nice about the iPads is that they can do it, they can get it wrong and it didn’t matter because they weren’t wasting paper and like the cubes they could pull them off and stick them somewhere else. Also, they could have evidence that they have done that.

Sam found a website that allowed students to draw the way she had hoped. As shown in Figure 13 and 14, students were able to draw colourful blocks and move them around as they pleased. Although this offered most of what Sam was hoping for, she did say that she would like to modify the program to make the workspace have limitless boundaries. At the time it was used, there were boundaries to the workspace that limited the size of a shape, particularly if it was built close to the edge of the workspace.

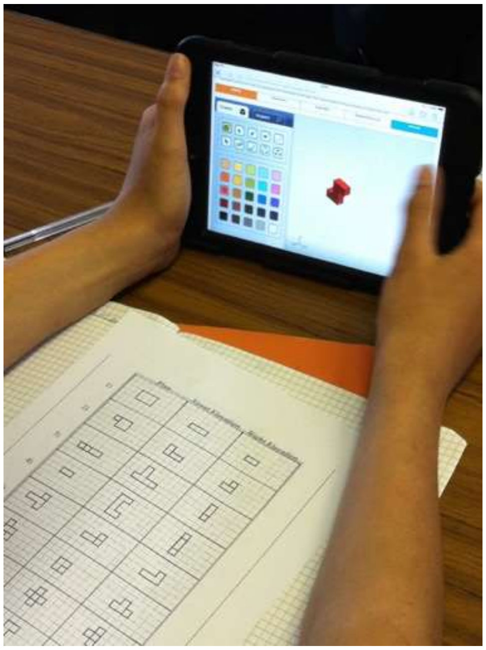

Figure 13 2D and 3D construction activity

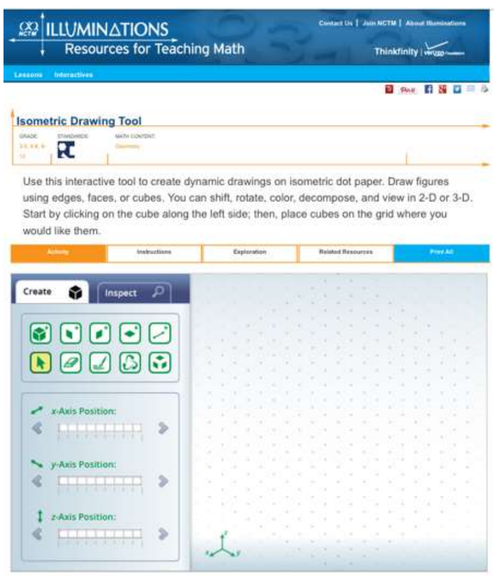

Figure 14 Screenshot of 2D and 3D construction activity program

Initially, Sam did not know what kind of app she was going to use for this lesson. After searching online, she found out about this website from Charlie, who had put it on the shared document, that the group developed in the first group meeting. Although the shared document was rarely used, as I will discuss in Section 4.3.3, this was one of the few ways in which it proved successful. Charlie had put up this website as one of the few resources she was aware of. As Charlie already stated in the initial individual interviews, she did not use the tablets in her class and was quite intimidated to use them. Even though Charlie was the least confident and least active user of the tablets, it was her suggestion of a resource that helped Sam. This highlights an important aspect of using educational technologies in teaching. There is such an abundance of resources that are scattered in different places, that it is difficult for any one person to know about the best resources for every topic. However, even someone with extremely limited experience, may know of one or two resources that other more experienced users have not heard about. This highlights the importance of leveraging and disseminating everyone's knowledge as a way of developing every teacher's professional practice, which is an important aspect of having the group meetings and fostering a learning community among the teachers.

Throughout the activity, Sam asked students to take screenshots of their finished drawings and email them to her. She used email to collect and organise the work each student did. There were a few technical issues in sending emails, with some students not able to send them. Although Sam rarely makes any comment that refers to her self-efficacy in using the tablets, she exhibits a positive self-efficacy as she listened to students' suggestions to use a file sharing program to send her the screenshots. Sam never used that program before, but was instantly willing to look at it and explore how she would use it in another class, demonstrating the self-efficacy she has in exploring new and different ways of using technology in her class. The task of emailing screen shots of student work, also served as a way of sharing and demonstrating students' work to the class. Sam describes the benefits of this and the reasons why she thinks tablets serve a very useful role in her class.

> What is nice about email is that some of them made their own screen shot of the elevation and the program lets them do. [what did they do?] they made their own shape, so they built it on the program, and there is a button on the program that allowed them to look at the plan, an elevation of the shape they had done, and without them thinking about it. This allowed them to check their work for the first bit and I asked them to take a screenshot and I can project it in the next lesson and ask them to have a go at making Jackson's shape because this is his plan, front elevation, side elevation and people can have a go at that.

Classroom management stemming from the use of the tablets, once again caused some concern, as was the case in every class that I observed. It was not completely disruptive to the class, but that may be to Sam's credit, who was an experienced teacher. In this case there were three students in the class who did not bring their tablets. Prompting Sam to pair them up with other students and instruct them on how to share the work so that they could all benefit from the class. This may not always seem like a big disruption to the outside observer, but here Sam discusses the impact that such setbacks can have.

> It's disappointing that three of them didn't have their iPad, so they worked with the person next to them. So, they all had a chance to draw and look at it, but they couldn't do it individually and they were talking a lot more to the person next to them rather than experimenting themselves. So, it was a different experience. Not necessarily bad, but different.

At the end of the class Sam asked every student to log into Socrative and complete a short quiz that evaluated their understanding of the lesson.

Overall, this was another successful class for Sam and she was happy with the way it flowed. She used five different tasks with the tablets and although there were some disruptions, she was able to navigate the class in a way she was happy with.

Summary of Sam's Post Observation Interviews

Over the four post-observation interviews with Sam, there were two key points that came up on several occasions, which was technical issues and classroom management. Sam mentioned on several occasions the concerns of technical issues, such as an app or website failing and her needing to find alternate solutions for the lesson. The most frequent factor of all the ones she mentioned was classroom management. As can be seen in Table 12, she spoke of classroom management issues ten times over the four interviews. These issues often related to students not having their tablets in the class, which left her having to pair them with other students who did have a tablet, or something like a delay in accessing an app or website causing students to go off track and start talking in the class. Sam did manage these issues with confidence and ease, but it did present a challenge in the classroom.

In terms of Sam's views on having tablets in the classroom, she rarely expressed her views. Although she often used tablets in her lessons, more than any other teacher, and she appeared to be at ease with using them, she was more matter of fact in her interviews. As can be seen in Table 15, she only expressed positive views, and she often said that tablets were useful in the mathematics classroom. This might suggest that her lack of expressing views in terms of self-efficacy and ease of use of the tablets, might imply that she has a high level of self-efficacy and using tablets in her lessons is natural to her.

Regarding Sam’s desire to use tablets differently from the way she actually used them, she did not express any significant changes that she would have liked to make. Generally, Sam was quite happy with her lessons and the ways in which she used the tablets. It was often mentioned that she would have liked small changes to programs that she was using. She would have liked minor modifications or ways of customising the program, which was not possible.

Teacher - Alex

I observed a total of four lessons that were taught by Alex, which is summarised in Table 16 using the framework developed in Section 3.3.2. After every lesson we went to the mathematics office, which was shared by approximately five mathematics teachers, and we sat down to discuss the lesson. Alex always had another class right after the class that I observed, and sometimes her other class was located on a different school site, where she had to drive to. Taking into account the limited time, some of the interviews were conducted as Alex was preparing her things to leave and organising her class.

Table 16 Post observation interviews for Alex

		Classroom Lesson 1	2	3	4
Views	Tablet self-efficacy (positive/negative)	1	1		2
	Perceived ease of use (positive/negative)				1
	Perceived usefulness (positive/negative)		1/2	2	1
Factors	Time			1	
	Resources			1	3
	Techical issues	1			
	Mathematics missunderstood				
	Support			1	
	Management				
	Classroom management	2			1

Classroom Lesson #1

The first of Alex's lessons that I observed happened after the second group meeting. The reason for this was that Alex was not using the tablets as she had a teacher trainee that had to teach more classes at the start. As I outline in Section 4.3.3, Alex was very inspired during the first group meeting and she spoke about the influences those ideas had on this lesson, where she integrated new ways for her to use the tablets.

At the start of the class Alex asked the students play a numeracy game on the Tansum.org website. This allowed her to hand back the tests and other worksheets she needed to give the students. The main purpose of the lesson was to review a test that the students had written. Alex said that she disliked these type of review lessons, because they are harder to teach as the students are distracted and more disruptive than in other lessons. Alex wanted to try Padlet to make this lesson a bit different and more engaging. However, she has never used this program before but learned about it from one of the other teachers during the first group meeting. Because Padlet provides a common workspace visible to everyone in the class, Alex decided to use this as a way for every student to contribute by adding a picture of the test problem they wanted to review. Alex describes her views on this lesson and why she wanted to use this program in the following way.

> I have to do a review lesson after each test and they are quite noisy and their behaviour is bad and they don't want to listen to how they can get better. I felt that using the iPad in that way did kind of help. [How?] With their focus on improving, combined with that I have never used Padlet before and I think at one of our group meetings someone had said that they used Padlet. I felt like this is the moment to try it. I tried it at home and I felt it was worth a go at least. I wanted to work towards where the kids could tell each other how to improve on the questions but I'm not quite sure.

Alex's initiative to try a program she has never used before during a difficult class shows that she does have a positive self-efficacy. However, the experience was not seamless. The factors that inhibited the flow of the lesson were technical issues and also classroom management issues. Although I observed several technical issues, Alex only spoke of them once in the short post observation interview. During the lesson, the many technical issues were the internet crashing when Alex tried to first open Padlet on her tablet, Padlet crashing on some of the student tablets, and some students not being apple to open their email in which Alex sent the link to the Padlet site. When Alex first tried to open Padlet and the internet crashed, one of the students yelled out "technology not working, shocker!" It almost seemed like the students expected the technology to stumble along the way.

On several occasions during the class Alex had to find alternate ways of doing things she had planned. Because some students could not access their emails, some never having installed email on their tablet, Alex realised that she should post a QR code for students to access the Padlet site. She quickly made a QR code and pasted it onto the shared workspace on Padlet, which was projected on the board.

Once all the students could access Padlet, Alex asked everyone to take a picture of a question on their test that they would like to learn how to solve. All the students used their tablets to take a picture of the question they chose, and posted it to the shared workspace on Padlet, which made their picture instantly appear on everyone's screen, as well as Alex's screen, which was projected on the board. In this way Alex took individual pictures in turn and discussed with the entire class how the question was solved and how it could be solved correctly.

As the class went on, at one point the picture Alex switches to was a slogan with slightly rude connotations. Because the program does not give a teacher control to accept the pictures students post, there is the possibility of having disruptions during the class. Alex tells me the impact this has on her class and how she would like to modify the program, also addressing some technical concerns.

> The lack of control in the software. I would have loved to be able to have some kind of control on whether a post was uploaded. So, this is a very good class and even when they are being rude they are mainly silly, but if it were offensive I had

> no control to accept or deny what goes up there. I also think the software couldn't really cope with 33 people post, since some people lost their post. I might need to see if I can change the settings.

She warned the students on several occasions that if they misbehave she will no longer use Padlet in the class, almost as a punishment. This gave me the impression that using the tablets was a form of reward for the students. I asked Alex how she thought having the tablets in this lesson helped improve the teaching and learning, which she replied to in the following way.

> The one difference would be the attention they paid to it. The previous time I did it by me going around and taking photographs of their work and we discuss those five or six questions. But I felt that them uploading the questions gave them more voice. It was better when they chose the question and upload it, it was even more of them choosing where we went. But I think that was the only difference.

Overall Alex was happy with the way the lesson went and even though there were some classroom management concerns and technical issues that she had to work around, she felt that this was a successful lesson. When I asked her what she would have liked to do differently in this class, even if she isn't aware of a particular program that she could use, she focused on features of the tablet rather than conceptually different program. As I noted with previous teacher interviews, she also focused on tweaking and customising features.

> I would like to have some way of students being able to add comments to suggest ways through some kind of digital thing, in helping other students answer questions. In the non-digital world I would just put people into pairs and they can teach each other.

The one main fundamental difference in how she would like to use tablets, but does not know how at this time, would be to find a way to multiply her efforts, in a sense add more teachers to the classroom. When I asked her what she thinks tablets could add to her teaching she said that “you might be able to help multiple people at the same time, but I’m not sure. It’s something like that.”

Figure 15 Projection of student work

Classroom Lesson #2

This was a dynamic lesson in which Alex tried several new teaching strategies. The aim of this lesson was to learn about the properties of different graphs and how to draw pie charts. Throughout the lesson there were several unexpected outcomes and Alex seems to have taken away many points on how she will teach future lessons.

At the very start of the class Alex asked students to log into the Socrative app. This was the first time that Alex used this app, after learning about it from previous group meetings. She used it both at the start and end of the lesson as a way of quickly assessing students' understanding. At the start, Alex wanted to use Socrative to facilitate with a new initiative that the mathematics department was trying to incorporate into lessons, which is the use of diagnostic questions. Alex discovered a bank of diagnostic questions and she thought that Socrative would be a good way to have the students answer them. Although the program instantly accumulates and summarises all the student responses, Alex discovered that the program does not allow for long answers. She did not know this previously, but said will know in the future how to more appropriately use the program. At the end of the lesson Alex also asked students to use Socrative to answer diagnostic questions about the lesson they just had. Because the program instantly summarises the answer, she knew that most of the students had a good grasp of the lesson by the time we had our interview directly after the class.

The core of the lesson was to learn the properties of graphs, specifically pie charts, and how to calculate and draw them. Alex was keen to try a different pedagogical approach that she called do-talk-record. She describes her rational and process of designing the lesson as follows.

> The stuff about the pie charts, that was a lesson I had developed using kinaesthetic learning. One of the things that that I fond when I was researching it was that taking photos might help them understand this more.

Alex described in previous group meetings, that researching is challenging for her because she has Dyslexia. Regardless of this, she eagerly tried to overcome her challenges and find ways, both with and without the tablets, that would help her teaching of mathematics. Implementing her new strategy in teaching pie charts, Alex got her students to go outside where they formed different type of pie charts by standing in a circle and calculating angles depending on how many students were forming the circle. Alex had two student volunteers taking pictures of the formations with their tablets. Unfortunately, the pictures were taken from the same elevation as the circle being formed and therefore were not able to capture the image of the pie chart the students were forming. As the students returned to the classroom, Alex projected the pictures taken on the board, and the students were meant to draw the graphs in their books. Unfortunately as the pictures did not show the formation of the graphs from above, they were mainly depicting students standing. Although the activity did not work quite as anticipated, Alex tried a new way of incorporating the tablets into her teaching strategy, and after trying it for the first time she came away with some ways on how to improve the lesson in the future. She recalls the activity and her thought processes in the following way.

> The idea of it is that they do a kinaesthetic activity and we talk about it and they record it themselves. It’s a methodology which I call ‘do, talk, record’. Where you do something, you have a talk about it and the students have to embed it in words or pictures themselves. Usually the pictures turn into the diagrams you use. I thought if they had some moving from outside to inside, if they had a stimulus, telling them they had stood in a circle, that might help them when they try to do that written thing by themselves, they have another try of doing it. That was the idea of it, but I don’t think the pictures were useful enough.

Although there was significant initiative taken by Alex to use the tablet and to use it in a valuable way, this activity provided more lessons for Alex than for the students. However, Alex tried something that was completely her own initiative and using the tablets in a way that did not seem to be used by other teachers. Possibly more time in the planning process might have let Alex to realise that the pictures should be taken from above. Although she did not mention it in this interview, she and other teachers have mentioned several times the need for more time to prepare for lessons and plan ahead.

After returning to the class and discussing the pictures taken outside, the students had a worksheet on which they needed to calculate the angles of pie charts and draw the pie charts. I noticed that students were using a variety of calculators to do this. Some had their own calculators, and others were using a variety of calculator apps or websites on their tablets. This caused some frustration for Alex.

> It’s not standard which is ridiculous. It’s the one thing that I really wish they wouldn’t use because their iPad calculators are old fashioned and modern calculators are better. I wish they didn’t use their iPad for this, or I wish there was something as good as a calculator.

This was one of the two views Alex expressed that indicated she did not perceive tablets to be useful. The other reasons was that Socrative did not allow for long worded answers. This brings to light once again that teachers have expressed ways in which they would like to tweak or customise the existing apps and programs that they use on tablets. Alex did not express a desire for a type of app or program that she thought would be useful but could not find, rather she expressed a desire for small changes to the software she used that would make it more useful for her class.

Classroom management was an issue that was observed during this class, although Alex did not discuss this during the interview. Possibly because she was concerned with explaining a new teaching strategy and the challenges she faced because of it, but she did not focus on factors impacting her lesson. However, I did notice that some students did not have their tablets, which required them to pair up with other students and Alex gave her mobile phone to one student to use for the Socrative quiz. There were also some delays as some students mistyped the code to access the Socrative quiz or they were playing with their tablets when Alex was giving instructions at the front of the class. It is not unusual for students to cause disruptions in class or not be attentive, but the tablets presents a different set of ways they can do that, requiring the teacher to use new strategies. One strategy Alex used, was asking for the tablets to be put face down before she started giving instructions at the front of the class. This was a strategy also used by some of the other teachers.

During the interview Alex had the opportunity to reflect on one of the ideas that came to her while she was teaching. As she discovered some of the limitations of the Socrative program, and the limitations of her activity of going outside, she realised that she could make this lesson engaging without using kinaesthetic learning by using student data to show how to create pie charts. She described that in the future she will use Socrative to pose personal questions to the students, such as “what is your favourite colour?” or “how many siblings do you have?” and use that multiple-choice data, which is instantly summarised by the program, as the basis for creating pie charts. She reasoned that since the students have emotional connection to their answers, it would be an engaging way for them to see how pie charts are calculated.

This lesson was significant for Alex. She had the confidence to try a program and a teaching strategy that she has never tried before. Although in the interview she did not discuss her views as representing a positive self-efficacy, her actions spoke volumes. Alex was hardly using tablets at all before being involved in this research, and at this point she was venturing to use new programs that she learned about from her colleagues during the group meeting and trying new teaching strategies in which she found ways of using the tablets in new ways. Although the lesson did not achieve what Alex had hoped in every way, it was a significant demonstration of Alex’s development in using tablets in her teaching.

Classroom Lesson #3

The objective of this lesson was for students to learn how to calculate the diameter and circumference of a cricle. This was a topic that Alex said the students did not fully grasp at the start of the year and needed to be retaught. Alex used four different tasks requiring the tablets throughout the lesson, which were all categorised as Material, but they facilitated the class to be more efficient and engaging, particularly by giving instant feedback to studnets and helping them engage with their work.

At the beginning of the class Alex posted two QR codes, each leading to a differnet activity on the tablets. The students were instructed to start with the activity that could be accessed with the first QR code and then move on to the second one. The first activity was a electronic worksheet for the students to solve. Part of the worksheet can be seen in Figure 16. The students had to work out the problems in their books and put the answers in the worksheet to check if they were correct. The second QR code led to an app that allowed students to put in measurements of a cirlce and the app calcuated the remaining dimensions. This app was to be used with a paper handout on which students had to measure properties of a circle and calculate either the diameter or the circumference. This app was particularly useful as measurements made by hand are often inacurate, which would lead to different results of the calcualtions. Having an app to calcualate the differnet dimensions of a circle allowed for every student to check their own unique measurements. This activity can be seen in Figure 17. Alex explained that this type of easy access to digital resources can help individualise learning in a mathematics classroom and also save time and resources for the teacher.

> The thing about differentiation in maths is that it has to be very paper based. You have to photo copy every resource for every student and then you are in a snow of ‘ok you are done this task now do this task’. It was quite nice to be a lot simpler to plan when people are moving to the next thing when they need it.

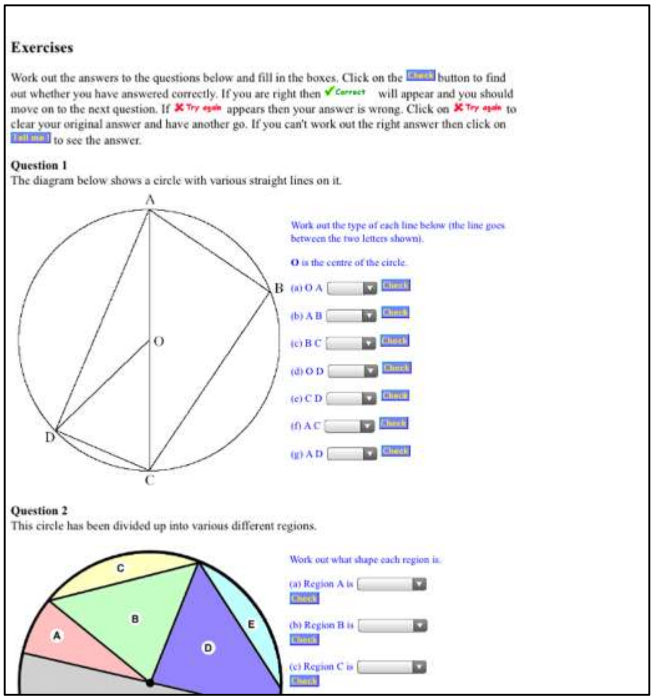

Figure 16 Interactive worksheet for circles

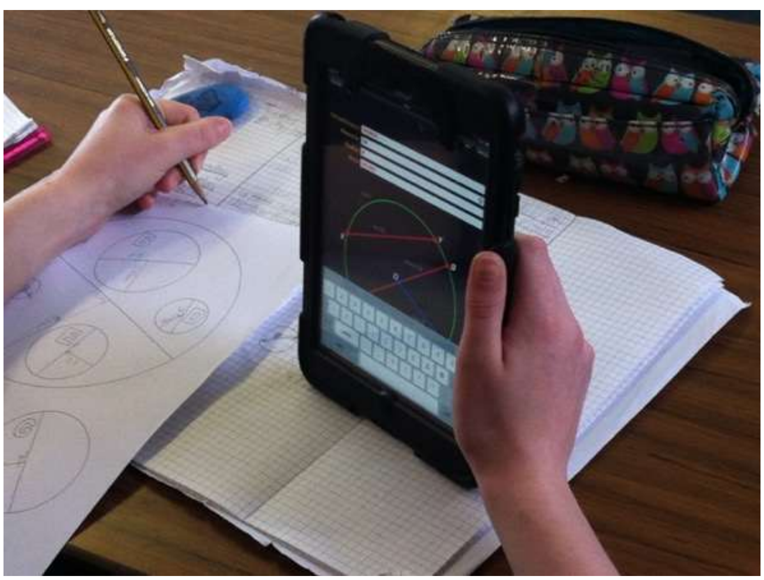

Figure 17 App to calculate dimensions of circle

Finding the app that calculated the properties of cirlces was something that Alex may not have thought about where it not for the group meetings, in which she had the opportunity to collaborate with her colleagues. As an enthusiastic user of technology, Alex tried to use the tablets when they were first introduced to the school, but withdrew for the many reasons she described in her individual interview at the start of the proejct. However, talking to Sam in the group meeting reminded her of some great resources, as she describes how she found the app and why it is useful.

> I found it ages ago, I found it when I was first looking at maths apps about two years ago, when I just typed in 'maths apps' and this came up. When we were talking about ways to check things, and I think Sam was talking about possibly typing numbers into a spreadsheet to check if the angle looks the same as what was done. At that point I thought maybe we can use that app to check whether our calculations are correct. It was actually designing the lesson from there and saying well actually I have these sheets which would be really good for them to measure and calculate, and they could measure slightly different values that they can say is 7.9 rather than 8 and they would be able to get feedback on them being right or not.

Alex found the class to be a success, even though there were some classroom managemenet and technology issues. She did not even mention these in the interview as it seemed that they did not preoccupy her, she just focused on the new ways she was using the tablets. However, there was significant problems with the teacher computer at the start of the lesson and the projector initially projected the instructions in tiny print, making it unreadable. Alex had to call the school's technical support to help fix this problem. There were also classroom management issues where some students did not bring their tablets and had to work in groups, and Alex gave one of them her private smartphone. At one point her phone started to ring which the student using it anounced to the class, causing a small disruption.

At another point in the class, Alex went over to one student and asked him to focus on work and stop using the tablet to shop online. These are new types of issues that are pressented to the teacher with the introduction of tablets. These incidents were not mentioned by Alex duirng our meeting, possibly because they have become normal classroom occurances and maybe this reflected the greater ease with which Alex was juggling the use of tablets in the classroom and the obstacles they pressented.

At the end of the class, Alex wanted a short diagnostic quiz to see where studetns stood with their understanding of the lesson. She posted two questions on the board and asked students to calculate the answer, write it on the Whiteboard app, and hold it up for everyone to see. This gave a glimps to Alex, and the other students, what everyone replied to the quetsions. In the interview Alex said that she wanted to use a Socrative quize for this, but since the class went overtime, this was a faster way of getting a quick diagnostic.

Alex was happy with the way this lesson went and how she incorporated technology. She felt that she achieved what she wanted. Again, when asked what she might have wanted to use for this class, but either couldn't find or possibly doesn't exist, her answers focused on small tweeks and customisations to the programs she did use. For instance, she wished that the digital worksheet did not have a buttom to reveal the correct answer, rather she wanted it to only say if it was right or wrong.

At the end she used the whiteboard app for quizes, she wanted it to be Socrative but they ran out of time so she could not get students to do that. For the app, rather than act as a calculator for the measuremeants of a circle, she would have prefered to allow students to enter the answer and only say if it was correct or not, without revealing the answer. These are small modifications but the way Alex experesed it they would make a big differnce in helping students focus on working out the correct answer and not be able to simply get the right answer. This notion of tweeking exisitng apps, or customising them, has come up on several occassions from teachers and is something that I realised through the analysis that needs to be highlighted, as it may hold some significance for the way programs might be designed in the future.

Classroom Lesson #4

I arrived early to the class I was about to observe and waited for Alex. When she arrived, she was surprised to see me and said that she forgot that I was observing her class today. But this brought to light how natural it became for her to use tablets in her teaching, as she reflected that “it just goes to show how embedded it is in my practise already".

The focus of the lesson was on calculating the area of compound prisms, with most of the time dedicated to students practicing by solving many different problems. There were two tasks for which the tablets were used, the first being a QR code which launched a PowerPoint presentation on each student’s tablet. The second task was using these

PowerPoint slides as a worksheet. The slides had some instructions on how to solve the area of compound prisms and many other problems for students to solve. Both of these tasks can be categorised as Material in terms of Instrumental Evolution, as the task would be the same if the teacher handed out paper worksheets to every student or used a textbook. When I asked Alex, how these tasks were different if she did not have tablets, she said without hesitation that they are not. However, the school does not have textbooks and it seems to be the general understanding among the teachers that so many photocopies cannot be made. These do not seem to be reasonable justifications, as it would certainly cost less to buy textbooks and make photocopies than to provide each student with a tablet. Although this might be true, it is likely the compounding benefits of using the tablets in this way, to replace some other resources, and in ways that improve teaching and learning. Whatever the justifications may be, from Alex's perspective using the tablets was a great improvement on what she otherwise would have done in this lesson, which is write the questions on the board. She explains her reasons for using the tablets in this way.

> The purpose was to allow them to be slightly more flexible about the order in which they worked through the questions. There is a finite amount of space on the board and it's allowing them to work at their own pace but still get review from me when they get stuck.

In addition to the reasons Alex described, she also said that having the problems in front of each student made them more engaged in their work than if the questions were projected, or written, on the board. I did not categorise this task as being engaging in my observations, because I did not see this connection, but from Alex's experience this was the case.

As the students were working through the problems, either on their own or with a friend, I noticed some students using the tablets in unexpected ways. As seen in Figure 18 the students were using felt pens, which they discovered can easily be erased from the screen of the tablet, and started drawing over the shapes to help them work through the problems. Rather than redrawing the shape on paper, they saved time by segmenting the shapes into more manageable segments that they can solve for the area. Alex was quite surprised and pleased to see this initiative. She took one of the tablets and showed the class that this form of helping them visualise the smaller segments of shapes might help them solve more easily. In this lesson, and the previous ones that I observed, Alex seemed to be very comfortable embracing situations in which her students were more knowledgeable or innovative in using the tablets. She did not shy away from asking students to help with technical difficulties, or celebrating students' ideas or initiatives on how to use tablets in the classroom.

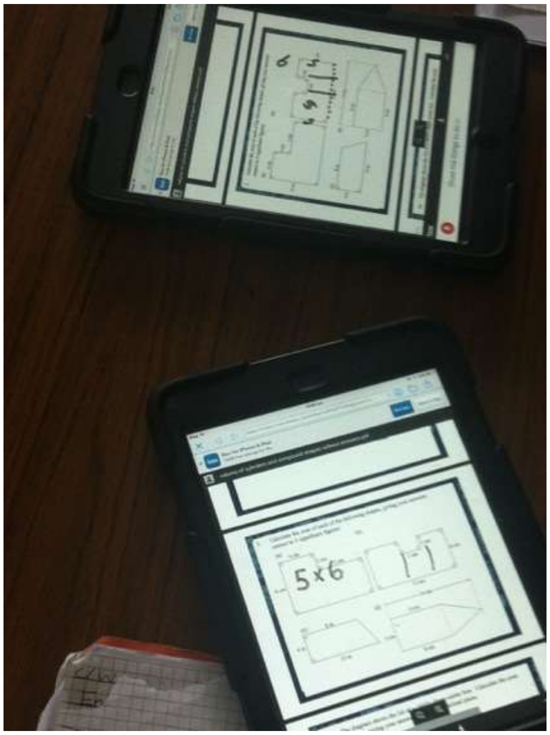

Figure 18 PDF worksheet

Alex was generally quite happy with this class, despite the regular issues classroom management that arose from the use of tablets. Once again, three students did not have their tablets and half way through the class one student's tablet ran out of power as it was not fully charged at the start of the day. Alex paired students with those who had tablets and also handed out her personal smartphone again. Later in the lesson Alex noticed that a student did not have a tablet but did not raise her hand at the start to say she needed one. This time Alex gave her laptop to the student. Although Alex made remarks during the class about these incidents, which were disruptive as she was distracted by having to manage these incidents and had to give up her own devices, she did not mention them during the interview following the lesson. She was focused on talking about the tasks how she would like to improve them. Possibly she has gotten used to these type of classroom interruptions and manages them with the same ease as any other classroom management issue. This may also represent a level of comfort that Alex has acquired with the use of tablets. It is hard to tell if these classroom management issues compound on previously existing issues or if they have replaced other classroom management issues. It is not clear if in the long term, once the technology is no longer a novelty and students and teachers are accustomed to it, the use of tablets causes more classroom management issues than before. However, it is possibly a good indication that after a while classroom management is not the main issue on Alex's mind following a lesson.

When asked what she could imagine as being the most beneficial way of using technology in this type of lesson, Alex had several suggestions. She did not describe a completely new program that she might imagine benefiting the learning of this lesson, rather she described modifications to the existing way in which she used the tablets. Alex focused on characteristics that would mimic the instructions a teacher might give, in essence multiplying the teacher in the class. She described what she would like to see in the following way.

> Something that would talk them through the shape. The girls at the back of the room were drawing it out on top of the shape (on iPad) with a whiteboard pen and that allowed them to be more confident with what they were doing. If something prompted them through the chopping up of the shape, maybe asking what the individual sides were, because I get questions of 'what's this' 'what do I have to do next' but they just can't do it on their own.

When I asked her if she found a program like this, she said no, and actually she did not even try to find it. She said that actually she did not have the confidence to find programs that would work most of the time. This lack of self-efficacy was evident in this lesson. Although she finds the use of tablets useful, the technical issues and the possibility of a program not working during the lesson loom large in her mind. Alex also was starting to become quite frustrated with the type of programs she was able to find. In each interview, she expressed changes she would like to see in the programs she used, but now her frustrations were becoming clearer.

> I have never found exactly what I want, so I have given up looking for it. I'm so specific of what I want, there is no way it is going to exist. Maybe I should make friends with some app developers.

Even with her frustrations, Alex had many ideas on what she would like to see in the tablet programs she could use in this lesson. Although she did not mention any tasks that could be categorised as anything other than Material, her rational for the programs she would like to see were linked to how they would be helpful to students' learning.

> I would really like to look at doing screen casts with a little video writing and someone explaining. So when they are stuck in a lesson they can press on something and it would go 'actually when you are doing this lesson you need to think about this and this' I think that would really help this class.

Summary of Alex's Post Observation Interviews

Over the four post-observation interviews with Alex, there were two key points that came up on several occasions, which was Alex's desire to design tasks that facilitated individualised learning and the modifications she would like to make, but could not, in the tablet programs she was using. Throughout the interviews, it seemed that Alex was enthusiastic about using the tablets and developing her practice. She talked about the ways she researched and found programs, also mentioning ideas she acquired from her colleagues. But her frustrations were also evident. In almost every program she used on the tablets, there were ways that she would have liked to improve those programs and make them more useful for her class. She wanted to help her students learn at their own pace and at their individual skill levels, but most often this was not fully possible. As part of this effort she was keen to find ways of multiplying her own efforts, by having tutorial or demonstrations on the tablets. Although there are many YouTube videos, Khan Academy tutorials and demonstrations of mathematical concepts online, Alex did not embed these resources in her lessons. This may have been because she was already making significant changes in using the tablets and trying new programs on them, something she did not due at the start of this project. Although in the observations it appears that she was using the tablets extensively in her lessons, this was not the case at the start of the project. Because of scheduling setbacks, the first observation that I was invited to took place after the second group meeting. Alex eagerly embraced ideas on how to use the tablets starting at the first group meeting and immediately implemented some ideas in the lessons following the meeting. These will be discussed further in Section 4.3.3 where the results of the group meetings are reviewed.

In terms of the views that Alex expressed over the four post observation interviews, she had a mix of positive and negative views. Overall, she was quite positive about how she perceived the usefulness of tablets in teaching mathematics. It was striking that her self-efficacy progressed from positive to increasingly negative over the four interviews. This might be due to some of the factors that impacted her use of tablets.

Generally, Alex focused on discussing the ways she used the tablets and how she would like to use them, but did not talk a lot about the factors impacting her use. Most frequently she mentioned classroom management concerns and resources. It was evident in the observations that she regularly had classroom management concerns, particularly in the sense that in every class there were several students who did not bring their tablets. In terms of resources, Alex was frustrated by the difficulty in finding the programs she wanted and used the tablets also as a replacement of physical resources that were not available in the school.

Teacher – Charlie

I observed a total of two lessons that were taught by Charlie, which is summarised in Table 17 using the framework developed in Section 3.3.2. After every lesson, we stayed in the classroom where Charlie taught, which was usually quiet and undisturbed. She teaches a very small class, with only nine students, but every student in her class has special needs and significant learning difficulties. They are all in Year 8, but they are working around a level two since all of them are very poor in their basic number skills. Because all the students need very individualised attention, Charlie also has a teaching assistant in her class at all time.

As Charlie explained in the initial teacher interviews in Section 4.3.3, she never used the tablets in her teaching and did not even know where to start in terms of finding the right programs to use. In Charlie's first lesson that I observed did not involve any activities using the tablets, however it is valuable to include this interview as it provides some information on why Charlie did not use the tablets and how she was preparing to start using them.

Table 17 Post observation interviews for Charlie

		Classroom Lesson 1	Classroom Lesson 2
Views	Tablet self-efficacy (positive/negative)	1	2
	Perceived ease of use (positive/negative)		1/1
	Perceived usefulness (positive/negative)		2
Factors	Time		2
	Resources		1
	Techical issues		
	Mathematics missunderstood		
	Support		
	Management		1
	Classroom management	1	

<u>Classroom Lesson #1</u>

The purpose of this lesson was to teach the students to divide by four. Charlie used a variety of different learning strategies and activities to help build the students' knowledge up to the point where they can calculate what a quarter of a number would be. Before discussing the mathematical tasks and activities, it is important to understand the needs of her students as it greatly influences her teaching and the technology that she could choose in the future. In addition to her students having very low numeracy skills and a variety of different learning difficulties, Charlie said that the biggest thing that she struggles with is dealing with their social interactions. The students do not support each other and very often shout out during class. For this reason a few weeks prior to this lesson Charlie introduced 'behaviour objectives' which she learned that educational psychologists suggest in order to help them show respect. This works by Charlie putting a tick next to the name of a student who puts up their hand and -1 when they shout out. The goal is to end each lesson with more ticks than they had at the start of the lesson. When a student reaches 15 ticks, they get a prize.

In this lesson Charlie used several strategies to help students understand the meaning of dividing something by four. First, she used a meter stick with stickers at every fourth number. Then the class counted in fours together and then in small groups. The main activity was for students to work in pairs and find a way to cut objects into equal quarters. Charlie showed them the objects they would have, which can be seen in Figure 19 and asked them to first discuss in pairs how they would be able to cut them into four equal parts.

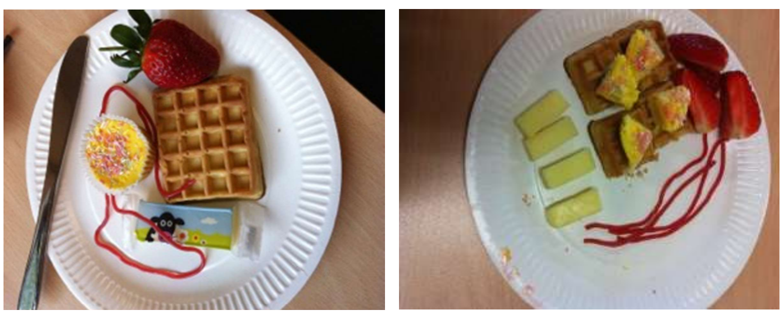

Figure 19 Equal quarters activity

Charlie summarises her main goal for most of her lessons. “It’s all about making that visual link for them with what they are trying to do mathematical, with something visual that will support them.” This is something that the tablets would ideally help in her class, particularly as one of the largest categories of mathematical apps are to visually enhance numeracy skills in younger learners. However, at this point she did not find a way to incorporate them. What is also important for Charlie is for her to see the students create during the lesson, because it not only creates a memorable lesson for the students but Charlie is also able to understand how the student is thinking when she sees them creating something in order to learn mathematics.

Through most of the post observation interview, Charlie focused how and why she used the strategies she did to help them learn. Since she did not use the tablets, and she already explained her reasons in the individual interview as well as in the prior two group meetings, I did not ask her about why she did not use tablets or how she would like to use them in the future. However, it was evident that Charlie saw value in using the tablets and was trying to find a way to use it in her class. She started discussing this towards the end of the meeting when she was summarising what her students needed as learners.

> Charlie: You have to make them feel that bit of success, without making it too easy. This is quite challenging. This could be where the tablet might come in to be honest. They might actually be more motivated to try something on the tablet.
>
> Me: What about it would be more motivating?
>
> Charlie: I wonder... My worksheet goes up in difficulty. If they were playing a game or something, so that once you get through the first ones it got harder and it would respond to what they were doing.

Charlie seemed to be focused on ways to engage her students and try to individualise learning in order to accommodate their different abilities. These characteristics exist in several numeracy apps, particularly for early years mathematics, which is the level she was working on. When I asked Charlie what the reasons were that she decided not to try and find an app for this type of work she quickly responded.

> Oh I wouldn't know where to start with the tablet to find anything. I've had such bad experiences with other classes, to be honest. It was the cover lesson from hell. It was all an emergency, so the teacher wrote one sentence what she wanted the students to do. I knew it was a demanding class because of their personalities and half the class didn't have their tablets. It was horrible, they didn't want to share, and there weren't any tablets to go around. It was ghastly.

The first issue raised is what Charlie had said before, she does not know where to begin finding programs for the tablets. The other issue revolves around classroom management. As I observed with the other teachers, it is a regular occurrence that some students do not have their tablets, requiring the teacher to find a solution on the spot, juggling several classroom management issues at once. As it could be seen in Alex's interviews, she always had classroom management problems, but over time, as she became more familiar and comfortable using tablets in her class, she was able to more comfortably manage these issues, to the point where she often did not mention them. Before a teacher becomes familiar and comfortable using tablets, or other technologies, in the classroom there are many different hurdles that are piled up at the very beginning of that journey. It is not just about learning to use tablets and finding the right apps, but also about managing technical difficulties and the different type of classroom management issues that are brought on by tablets.

Classroom Lesson #2

This was a successful lesson and a big milestone for Charlie. This was her first time using tablets to teach her class and she was happy with the results. The focus of the lesson was on learning to convert the representation of time from analogue to digital, and vice versa.

At the start of the lesson Charlie asked every student to download the two apps they would use in this lesson, they were both apps to help connect the digital and analogue representations of time. The act of downloading the app required some time as students needed guidance and some forgot their Apple ID or passwords needed to download. Once everyone was settled, Charlie started to teach the conversion of digital to analogue by show a hula-hoop with tickers marking the hours like a clock. She broke the hula-hoop and stretched it into a line, showing the students that a clock was the same as a number line. This type of visual representation is a central part of Charlies lessons and something that she says is essential for her students to learn.

Moving on to the tablet activity, Charlie had a very clear idea what she wanted to achieve. Although she never used tablets before, and was extremely hesitant and nervous to use them, she knew what she wanted to find.

> I wanted them to make lots of mistakes and know instantly where their mistakes were without me having to mark it and tell them where their mistakes were. I wanted it to be instant feedback to see whether or not they got it right and also to have a second chance at getting it right.

Similarly, to the other teachers, Charlie was looking for a program that gave instant feedback to her students. She wanted the students to have the opportunity to experiment over and over until they started to make the connection. This is similar to what other teachers wanted to achieve by having the students graph many equations to gain an understanding for the relationship between the equation and its graphical representation. This type of connection is not possible with a paper and pencil task, which is why Charlie's activity was categorised as Connect in terms of Instrumental Evolution.

In addition to the connections being made for the students, they were also able to control the level of difficulty of their task, depending on how well they were doing at getting correct answers. Charlie noted that she greatly appreciated this because it made the task a very personalised learning experience. This idea of personalised, or individualised, learning has been raised by other teachers as well and something that I started to notice as a trend throughout the interviews. This was not something I had coded for in my observations, but it was becoming obvious that it was important for teachers.

As Charlie mentioned in the first post observation interview, as well as in the group meetings discussed in the next section, she was very nervous about using tablets in her lessons and she was expressing several negative views regarding her self-efficacy.

However, this lesson started to shift that view for her. She was happy to recall how the tablets worked in her lesson.

> This was my first go using iPads, I've never done it before so I was anxious about how they would load it on their iPads. But it went much smoother than I thought it would be. I thought it was going to be a major hassle, but it wasn't. The bits that I liked about it was that it actually engaged which I don't think they would have been if it were a paper activity. It meant that they had some selection about how hard it was.

She was very pleased by the progress her students were making and she said that she did not think the same would have been possible using pencil and paper. Although Charlie often stated that she sees potential for using tablets, and that was a reason why she decided to join this project, but as she was starting to use the tablets these views were become more solid.

As Charlie's views were becoming more positive, there were still several factors that she felt strongly inhibited her ability to use the tablets. Time and resources were some of these factors. She recalled how it took her hours to find the apps that she did, sifting through many apps that were not suitable or simply terrible in their design. She had to do these preparations during the weekend as she did not have time during her busy work schedule or support to help her find the right app. She said that in time and funding would be very important for her. She found some apps that would have been very useful for her lesson, particularly with the special needs students she has, but the resources are not in place at the school to fund that. The issue of resources extends to both, the availability of quality apps as well as the resources offered by the school in terms of time and budgets given to the teachers in order to help them use the tablets as effectively as they would like.

Another factor that Charlie indicated would be helpful to her would be to talk to her colleagues who use tablets to learn what they are doing with them. This was not something that Charlie could easily do before I organised the meetings, that are a significant part of this project, because of the structure of her work schedule. However, when I asked if she wanted to use the tablets in future lessons her resounding answer as “Yes, definitely”. And as I wondered what she might do differently, her focus was on connecting with her colleagues.

> I would like to talk to Katie. Katie had this idea of me using this QR codes and I thought that it would be good. I tried to work out initially how to use them, but I just couldn’t. I need to talk to Katie to see how she does that. It was ok today, but I can’t imagine that on other days it would be so easy.

Having a variety of resources to help use the tablet and someone to learn from in how they use the tablets in their teaching, were strong factors that impacted Charlie. Although her views were always that the tablets are a useful addition to teaching and learning of mathematics, and particularly she felt they would benefit special needs students, she needed a variety of factors in place and support to make this a reality and continue building her self-efficacy to help her try new ways of using tablets.

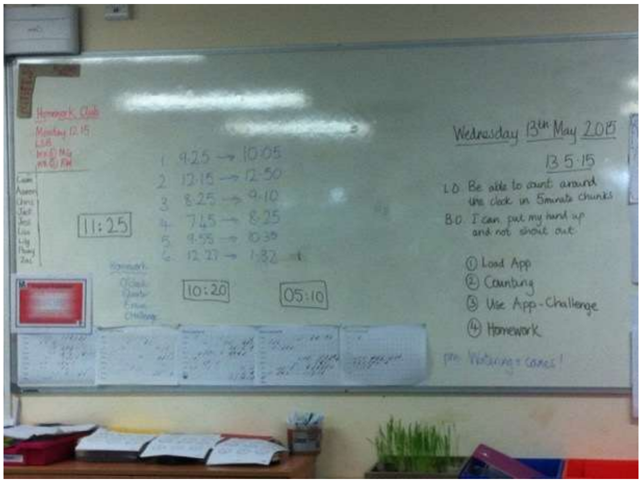

Figure 20 Organisation of lesson

Figure 21 Digital to analogue time app example 1

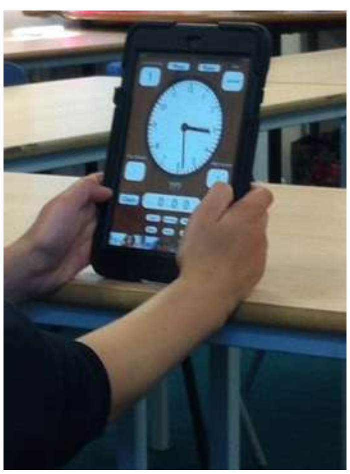

Figure 22 Digital to analogue time app example 2

Summary of Charlie's Post Observation Interviews

The class that I observed, in which Charlie used the tablets, was a big step for her. As she discussed in the post observation interviews, as well as in other conversations, there were several reasons that contributed to Charlie's slower adoption of the tablets in her teaching.

The students Charlie taught were very different from most of the Year 8 students. Her students had multiple social and learning difficulties, and they were at a much lower academic level than the other students. Although there were only nine students in Charlie's class, each of her students had very different needs and challenges that she had to attend to. Charlie often spoke about her lack of knowledge about tablets, and lack of time to research how to use them, but the barrier of entry to use the tablets was likely much greater because Charlie already had a lot of challenges to address with the students she had in her class. In addition to the extreme differentiation that Charlie needed to ensure in her class, she also had to guide her students more in how they use the tablets - remembering their passwords, instructing how to use programs, and bringing the devices to class. Charlie often focused on her own challenges of learning to use tablets and not having enough time to find programs that she needed, but the special needs of her students likely contributed greatly to raising the barrier of entry for Charlie.

With all the reasons combined, Charlie needed a specific and personally tailored approach to help her use the tablets effectively. She was adamant that she did not want to use them for the sake of putting technology in the class. With the support and guidance from her fellow colleagues in the group meetings, she could step over the barriers and start using the tablets in her class.

Summary of All Post Observation Interviews

The post observation interviews had the dual purpose of giving time for the teachers to reflect on their practice, as well as to give me the opportunity to better understand the teachers experience of using the tablets, their views, and the factors that impacted them. In Table 18 I present the combined results of coding from the interviews. Coding these interviews helps guide the analysis by pointing out particular trends, however the codes must be combined with the qualitative insights that the interviews provide. Since the interviews were open ended, the teachers did not answer the exact questions on every occasion, also because the teachers had full control of which classes, and how many, I would observe, I did not have equal number of classes for every teacher. These reasons prevent a direct numerical comparison among teachers and a clear indication of trends based on numerical values alone. However, the codes provide an overview and a different perspective that contributes to building the understanding that I seek in this study.

Table 18 Post observation interviews summary

		Total for all Classes by Teacher				
		Jordan (5 classes)	Sam (4 classes)	Alex (4 classes)	Charlie (2 classes)	**Total**
Views	Tablet self-efficacy (positive/negative)	4	1	1 / 3	3	**6 / 6**
	Perceived ease of use (positive/negative)	1 / 3	2	1	1 / 1	**4 / 5**
	Perceived usefulness (positive/negative)	11 / 1	10	4 / 2	2	**27 / 3**
Factors	Time	2	1	1	2	**6**
	Resources	1	6	4	1	**12**
	Techical issues	3	4	1		**8**
	Mathematics missunderstood					
	Support			1		**1**
	Management	1			1	**2**
	Classroom management	4	9	3	1	**17**

From what the teachers said in their post observation interviews, it appears that they have quite positive views of the use of tablets in teaching mathematics. There was a clear majority of positive views expressed about the usefulness of tablets in teaching mathematics, with 27 positive views compared to three negative, although there were slightly more negative views on their views of how easy they are to use. This imbalance might be because of the many factors expressed by the teachers that inhibited their classroom teaching. Most of the factors noted were classroom management concerns that impacted their use of tablets. Classroom management was often intertwined with resources and technical issues noted, but it was the main concern for teachers.

Classroom management was the most frequent concern stated by the two teachers, Jordan and Sam, who expressed the most positive views on their self-efficacy. Both Jordan and Sam only expressed positive self-efficacy views and yet they each commented on classroom management factors more frequently than any other factor. Alex had classroom management as the second most frequent factor after resources. From other data sources, Jordan and Sam were the most comfortable and frequent users of tablets at the start of my project. They also expressed significantly more positive views of the usefulness of tablets than Alex and Charlie. It is not clear why classroom management was more of a concern to Jordan and Sam than other factors, but it is also a bit difficult to compare directly, as there were not the same number of interviews for each teacher and with open ended questions, they were able to talk for as long as they liked about the issues most pressing to them. It is more important to note the main factors that the teachers discussed, which inhibited their ability to teach the way they would have liked.

Because the post observation interviews were in a short, and often hasty, period of time directly following a lesson, the teachers were very focused on what happened in the class. In these minutes of reflection, they did not discuss ways in which they would ideally like to use the tablets for the topics they were teaching, rather they focused on the way they planned to use the tablets in that lesson and the successes and challenges they had with their planned use.

Overall, the post observation interviews provided insight into the way the teachers thought about the use of the tablets directly following teaching with them. These interviews captured their views and the factors they felt impacted them, and they also shed light on how they intended to use them and what they experienced while teaching with them. The teachers raised topics of the features they valued, which were not always being captured by the framework, and provided insight into how they maneuverer challenges in the classroom and changed their teaching strategy.

4.4.3 Group Meetings

As described in Section 3.3.3, I organised the teachers to meet as a group, during which I facilitated the meeting with certain objectives in mind. There were four of these group meetings in total, which was less than I had planned for. The two factors that impacted the reduced number of meetings was firstly the change in the tablet policy at the end of the school year, that I described in Section 4.3.1, and the time available to the teachers. At the December 2014 meeting that I had with the mathematics teachers and the head of the mathematics department, we discussed and negotiated the logistics of Phase 2 of the project. The original number of eight meetings were more than the teachers could commit to, therefore the number was reduced to five.

The timing of the meetings was scheduled directly following the last class of the day and the location was in the school library. Since the library was generally empty after school had finished, the teachers agreed that this would be a good location. Prior to each meeting I came early to set up my computer and make sure everything was in order at the library. As a gesture of gratitude for taking their time, I always brought pastries and made tea for everyone. When everybody arrived, there was always a few minutes of lively conversation before the start of the meeting. To maintain transparency and trust, I clearly told the teachers when I was starting recording with my laptop.

In the following section, I present the results for each of the four group meetings, by highlighting the key themes that emerged.

Group meeting #1

As outlined in Section 3.3.3, the aims for this meeting were mainly to have a group discussion establishing where the teachers were at the start of their project in their views on, and use of, tablets as well as an understanding of the factors that impact their use of tablets in teaching mathematics. These are similar questions to those asked individually during the teacher interviews, however, in a group discussion I expected the participants to bounce off each other's answers and delve deeper into the questions. The other goal of the first meeting was to ease into the group meeting structure and create cohesion.

Table 19 summarises the ways teachers expressed use of tablets, as well as the ways they desire to use tablets, which is represented by the number being placed in brackets. Desired use of the tablets refers to times when a teacher describes a way of using the tablets that they would like to try in the future, but have not yet done so. The table also summarises the teachers' views about using tablets in their teaching, and the factors influencing their use of tablets. Unlike in other data sets, I also code for knowledge exchange, which I defined and described in the coding portion of Section 3.3.3 in the Methods chapter.

Table 19 Key points discussed in first group meeting

			Jordan	Sam	Alex	Charlie
Use of Tablets (Values in Brackets Indicate Desired Use of Tablets)	Instrumental Evolution	Material	3	6	4	
		Connect				
		Enhance				
		Extend				
	Efficiency	Resources		2		
		Classroom management				
		Instant formative				
		Teacher multiplied		(1)		
		Increased exposure to subject				
		Speedy access				
	Engagement	Instant feedback		1		
		Creative				
		Student as teacher				
		Visually enticing				
	Views	Tablet self-efficacy (positive/negative)			1	2
		Perceived ease of use (positive/negative)		1		
		Perceived usefulness (positive/negative)	1	2	2 / 2	1
	Factors	Time		1	2	1
		Resources		1	2	1
		Technical issues	2		1	1
		Mathematics missunderstood	1			
		Support	1	1	1	
		Management	2		1	
		Classroom management			2	1
	Knowledge Exchange	Conversations in which help was offered or knowledge was exchanged	4		5	1

Overall, the teachers were very much in agreement on the issues being discussed, which mainly revolved around the factors that impacted their use of tablets, such as time allowed by the school to learn to use tablets and support from the school in helping them use tablets. Although they were all at different stages of using tablets in their lessons, they faced very similar frustrations and desires for improving the use of tablets. The discussion was highly participatory with people expanding on points that one person was making, and growing the ideas into new directions. Each person seemed very open to discussing their experiences and feelings on the topic, there was not a sense of hesitation.

Use

As can be seen in Table 19, there was minimal discussion about how teachers used, or intend to use, tablets. Charlie described a vague desire to use tablets as a way of demonstrating mathematical ideas to her students who all have special needs. She was describing a way to visualise and make connections to mathematical ideas that are not possible, but she did not know how this could be achieved on a tablet.

Although they all used tablets differently, they all agreed that the goal for using tablets was to have students learn independently, which was something Charlie mentioned first. This was not a code that I originally had, but I decided to add new codes when the teachers were discussing ways in which they would like to use tablets that was not part of the framework used. Alex was the first to raise this point as she frustratedly explained that she only used tablets as a calculator or to plot graphs, but she was completely against this practice as it simply replacing other technologies. She felt that there are ways of getting students to learn independently, but everyone agreed that this was a massive leap from where they, and the school, were at the time. The most important factors were having the resources and the time to achieve this. Alex acknowledged that although she would very much want to get to this place of independent learning "It's quicker and it's safer to stand at the front of the class and explain it to them." Jordan said that it would be ideal if they could have one curriculum, like they have all seen in primary schools, but they have not found the same resources to do that at the lower secondary level.

Views

As can be seen from the Table 19, the views expressed were mixed in terms of positive and negative views. Each teacher described some ways in which they thought tablets were useful, although they have not all found ways of tapping into that potential. Alex and Charlie indicated that their self-efficacy was quite low with Charlie saying that "I want some confidence to have a go". It wasn't quite the fact that they thought tablets were difficult to use, rather the conversation focused on a multitude of factors that impacted their ability to use them.

Factors

As can be seen from the Table 19 above, most of the conversation focused on the factors impacting the use of tablets in their teaching. This is not surprising as Mumtaz (2000) also outlined a multitude of factors that was synthesises from literature. One of the greatest factors impacting teachers' use of tablets was time because the "pressures of work inside and outside the classroom, timetabling does not allow time for such learning [about ICT]" (p 334). This is very much in line with what teachers said, with the topic coming up four times, with extensive conversations surrounding each.

Another factor that a lot of the conversation focused on was that mathematics teachers felt disconnected from other subjects and the leadership that was implementing the one-to-one tablet program in the school. "We do swim in a slightly different boat a lot of the time" stated Alex, to which everyone agreed. The professional development offered to the teachers seemed to miss the requirements that the subject of mathematics has. Jordan expressed frustration at the IT director, who tried to insist that all teachers try to be creative and use programs that make movies and collages as a way of engaging students. The mathematics teachers agreed that they could only do so much with these programs that do not offer any insight into the understanding of mathematics and on many occasions they found traditional lessons conveyed the learning more effectively. As an example, the teachers mentioned iMovie program as being highly recommended by school. The teachers said that they could see how this might be useful in other subjects such as history, but they could not do too much with this program. They said that although it might be captivating for the students to make a short movie demonstrating their understanding of a mathematical concept, their mathematical knowledge could not be pushed too far using such programs. The teachers said that this disconnect was actually preventing them from using tablets at all and some of them have been using tablets significantly less than they did early on when the program was introduced. The narrow vision that the leadership was promoting was inhibiting subjects like mathematics. Rather it should have been recognised that mathematics has special needs. Sam suggested that if there were someone made responsible for finding applications specifically for mathematics, that would make a big difference in enabling the teachers to use tablets more widely and successfully.

Summary

Although the four teachers were already colleagues in the same school, the hour spent on discussing experiences and ideas created common ground. I rarely had to ask questions or direct the conversation because the four teachers easily built on each other's answers. There was a sense of understanding and camaraderie as they all shared the same goal of growing their practice in using tablets to teach Year 8 mathematics. Among the discussion, there were five discussions in which knowledge was shared, as shown on Table 19. By the end of the conversation there were ideas and resources being shared among the teachers, and some of them were making plans to meet at a later date so they could spend more time demonstrating to each other how to use certain programs on the tablet.

I asked the teachers what they wanted to get from these group meetings in the next few months. Unanimously they said that they wanted to get ideas and inspiration on how to use tablets. Jordan said that she also wanted to have shared experiences, where she got to talk to others who were further on in their practice of using tablets in certain ways. As she explained, everyone agreed, they were looking to learn from each other. Charlie added that she just wants to grow her confidence. When I asked her how this group will help with that, she said the following:

> It's quite nice that not everyone here is a real wizard. Because when you go to any of the training I just sit and feel completely and utterly overwhelmed. I watch it all going on and it's like I'm not even in the room, I'm on the ceiling thinking oh my, I will never be able to do that. So it's nice to hear that other people also feel that.

This speaks to the importance of the shared experience and understanding that was central to the design of the group meetings, which intend to create a professional learning network for the teachers. Everyone felt that they had a lot to learn about the use of tablets in teaching and although they had different levels of experiences in this, they also had something to share.

Group meeting #2

Following the first meeting, in which the teachers' use of, and views on, tablets in teaching mathematics was established, as well as the factors that impacted them, the focus of this meeting was to discuss how the teachers have been using the tablets since the first meeting and discuss ways in which they might use them moving forward. To guide the discussion, I asked the teachers to think about the concepts they will be teaching in the coming weeks, which of those concepts they think would be difficult for students to understand, and ideas on how the tablets might be able to help understand those concepts. At the end of the meeting, I asked the teachers to talk about the ways in which the tablets might be useful to teach mathematics to different type of students in their classrooms.

As for every group meeting, Table 20 summarises the ways teachers expressed that they would like to use tablets, their views about using tablets in their teaching, and the factors influencing their use of tablets. I also coded for knowledge exchange, which I define and describe in the coding portion of Section 3.3.3 in the Methods chapter.

Table 20 Key points discussed in second group meeting

			Jordan	Sam	Alex	Charlie
Use of Tablets (Values in Brackets Indicate Desired Use of Tablets)	Instrumental Evolution	Material		1 (1)	2 (4)	(2)
		Connect				
		Enhance				
		Extend				
	Efficiency	Resources				
		Classroom management				
		Instant formative				
		Teacher multiplied				
		Increased exposure to subject				
		Speedy access				
	Engagement	Instant feedback		(1)	(1)	
		Creative				
		Student as teacher				
		Visually enticing		1	(2)	
	Views	Tablet self-efficacy (positive/negative)			2 / 2	2
		Perceived ease of use (positive/negative)				
		Perceived usefulness (positive/negative)		2	1	2 / 1
	Factors	Time		1	1	
		Resources		1	2	1
		Technical issues		2		
		Mathematics missunderstood				
		Support			3	
		Management				
		Classroom management		3	1	1
	Knowledge Exchange	Conversations in which help was offered or knowledge was exchanged		13	15	12

This meeting can best be described as a vibrant exchange of ideas. Where in the first group meeting the focus turned out to be on factors impacting the way tablets are used by the teachers, this meeting was highly focused on exchanging ideas, with sixteen different conversations taking place, in which one or more ideas were exchanged. This active exchange took place between the three teachers who attended, as Jordan was absent because of a last-minute emergency.

Even though the teachers were enthusiastic to participate in this study and the school was supportive, there were always challenges in getting agreement on dates for group meetings and classroom observations. This was again evident at the start of this meeting. At the start of this meeting I asked gently for dates that each teacher would like me to observe their classrooms. Because of school schedules and lack of time, I was not yet given any dates for observations. Sam offered to organise this among the teachers and send them to me shortly. I made sure to emphasise that the observations were not in any way an evaluation on what the teachers were doing. Although they all seemed enthusiastic and not hesitant in the past for me to observe their lessons, I wanted to reiterate the purpose of my study to address any possible concerns, in case that had any role to play in the delay of them providing observation dates.

I asked the teachers to discuss the topics that they would be teaching in the coming weeks, and focus on the concepts that they believed will be most difficult for their students to learn. They said that their main topics will be teaching geometry and specifically construction and loci. They all agreed, that the challenge they anticipate with most of their students would be their ability to physically draw and measure the shapes on paper using a protractor. When I asked if this challenge could be addressed by the tablets, they all felt that the most important way of helping students would be to have a teacher next to them guiding them step by step on how they should construct the shapes and measure points. Sam suggested that the ideal solution would be for every student to have a video demonstrating in detail how to do this, which they can watch on their tablet and replay as needed. The task would be considered Material in nature, but as the teachers discussed their students' needs, this was what they thought would be the need that they could fill. Alex even said that she saw this as the most important way of using tablets, when she said, "That's the best one-to-one use of an iPad, to turn it into a little teacher."

This idea of using the tablets as a way of replicating and multiplying the teacher, has come up on several occasions. From the way the teachers were discussing this idea, it was not by any means suggesting that tablets might replace a teacher or be better than what a teacher does. Rather, what seemed to be suggested by the teachers from previous interviews and the first group meeting, was that the tablets could be used to multiply the teacher's efforts, as if the teacher could be multiplied in the classroom. The use of videos in the classroom were unanimously seen as a contribution to the lessons being discussed. However, they were not using videos in this way at the time. It was not clear why they were not already using these type of techniques, they did not have a clear answer. It is possible that the combination of several factors, such as the lack of time and not finding the right resources, crowded out this possibility. Sam did raise a concern about whether even adding the extra step of stopping and starting such a video, would help or hinder students, as they already struggled in multitasking when having to measure and draw shapes on paper.

The teachers also wanted to find a way to help students visualise concepts. Students had difficulty with balancing equations, which the teachers thought they could help visualise. Sam said that she spends a lot of time drawing things like scales, to demonstrate how to balance. But she knows what she would like from an app. "I dream of this app with little balloons on one side" she describes, but she had not found something like it.

Use

Discussing how the teachers used the tablets since the last group meeting, Charlie said that she did not use the tablets at all, but was still eager to find a way to do that. Jordan had reached out to her after the last group meeting to help her start using the tablets. Unfortunately, time and scheduling pressures prevented that from happening but Charlie still intends to follow up with Jordan. Both Sam and Alex said that they have used the tablets significantly more since the last meeting, sometimes successfully but often they faced some challenges. Sam gave an example of how she tried to get all the students to use their tablets to place a point on a shared graph that was project on the board. Unfortunately, the program was not loading properly and the students could not see the points on their individual tablets. This delay in the program caused a disruption and classroom management issues that Sam could not recover from, as she describes:

> I tried to get them all to put the point on the graph using Padlet. I thought it would be amazing if they all put their point on and it would all appear on the screen. But it didn't work because their iPads didn't load Padlet properly, and they couldn't all see the point. So, it was never going to work so they all started writing stupid things on there just because they could.

Alex described a success that she had, as she used her tablet to take pictures of solutions students wrote in their notebooks. She projected these pictures on the board as a way of sharing student work with the class, without having to spend a lot of time for students to write their work on the board. This allowed her to engage the entire class in discussing the different strategies students used to solve the problems. Alex was recognised and awarded for this initiative by the IT manager, when he saw her do this on the tablet theme day, when all the Year 8 teachers were asked to use the tablets in their teaching for one day and were given activities they could follow. Alex was recognised as having a unique way of using tablets. Hearing this, Charlie recalled that she tried to connect the tablets to project on the screen, but it did not work. Hearing the way Alex used the tablets, Charlie asked if she could show her how to do this as it would be useful for her own class. Alex was happy to agree and offered to meet with Charlie on a day following the meeting.

In addition to this simple, but useful way of using the tablets, Alex also revealed that she was working on designing an app she was hoping to use in her class. Considering that in the previous group meeting Alex said she had stopped using tablets in her classes, this was a significant jump. Everyone was eager to hear what Alex was working on. Alex was designing a digital worksheet, an idea that came to her during the last group meeting. She describes her process in the following way.

> I came away from the last meeting where we spent a lot of time discussing how we could use digital worksheets. I thought, well wouldn't it be amazing if there was a way to write our own worksheets really quickly and put them online and have students mark them. My boyfriend has basically programmed it for us and now I'm trying to get through school logistics to try and have it put on the school server.

Sam and Charlie were enthusiastic about this initiative and started enquiring about how it could be implemented in the school, and they were sharing ideas on how to achieve that as soon as possible. Alex seemed thrilled to have the support of her colleagues, encouraging her to think of ways to push her ideas further:

> I just think it's interesting that it came out of [the meeting, thinking], well this is what I'm trying to do. So actually, I have more ideas for what I want to do.

As the discussions progressed, I wanted to find out if the tablets were also used at home by the students. The primary benefit of each student having their own tablet, is that they could continue learning outside of the school, I was curious to see if that was taking place. Both Sam and Alex said that they do not assign homework on the tablets. Sam said that if a parent called her to ask for extra work, she did direct them to some tablet resources that they could use. However, the teachers agreed that the combination of not being able to check if a student did their work, and the fear of the technology not working all the time, prevented them from assigning homework on the tablets. Alex did say that she tried to ask her Year 12 students to watch videos at home, or read a website about a concept they will learn, but she realised that without giving them specific tasks, such as answering questions in their notebooks, the students would not watch the video or read the website. Although the Year 12 students did not have tablets, Alex send them emails with links to these resources knowing that they all owned technology on which they could view it. This again was a surprising revelation about Alex, as she was using basic technology that she could use, like email, to use technology enhance her teaching. When I asked why she did not do this with her Year 8 students, it was because they were much less likely to view material at home. Sam also said that because the apps and technology is unpredictable, they would never be able to fully verify that a student did not do the homework because the technology did not work or if that was an excuse. This seem like an issue that can be resolved, possibly it is a hesitation because the teachers have not yet developed processes to manage these scenarios as they are still adapting to using tablets in the classroom.

Views

In terms of the teachers' views, they were generally positive. As in other interviews, Sam did not readily express her views, rather she focuses on discussing ideas and ways of using the tablets. Unsurprisingly, Charlie had negative views of her self-efficacy, making such statements as "I haven't got a clue how to do that!" which was consistent with her not using the tablets in her teaching. However, she engaged in the conversations by sharing her challenges and looking to the other teachers for ideas and help to get her started. Alex on the other hand, had a mix of positive and negative views of her self-efficacy, two expressions of each. This was starting to show a shift from the previous group meeting where she only had negative views of her self-efficacy. This was reflected in her achievements and the initiatives she took to innovate with the tablet.

Factors

The two most prevalent factors discussed during this meeting were classroom management concerns and resources. The classroom management issues impacting the use of tablets was mostly about students being disruptive when a technology failure allowed for a pause in the lesson. The teachers are hesitant to use tablets in those classes as they feared loosing control over the class. To some extent this concern may be alleviated as everyone becomes more accustomed to using tablets, but a loss of control is significant as an important element of a teacher's job is to keep the class focused on the lesson.

The inhibiting factor of resources seemed to me as a very significant issue. Specifically, the resource the teachers were discussing on those occasions was the funding to pay for apps. The teachers often discussed that they knew of apps that would be good for their class, but the fact that there was a fee, regardless how nominal, made it an inhibiting factor. The teachers discussed the dilemmas of paying for an app that would rarely be used, or the cost of having every student purchase a costlier app. There were also discussions about whether it would be useful to buy only one version of an app for the teacher and project it on the board. However, it was agreed that this would make any app much less useful if students could not use them individually. This issue of fees on apps raises an important issue for tablets in the classrooms. There needs to be a school policy or process for how much funds can be devoted to apps, and how to select which apps to pay for. It seemed to be an unspoken rule, that only free apps would be used unless special permission was granted by the school. This presents a logistical hurdle and possibly prevents the best software from being used on these powerful devices. During my time with the teachers, it was the general understanding that they were always looking for free resources, but that kind of policy might have to be reconsidered especially considering the hurdles it created for the teachers.

Summary

Overall, this meeting evolved into a continuous exchange of ideas and making connections for teachers to continue discussions at later dates. Although my focus was to try and get teachers to think about ways the tablets could help to teach the more difficult concepts they will be teaching in the coming weeks, the focus turned out to be more on a multitude of ideas of ways teachers were currently using tablets, sharing these ideas with colleagues, and building on their own ideas as they discussed them in the group. The teachers spoke about ways of using tablets that could be characterised as material in nature, and they had many reasons why those tasks were beneficial for their teaching and their students. Although I hoped to push the conversation in such a way as to help the teachers develop tasks that might be more complex, and could be considered as a connect task, I did not want to interfere with the exchange of ideas and knowledge that was on topic and of interest to the teachers. It was a very lively conversation and the teachers went away with great enthusiasm, knowing more about their colleagues use of tablets, their challenges, and having learned about ways they can use tablets in the future.

Group meeting #3

The previous meeting aimed to focus the teachers' attention on how they might use tablets to teach the most challenging topics in the coming term, which resulted in many vibrant discussions during which teachers shared ideas on how to use the tablets and they learned from each other. Building on that, this meeting aimed to encourage teachers to think about ways in which tablets may be used for tasks that could be characterised as more complex, as described in Table 21. To guide the discussion, I asked the teachers to recall the successes and challenges they encountered using tablets in the previous several weeks. Following this, my intention was to ask the teachers to discuss how they may use the tablets in the following weeks and think deeply about why they want to use the tablets and how they may be used in ways that are unique from what traditional paper and pencil exercises could offer.

As for every group meeting, Table 21 summarises the ways teachers expressed that they would like to use tablets, their views about using tablets in their teaching, and the factors influencing their use of tablets. I also coded for knowledge exchange, which I define and describe in the coding portion of Section 3.3.3 in the Methods chapter.

Table 21 Key points discussed in third group meeting

			Jordan	Sam	Alex	Charlie
Use of Tablets (Values in Brackets Indicate Desired Use of Tablets)	Instrumental Evolution	Material	1	(1)	2 (1)	(2)
		Connect	(1)	(1)	(1)	(1)
		Enhance				
		Extend				
	Efficiency	Resources				(1)
		Classroom management				
		Instant formative			1	
		Teacher multiplied				
		Increased exposure to subject			(2)	
		Speedy access				
	Engagement	Instant feedback	1		1	(2)
		Creative				
		Student as teacher				
		Visually enticing		1		
	Views	Tablet self-efficacy (positive/negative)			2	1
		Perceived ease of use (positive/negative)	1	1	1	2
		Perceived usefulness (positive/negative)				
	Factors	Time	1			1
		Resources	2	1	5	1
		Technical issues	3	2	2	1
		Mathematics missunderstood	1	1		1
		Support	2	1		1
		Management	1		1	
		Classroom management			1	
	Knowledge Exchange	Conversations in which help was offered or knowledge was exchanged	13	14	12	14

As can be seen in Table 21, this meeting was very vibrant with a lot of different topics being discussed. In total, there were 19 knowledge exchange conversations, with everyone participating in the majority of those conversations, but Sam and Charlie were the most active by participating in 14 knowledge exchange conversations each. Many of these exchanges were not only exchanging knowledge, but also searching for apps, trying out the apps together, and discussing ideas on how to use apps in the classroom. Throughout this meeting it was evident that participating in a learning network was very valuable to the teachers. Although they had other ways of learning how to use the tablets, through professional development offered by the school, and their own research, there was a need to be able to learn from their own colleagues who taught their subject in their school. Jordan summed it up when he explained to me:

> You know when we had that pre-meeting, and we said that maths has that different approach, and we feel a lot of this stuff has been decided from a non-maths point of view, a very creative and artsy point of you, that these are useful programs and actually a majority of them don't work. The issue is that most of the training sessions are on using those kinds of things.

During this meeting, the idea was raised that it would be useful to extend this learning network that we had developed. I asked if it would be useful to create a platform on which the teachers could post and share ideas, or questions, between meetings. Everyone was enthusiastic and Jordan quickly suggested that she would set it up as we spoke, so that all the teachers could have it before the end of the meeting. It was decided that they would create a Google Docs, that is an online shared document that only the four of them could view and edit by clicking on a link on their tablet. All the teachers were enthusiastic to have this platform to communicate between meetings. Sam did warn of the possible challenges, as she tried a similar initiative in the department a while ago, but it did not take off. She used Padlet mainly because participants could post comments without the need for long email chains, but somehow it did not take off, as Sam described:

> I asked for comments on things, and I think it's just because people read stuff and they say 'ya ya I might do that at some point'. I asked for comments on homework and one member of staff logged on and wrote some stuff and I replied, but then no one else did. It just didn't take off.

It was not clear why that effort did not succeed, but the enthusiasm of the teachers in this meeting seemed to suggest this might turn out to be a different experience. Everyone was eager to be able to easily communicate with each other between meetings and have a platform on which to share ideas. The document was set up by the end of the meeting, and Jordan ensured it was active on each teacher's tablet.

Use

In discussing the way tablets were currently being used, Jordan and Alex mentioned using digital worksheets, which Charlie said she would also like to incorporate in her classroom. However, the teachers chose to focus more on the way they hoped to use the tablets in the future. In these discussions, they spoke of several different features of tasks that they hoped to use, but two features emerged as being important to the teachers, that were not being captured by the framework. Features of a tasks having a (1) *skills focus* and assisting in (2) *visualisation* emerged out of the conversations in in the following ways.

(1) Alex described the desire to find an app that she could use to teach the properties of pie charts. She wanted an app that would enable the user to set the properties such as the angle of the pie chart. The critical point was that Alex wanted to eliminate the need for students to have draw the pie chart. She said that many students do not have the ability to precisely draw the pie chart, which takes away from the skills she is trying to focus on, which was the properties of pie charts. The feature of this task that she was describing could be described has having a *skills focus*, a similar feature was described in the previous meeting, leading me to believe that this is an important feature for teachers and should be included in the framework.

(2) Alex also described a different type of task, as she described as “A tool for visual aid. Like manipulating shapes. All of them would be able to do different things, being able to manipulate shapes to get a better understanding.” Charlie also mentioned something similar at a different point in the meeting. She described the following features of an app:

> Something where you cannot do something any other way, that would be really really good. We have limited equipment in class, some things they can manipulate. In primary they have building things that they can use, but if there were images of things on the iPad that would be great, because they would supplement our lack of equipment to see it and experience it.

Although she talks about the lack of resources, such as having the equipment her students would need, she does express a desire to use the apps for tasks “where you cannot do something any other way”. Sam also touched on this type of characteristic when asked what kind of apps she would like to find “I think I already said visual stuff and let them be able to explore maths". This exploration she hopes to have students do may be indicative of a desire for an app that helps student make connections between mathematical ideas. This indicates a hint towards a Connect task and the need teachers have to help students visualise concepts. This feature of a task might be called *visualisation* and should be included in the framework.

Views

Few views were expressed throughout this meeting, possibly because the teachers were enthusiastically sharing their knowledge and ideas on how to use the tablets. However, Alex and Charlie did make statements that indicated a negative self-efficacy. Charlie expressed this at one point in the following way: "For me, it's all about the fact that I have no idea where to start. That is absolutely my problem. I don't even know where you find these things. Do you go into an app store?"

Charlie has often described in previous meetings, and during the interviews, that she wanted to use the tablets, but the barrier of entry for her was quite high. Her desire did not wane, as she was very active in the meetings and looking to learn how to move past this initial barrier.

The most prevalent view given by every teacher was the negative perception of how easy the tablets were to use in teaching. Particularly, all the teachers were focused on the difficulty of finding apps and resources that they were looking for and would be useful in their teaching. Alex reiterated the sentiments of all teachers when she said "I know I have said this before, but it's the limited knowledge, knowing where to look, knowing how to find what you want. It's unlocking this."

But it was not just a lack of knowledge on the teachers' part, it was also the disparate sea of resources, which Charlie described as a feeling that "we are lost in a world of a million apps or no apps". This abundance may be beneficial, but it is the lack of clear curated quality resources that contributes to the added complexity of using tablets in teaching.

Factors

All the teachers spoke about a variety of factors that impacted their use of tablets. However, resources and technical issues were the two most commonly discussed factors during this meeting. The focus in terms of resources, was on the lack of quality apps available, or not finding the type of app the teachers imagined being useful for a lesson. This ties into their negative views described earlier. In this meeting, it seemed that the teachers reached a point in their use of tablets where they all had images of how they could be useful. Without knowing of a specific app or resource, all the teachers imagined ways in which the tablets would help their class. Jordan captured the essence of this when she said that: "Sometimes we have an image but no app for it. Like in algebra with the balancing scales, but we don't have scales."

But the frustration of not being able to find exactly what they were looking for became a major debilitating factor for the teachers. Jordan stated that "there's an equal measure of over and under abundance. There is an overabundance of some stuff." It became clear that having access to a curated list of useful resources would be essential for the teachers, but none of them have found a list of that type of material. There are certainly lists of the top ten best apps for this, or that, which can be found on some blogs or websites. Jordan did mention having found some apps on similar lists, but these lists are not well aligned to what the teachers are teaching, nor are they easy to find for topics they need them for. Rather than lists, what the teachers were describing was a customised curation that can be easily accessed for the topics they were teaching. Such a resource would greatly reduce the amount of time they were spending to find resources, and the barrier of entry for teachers who may not know what they are looking for.

Technical issues were once again a key factor for all the teachers. The issues ranged from insufficient infrastructure in terms of losing internet connection to the unpredictable nature of how apps work. Teachers expressed frustration at not being able to predict how the technology would work even when they prepared and practiced using it before the lesson. This unpredictable nature of the technology not only adds a lot of time to the preparation needed by teachers, but the extra work they spend on diligently preparing does not eliminate the disruption caused by the technology not working during the lesson. It is this unpredictability that was mentioned in the first group meeting where the teachers said that they have to prepare two lessons, one if using the technology and another traditional lesson in case the technology stopped working. Although this is a difficult factor to address, as there are many reasons for this unpredictability, but from the amount of frustration expressed by the teachers it is easy to see why this factor alone might hinder the initiative to use technology in the classroom. Possibly as technology advances, and the teachers and school become more accustomed to using the technology, these issues will subside, but this was a significant inhibiting factor expressed in this study.

Management, and the support they provide, was a key topic relating to the initiative the Alex took to design a software that would be valuable for all the teachers. As described in the previous meeting, Alex asked her boyfriend to program a resource for the tablets that combined features that she could not find in another app, but would be valuable to all the teachers. She describes the stage she is at in the implementation of her program when the other teachers enquired about the program:

> It's all there, it's all been written , I just can't get the IT department. Its just that classic thing. I went to finance and they said that before they pay for it I need to go to IT and they need to sign off on it that it's for work. That was a long time ago. I even got IT manger involved and I said this is the way we want to go in maths, and every week he said he will get back to me, but he still hasn't replied. This is the way IT department work, they get things done very quickly that they want to get done but not others.

Although this was disappointing, and another roadblock experienced in using tablets, having the support of the other teachers in this meeting proved useful when Sam provided an alternative for the resource. She suggested the use of CIMT worksheets, that are similar, but did not have the customisable feature Alex had designed into her interactive worksheets.

Summary

Continuing from the last meeting, this was also very rich in the number of knowledge exchanges that took place, with fourteen such conversations in total. The concept of having a learning network, which is what the group meetings were designed to be, was not only embraced by the teachers, as has been evident in the numerous interactions in in each meeting, but also the teachers were now taking the idea of a network further. The fact that the teachers had the idea and initiative to suggest broadening the network to the times outside meeting times, suggest that they find value in this format. Using their tablets to develop this platform further points towards the uptake of using the tablets in their work.

Group meeting #4

At the time when this meeting was being scheduled, there were unexpected delays. For some time, I waited to hear back to several emails and phone messages that I sent to Jordan, who was my primary contact to schedule my visits to the school, but for a period there was an unusual silence. When I could reach Jordan, she told me that significant changes to the tablet program will happen in the school, but that most of the staff has not yet been notified. Knowing this information, she was hesitant to make any arrangements for the next group meeting with the teachers, not to mislead them as she had privileged information about the use of tablets in the future. She told me that in the next few days an announcement would be made in the school, letting everyone know that the all the tablets need to be returned to the school immediately and they would not be available until next academic year. School management decided to change the tablet programme from a one-to-one programme to having class sets of tablets available to the entire school. Once this was announced, Jordan scheduled this meeting. Since the school had stopped using tablets at this point, this was the final group meeting with the teachers. This change in the school policy cut short the number of classroom observations that I intended to have, post observation interviews, as well as the fifth group meeting that was originally planned.

Considering the circumstances, I changed the plan for this final meeting to focus more on reflection and hypothetical ways the teachers would use the tablets, if they were available. The teachers discussed their most prevalent and valued use of tablets, their experiences participating in this study, their opinions about the change in the tablet policy, the factors that impact their use of tablets, and their ideal ways of using tablets in the future.

As for every group meeting, Table 22 summarises the ways teachers expressed that they would like to use tablets, their views about using tablets in their teaching, and the factors influencing their use of tablets. I also coded for knowledge exchange, which I define and describe in the coding portion of Section 3.3.3 in the Methods chapter.

Table 22 Key points discussed in fourth group meeting

			Jordan	Sam	Alex	Charlie
Use of Tablets (Values in Brackets Indicate Desired Use of Tablets)	Instrumental Evolution	Material	(2)	(1)		(1)
		Connect	(1)	1	1	2
		Enhance				
		Extend				
	Efficiency	Resources	1			1 (1)
		Classroom management				
		Instant formative				
		Teacher multiplied				
		Increased exposure to subject		1	1	
		Speedy access				
	Engagement	Instant feedback				3
		Creative				
		Student as teacher				
		Visually enticing				1
	Views	Tablet self-efficacy (positive/negative)				
		Perceived ease of use (positive/negative)				
		Perceived usefulness (positive/negative)	4	2	2 / 1	3
	Factors	Time				
		Resources	2	1	1	2
		Technical issues			2	
		Mathematics missunderstood				
		Support	1	1	3	3
		Management				
		Classroom management				
	Knowledge Exchange	Conversations in which help was offered or knowledge was exchanged	2		1	2

Since the teachers and students were no longer able to use the tablets for the rest of the academic year, the meeting had very few knowledge exchange conversations. The focus of the meeting was discussing how the teachers most frequently used the tablets, how they would like to use the tablets in an ideal situation, what they valued about using the tablets, and their general opinions on participating in this research project and meeting as a group.

Use

As the teachers discussed their use of the tablets, they all said that they have been using them more frequently in the last few months. For Jordan, Sam, and Alex using the tablets had become a more integrated part of the teachers' practice, which Jordan described:

> One of the things I found, particularly in the last half of the year, is that it starts being less of, this is an activity and more that it is just part of the lesson. There have been times when I have just given an explanation and they just looked up the definition on their tablet when they need it.

Often the teachers were not talking about tasks for which tablets were used, rather they were describing the characteristics of those tasks. Looking at Table 22, it may appear that the teachers spoke very little about their use of tablets, but that is because they did not describe specific tasks, rather focusing on general characteristics, and because some of the characteristics they spoke about where not being captured by the framework.

One of the key characteristics that all the teachers talked about, in different ways, was the potential for programs on the tablets to help students visualise concepts. Charlie spoke about wanting an app that could help students learn to divide objects into equal parts, similarly to the activity in her first classroom observation, where she asked students to cut different foods into equal parts. Having an app that could guide students and allow them to do that digitally, would be more efficient and complement her teaching with more guidance. Teachers also spoke of visualising three dimensional objects, graphs, and more generally helping students visualise mathematical concepts. Jordan spoke specifically about the properties of angles and lines, describing how a dynamic representation would help visualise and link concepts in students' understanding. As Jordan articulates the reasons why this would be helpful, she also outlines that she has not been able to find programs that cover all the areas she needs to cover:

> You can actually play around with it and see that it's always the same, that would be far more powerful than a simple diagram and you would remember it. Those are the kind of things that I know exists for circle theorems, but there are similar shape ones like the parallel line angle facts, where it does not exist. Being able to move lines and see that the angles are still the same, those are things that don't exist or at least we couldn't find and that would be again something that would immediately help. It's kind of like moving from the particular to the general. They keep seeing particular instances and we expect them to magically go like 'oh if I see the general case it will work' but if we only ever show them particular examples it will take a very long time for them to understand the general case.

This understanding, and reducing the time required to achieve it, is a reason that was repeated several times in different ways. But the obstacle of finding the right resource, that has come up in every meeting and many post observation interviews. Charlie particularly points to the limited number of good resources for higher mathematics, but the problem of limited good quality resources in a vast sea of resources is something every teacher spoke about.

Throughout the meeting teachers gave examples of different characteristics of apps that have, or could, benefit their students. As in previous meetings when the conversations quickly became very energetic and animated, with all the teachers sharing ideas of resources and ways of using tablets, in this meeting the same energy and diversity of ideas was evident, but this time discussions focused on the characteristics of tasks using tablets. The following is one of several examples of vibrant conversations where a diverse array of ideas was discussed. In this exert, the teachers talk about characteristics of tasks using tablets that range from visualisation, increased exposure to the subject, personalised learning and focus on specific skills. When I asked the teachers to describe some ways they can imagine tablets benefiting mathematical tasks in their classroom, the following was a part of that conversation.

> Sam: Just drawing basic graphs and equations. The ability to draw a graph and draw a different graph and know what you have done and how it effects the graph.
>
> Me: What about using the tablet makes this possible?
>
> Sam: If we didn't have the tablet, or any technology, we would physically have to draw the graphs and it would be very time consuming.
>
> Jordan: If they are exploring parallel lines that is massively slow or they have a specific example.
>
> Alex: Something I often do, and this is the classic 'I'm doing it on the board' so when I often talk about parallel lines I get Geogebra up and I will animate a line and I will change aspects and show what happens. I think there is something about movement that allows you to generalise a lot quicker than seeing 10 or 15 examples of something. That movement is a specific thing about generalising that gets to them quicker.
>
> Sam: Also it's very personal that they can try things they thought about and you can't do that in front of the class. They can do it for themselves and it's more memorable.

> Charlie: It's more instant too isn't it. They have very little patience. They ask a question and they want the answer right away and I think that with the tablet you have a question and you can find out right away.
>
> Alex: I was thinking about the other thing, where we are talking about what is happening, you have to go through the verbal understanding. But if you see something happening you can capture an understanding of it without even having to verbalise it, which is a different skill.

Isolating the skill that the teacher is trying to teach with a task, is an extremely important characteristic that has not been captured on the existing framework. All the teachers referred to this characteristic in some way. As Sam and Jordan pointed out in the conversation above, drawing takes time, which could be used to do more mathematics and focus on the specific skills being taught. This time allows for an increased exposure to the subject, as categorised in the framework, and it also allows students to focus on the skills being taught. As Sam discussed at a later part of the meeting, the skills being taught when students need to draw a graph is not necessarily the skill of drawing, rather to see the connection of the equation and the pictorial representation of the equation. Alex later described this characteristic by referring to the elimination of the skill of drawing accurately when all the students draw a pie chart. She said that inevitably if every student drew a circle with certain properties, the drawings would be inaccurate, and demonstrating the connection between different dimensions of a circle would not be possible if every drawing was slightly different, and therefore the teaching point would be lost. Sam added to Alex's example by saying that "because it's so inaccurate you lose the point so at the end you have to say well it should have looked like this, and then you have lost them."

Individualised learning was another characteristic that was often discussed. In the discussion quoted above, Sam says that having every student use their tablets to explore their own questions, which is a more personal experience, and as Charlie stated, it gives students instant feedback and they do not have to wait for the teacher to answer their question. Students can look up information, check their answer, and draw their own graphs and diagrams. These are all examples in which the tablets provide individualised learning, which the teachers feel is important because, as Charlie said, often students are impatient, and not only do these characteristics give them instant feedback, but it allows them to move at their own pace of learning. Sam reiterated these points later in the meeting, saying that it makes the work more personal and that makes it more memorable which leads to better learning. For all these different reasons, individualised learning is an important characteristic that teachers value.

As the teachers described the positive characteristics of tasks using tablets, I asked them if they ever required the students to use the tablets at home, taking advantage of every student owning their tablet and being able to use them anytime and anywhere, as many proponents of mobile technology indicate. I previously asked the teachers about the students use of tablets at home, but I wanted to ask again to see if that had changed over time. Again, the teachers all said that their students do not use the tablets at home for mathematics. They do not assign work that is dependent on using the tablets, because as they said in the last group meeting, they do not trust the technology to always work and they cannot check if a student was honest about missing homework because of technology or not. Even without the work being mandatory homework, the teachers did not believe that students did any mathematics work or games on the tablets in their time away from school. They did make suggestions to parents who enquired about resources their child could use on the tablets to practice mathematics, but these were infrequent occurrences.

As this was the last group meeting with the teachers, I wanted to find out how they would like to use tablets in their classroom in the future. I asked them to imagine ways that they thought the tablets would be useful, regardless if they knew of any programs that could do that or if it was even possible.

Having someone design or curate resources that can be used on the tablets, was a primary desire expressed by all the teachers. Throughout the project, the teachers often spoke about the large amount of time it took to find apps and the inability to find exactly what they were looking for. Although, often the tasks for which the teachers used, and wished to use, the tablets for may not seem as looking at mathematics in new and unique ways. However, the teachers indicated many ways in which these tasks facilitated teaching and learning of mathematics. On a few occasions, teachers also said that there might be ways of representing mathematics in new ways, possibly these might be categorised as more complex in terms of Instrumental Evolution, but often the teacher said they can not imagine what that might look like or where they could find such programs. It appears that the teachers knew that the tablets had the capacity to provide new representations of underlying mathematical concepts, but they were not aware of the programs that might offer this. Unfortunately, often even the programs they found did not meet all the needs the teachers hoped for. This could be an important consideration for the technology industry to help users find the appropriate applications for their needs, possibly through a well curated site that provides useful recommendations to teachers. Even more, this builds on the extensive research that shows the benefits of co-designing technology with teachers, rather than just for teachers (Mor & Winters, 2007). Alex summed up this desire in the following statement:

> In my perfect ideal world is that at school we had an app developer who we would go to meetings with and I could say I'm a maths teacher and based on the pedagogy I would like you to design me a set of apps that look like this and buttons that I can press and move around, and then they would actually go off and make an app for what I actually need to deliver in the classroom.

Another commonly expressed desire was for tablets to be resources that combined and eliminated the need for all other physical resources. Although these seems extremely basic, this comes back the desire of cutting out lost time in a classroom and allowing for more time to teaching and learning. The teachers said that they would like to have all the tools, such as a good calculator, ruler, protractor, manipulatives and much more, as quality resources in a tablet. Reducing the need for individual physical resources was something that the teachers found to be valuable. For the teachers, not only does that reduce the need to manage these physical resources in the classroom, it also would reduce the time and disruption to distribute physical resources in class, the limited supply of physical resources, and having to manage students who are missing resources. These reasons focused on classroom management issues, however, there are educational benefits for students to have tactile experiences with physical resources. This was not discussed by the teachers.

As the teachers described the different ways they have, and would like, to use the tablets, it seemed that they always had strong reasons for doing so. A lot of the tasks could not be defined as particularly unique or advanced, particularly in terms of the Instrumental Evolution framework. This is something that could have been addressed by the training the school provided to the teachers on how to use the tablets, but that kind of knowledge did not seem to have been provided. However, the teachers did always have reasons on how it would improve teaching and learning in the context they were working in, and with the resources they had. Charlie summed this up beautifully by describing the tablet as a window through which students can see, when she recalled a way she recently used the tablets in her class:

> I have a good example of that when we were studying sound and I had an oscilloscope app and it was great that they could see what volume looked like and what pitch looked like, and there is no way that I could have shown them that easily in the classroom. The iPad becomes the tool and the window through which they can see.

Views

In discussing the views teachers held about the use of tablets in their teaching of mathematics, they had many positive views in how the tablets would be useful. Possibly because the meeting focused on the features of tasks the tablets enabled, the teachers did not talk about their own self-efficacy or the ease of using tablets.

The negative point discussed, was that, as technology evolved, from computers to tablets being an example, the quality of resources designed for one form of technology did not get transferred over to the new technology. Alex referred to some programs that she liked using on the computer, but now that the tablets were being used, these programs were not available to use on tablets. This was expressed in previous meetings by other teachers, and it is certainly a loss that takes place with the quickly evolving technological world. Not only is there an overwhelming sea of resources, but once a teacher finds a useful resource, it is a matter of time until the technology is updated and they may lose the ability to use that resource. This problem goes beyond the program not being transferable to new technologies, it may also be the change in policy, where previously free programs change to fee paying programs. Alex recalled a website that she used in her teaching, but started charging a fee, she said that she felt like she had it taken away from her. This loss of good resources, that teachers have previously said takes a lot of time and effort to find, is a factor that impacts teachers use of technology, and their confidence that they will be able to reuse the good lessons they design.

Factors

Finding useful resources are not easy, the factors that inhibit using these resources can play a significant part on whether teachers will continue to seek out good resources and use the tablets in their lessons. Not only is there a sea of resources that teachers need to search through, but what is available is disproportionately distributed to lower mathematical skills. The teachers talked about not being able to find resources for their higher achieving students in Year 8, when they saw many wonderful apps for younger grades, and also having some topics that they could find any apps for. Even when they did find apps they did not fit all the requirements they had, as Charlie describes her experience:

> The interesting thing is that there are hundreds to choose from but when you start looking at them, they really don't do what you want them to do. They hit the surface but what we really need is to get to the conceptual bit. I didn't find anything that was the best, but I found something that would do. I went down the rout of what if I paid a bit to get something better.

Paying for apps is another factor that was often raised. Not only do teachers not have a budget, but it is also inhibiting to have to pay for an app even before the teacher can decide if it is worth buying. Having a curated list of apps would be very beneficial. Possibly even having access to a demonstration of how the apps works, would allow teachers to make the decision if the app is worth paying for. The teachers did not say that they were not able to spend any money on purchasing programs, but in the search for good programs, it was inhibiting to have to pay just to see how an app worked. It may not be reasonable for all educational apps to be free, but as this is a factor preventing teachers from using possibly brilliant apps, ways to alleviate this should be considered by developers and schools.

As the school had just changed its tablet policy from a one-to-one tablet programme to class sets, I wanted to get a sense for what the teachers thought about this change. The teachers all had mixed feelings about it. In one respect, they were all relieved that the students no longer will have a feeling of ownership over their tablets. This issue was raised on several occasions throughout the study, as teachers were often impacted by the tablets were either left at home, not charged, removed from the student by the school for disciplinary issues, or being broken. At the beginning of this study, Jordan also talked about the compulsive ownership students had over their tablet, many having to physically touch the tablet even when it was not being used. Teachers also complained that students had filled their tablets with games, did not remember their passwords, or were distracted by the programs they had on them. On several previous occasions teachers said they wished the tablets would be class sets, rather than individually owned. However, now they also discuss some of the advantages of this ownership. The teachers mentioned the benefits of the students knowing where certain apps are on their tablet and accessing it quickly, and now the teachers will need to load every new app on all the tablets, where previously they asked students to download it at home. The feelings were mixed, but Alex and Jordan also said that they were more worried about the consequences of the students feeling ownership of their tablets at the earlier stages of the program. It was not clear why the school made the decision it did, nor was it clear what impact this change would have on teaching and learning. There are pros and cons for both, as the teachers pointed out.

Being the final meeting, I also wanted to find out a bit more about why the shared document that the teachers initiated in the previous group meeting, was not used. The enthusiasm and initiative was there when the idea grew out of their discussion in the third meeting, however the platform was hardly used. The teachers still unanimously agreed that the idea was a good one, and should not be abandoned.

> Jordan: It was a good idea but didn't work, but the base idea is still there of trying to facilitate some kind of channel. This meeting in the end was a place where we could play and everyone could find something and share. If there is some way of doing that online.
>
> Sam: The problem is that if you don't think of something you don't look at it, and that's not the point. You get some people who are always thinking and putting stuff on there and others who never look at it and don't answer the questions.

This discussion falls in line with what research has found about online communities, and the difficulty of keeping vibrant conversations going and encouraging participation of the members. I assumed that since this platform was for people who already knew each other and were meeting regularly, this would not encounter the same obstacles. As the teachers continued to discuss the need for this platform and the ways in which it might be made to work, the key point that emerged, was the need for a trigger. Possibly if there was a reminder or trigger to regularly bring a teacher to the platform and encourage participation. Even when the motivation is there, as was the case for the teachers in this project, it seems that this would be a critical feature.

Summary

As the meeting came to an end, I wanted to understand what the teachers felt about having group meetings and participating in this project. I encouraged the teachers to be critical and give suggestions as the structure may help other teachers develop their own learning networks in their schools. I wanted to find out if, and how, these meetings impacted them. The teachers unanimously agreed that the meetings were extremely valuable to their development of using the tablets, and as Alex described in the first group meeting, she had stopped using the tablets altogether before joining my study. Some of the reasons why the teachers found this format useful are best described in their own words.

> Jordan: It was a stimulus to think and try. It was like well it's coming up, if nothing else it was the fact that the meeting was coming up and required some thinking and planning. I like the idea of using an ipad, sometimes you get bogged down because it doesn't work.
>
> Sam: And then it takes someone else to get inspired again.
>
> Alex: I just enjoyed the dedicated contact, dedicated time to improving this, and being on a separate site and the lack of conversations I have on anything related to pedagogy, means that this was like ok for the next hour I get to think about this. Sometimes in my own teaching practice you just get a nugget. It might be a single phrase of something someone said that gave you the confidence to go and try it and then use it in your own way and push it forward.
>
> Charlie: What I would say is that this was absolutely fundamental to me doing anything. If I hadn't come I wouldn't have tried. The main thing was that everyone was massively supportive and didn't make me feel like I was horrendous. Also, I think it's nice having a small group and everyone is not techy, well Jordan is. But in trainings here, everyone is going a million miles an hour showing things on the iPad and I can't keep up with it. Actually, I don't take much in.

As Charlie stated, the format of traditional professional development courses can be overwhelming and out of context for some people. Research has also shown that these forms of professional development are less effective than anticipated. However, I would suggest that they have an important role. Having external professionals, who understand the technology and are avid users, can share a wealth of information that would be useful for teachers. But maybe that benefit is missed if those sessions are not supported by regular opportunities for teachers to discuss and share their understanding among themselves in these type of learning networks. Sam articulated this when she described what she thought would be helpful for the teachers moving forward in using tablets in their teaching.

> What would really help and what would really be useful would be if we continued doing that and continued to meet. This is the only time we can focus on this. The shared document, ya it's great, but we need to look at it at the same time. We all need to be thinking at the same time and responding at the same time.

Having dedicated time is not the ultimate solution, but I would suggest it is the final piece in the puzzle that makes all the other great resources stick together, enabling teachers to use technology in the best way possible. This format, of having dedicated time for guided discussions, provides the glue and the spark, as Charlie summed up "Having these conversations sparked off the thinking. The individual discussions overlapped and sparked off together."

Summary of Group Meetings

The four group meetings quickly developed into dynamic discussion in which the teachers opened about their experiences using tablets, their worries, and shared their knowledge. In this learning network, the teachers exchanged many ideas on how to use the tables in the classroom, resources, and hands-on demonstrations to teach each other how to use the tables.

The open-ended structure of meetings allowed for these conversations to grow and flow as the teachers felt it was necessary, allowing them to discuss the aspects of teaching with tablets that was most important and valuable to them. With this structure, general themes emerged from the meetings. The first meeting resulted in discussing the factors that impacted the teachers' use of tables, the second meeting was focused on exchanging ideas on how to use the tablets, the third meeting was the most vibrant and rich in ideas on how tablets could be used and exchanging ideas and resources on using tablets. The fourth meeting focused on factors that impacted the use of tablets and reflecting on how tablets can be used, this was a more reflective conversation because the tablets had already been taken out of the school. Had there been an opportunity to have more meetings, I think the teachers would have progressed to discussing ways in which the tablets could be used in ways that would be categorised on the higher end in terms of the Instrumental Evolution. Unfortunately the tablets were suddenly removed from the school before all the meetings could be completed. All the teachers were very engaged in each of the meetings, and the conversations flowed with ease and ideas regularly grew bouncing from one person to the next. In terms of building knowledge, the third meeting was the most productive and vibrant. This hints at how rich, productive, and innovative these meetings could have become had the tablets not been removed from the school after the third meeting. However, the learning network that was created with these teachers during these meetings still had significant impact on their use and views of the tablets.

Combining all of the results from the four group meetings, the results are outlined in Table 23.

Table 23 Summary of key points discussed in all group meetings

			Jordan	Sam	Alex	Charlie	**Total**
Use of Tablets (Values in Brackets Indicate Desired Use of Tablets)	Instrumental Evolution	Material	4 (2)	7 (3)	8 (5)	(5)	**19 (15)**
		Connect	(2)	1 (1)	1 (1)	2 (1)	**4 (5)**
		Enhance					
		Extend					
	Efficiency	Resources		2		1 (2)	**3 (2)**
		Classroom management					
		Instant formative			1		**1**
		Teacher multiplied		(1)			**(1)**
		Increased exposure to subject		1	1 (2)		**2 (2)**
		Speedy access					
	Engagement	Instant feedback	1	1 (1)	2 (1)	3(2)	**7 (4)**
		Creative					
		Student as teacher					
		Visually enticing		1 (1)	(3)	1 (1)	**2 (5)**
	Views	Tablet self-efficacy (positive/negative)			2 / 4	5	2 / 9
		Perceived ease of use (positive/negative)	1	2	1	2	6
		Perceived usefulness (positive/negative)	5	6	5 / 3	5 / 1	21 / 4
	Factors	Time	1	2	3	2	**8**
		Resources	4	4	10	5	**23**
		Technical issues	5	4	5	2	**16**
		Mathematics missunderstood	2	1	0	1	**4**
		Support	4	3	7	4	**18**
		Management	3	0	2	0	**5**
		Classroom management	0	3	3	1	**7**
	Knowledge Exchange	Conversations in which help was offered or knowledge was exchanged	19	27	33	29	**33**

Use

The way teachers described their use of tables, as shown in Table 23, was in line with what was observed, and what the teachers described in the post observation interviews. Their descriptions of how they would like to use tablets was more elaborate from previous data sources. From the first meeting, teachers started talking about a desire for the tablets to allow students work independently and have tasks that focus on skills that the student needs to learn. Throughout the meetings the teachers also touched on ideas of wanting to use the tablets to multiply their efforts in the classroom and help students visualise mathematical concepts that are not possible without digital technologies. These characteristics I will discuss in more detail in Section 4.4.

Views

Regarding the views held by teachers, I observed the most significant change in their self-efficacy. Looking at the tablets, the number of times the teachers made references to their self-efficacy does not provide a full picture of what occurred. It was in their descriptions of how the meetings with their fellow teachers impacted them. Most notably, Alex and Charlie credited the meetings for initiating them to use the tablets in their lessons. Having a group of their peers to learn from and to hear about their own struggles, helped them realise they were not the only ones struggling and it provided them with support to try using the tablets. Having the organised meeting with their peers, who also taught mathematics, removed the overwhelming barrier of having to take the initiative to seek and find time to ask for help from colleagues who they perceived were far more advanced at using the tablets than they were. Removing this enormous barrier, allowed them to gain the courage and knowledge to use the tablets. Even if it was at a basic level at least the teachers were using the tablets which opened the possibility to progressively using them in more complex ways.

Factors

The factors impacting the teachers' use of the tablets were extensive and diverse. Some improved over time, such as the technical issues that arose from infrastructure issues, and some classroom management concerns that improved as the teachers and students became more familiar with the tablets. However, the web of factors that impacted tablet use are complex and do not have a clear solution.

4.5 Implications of Phase 2

Throughout Phase 2, as I used the modified TADT framework in the classroom observation, post observation interviews, and the group meetings, there were noticeable characteristics of tasks, that I saw in the classroom and heard teachers discuss, that were not being captured by the modified TADT framework. Teachers were using the tablets in tasks where they intended to *focus* either their teaching or what students were learning.

Focus is essential for gaining understanding and developing skills. Technologies in the classroom are often blamed for distracting students and preventing them from focusing on the lesson (McKnight, et al., 2016). However, some tasks for which tablets were used did seem to help students to *focus* on the mathematics they were learning or a specific skill, and some tasks helped teachers to focus their efforts to help the students who needed them the most. In the final TADT framework, I introduce the term *focus*, which I define as a characteristic of a task that helps the students *focus* on specific mathematical skills and help the teachers *focus* their efforts in teaching mathematics. As outlined in Table 24 below, I identified five characteristics of tasks for which tablets were being used to help students focus on the learning of mathematics: individualised learning, customisable, teacher focus, visualisation, and skills focus. There were many examples of tasks with these features, but I will now outline a few of the situations that led me to identify these five characteristics and the common thread of *focus* among them.

Table 24 Focus characteristics of tasks

Focus		
Individualised learning	Definition: The task allows the student to progress to questions that are determined by their previous results, enabling each student to practice the mathematical skills they require.
	Example: Game that determines the following mathematics question based on student's previous results, allowing the student to practice skills required for the questions they got wrong.
Customisable	Definition: The task is such that it can be altered by the teacher to suite specific students and/or lessons.
	Example: Digital application can be customized by the teacher, such as the questions on a digital worksheet, or parameters allowed in a program where students can build three dimensional shapes.
Teacher focus	Definition: The task allows the teacher to spend more time teaching and helping students who are most in need of assistance with mathematical concepts.
	Example: Having an electronic worksheet that provides instant feedback to students reduces the number of requests for the teacher to check student work.
Visualisation	Definition: The task demonstrates mathematical concepts in a non numerical fashion.
	Example: Allowing students to see the way graphical representation of equations changes with modifications of formula.
Skills focus	Definition: The task removes the need for certain skills to allow the student to practice a specific skill.
	Example: Graphing equations allows student to focus on the subtle differences in the graph when changing parts of the equation, rather than on the skill of drawing an accurate graph.

In several situations teachers wanted to find a way for the tablets to help students visualise concepts. These ranged from visualising the transition from two-dimensional to three-dimensional shapes, to visualising the properties of lines and shapes, to help students focus on the mathematical concepts being taught. Jordan described what he hoped to find in a program during the fourth group meeting.

> Something you can actually play around with it and see that it’s always the same, that would be far more powerful than a simple diagram and you would remember it. Those are the kind of things that I know exists for circle theorems but there are similar shape ones like the parallel line angle facts, where it does not exist. Being able to move lines and see that the angles are still the same, those are things that don’t exist or at least we couldn’t find and that would be again something that would immediately help. It’s kind of like moving from the particular to the general.

Examples of programs that would do this are dynamic geometry programs that show different examples of a particular definition, such as parallel lines. It is not that tasks using dynamic geometry programs cannot already be categorised using the framework, but certain features of these tasks that teachers value, are not represented. In this instance, it’s the visualisation element of the task.

Another example of a feature of a task was found when teachers tried to find ways of designing tasks that isolated the skills they wanted to teach and removed other skills from the task. They wanted to focus on a skill and not have to take the time to do skills that the student already knew, or be held back because some of the skills required for the activity were not developed in the students. One example of this is learning the graphical properties of general equations. This characteristic is defined ask *skills focus* on as show on Table 24. The teachers described an example of this in the fourth group meeting.

> Jordan: The number of skills involved. You would need to build a table, calculating and drawing the graphs. You also rely on it being accurate.
>
> Alex: It’s also 15 minutes of your lesson.
>
> Sam: And then you have missed the opportunity to discuss and all the stuff you can get out of it. Especially for the higher groups, you know they can graph, you don’t need to practice.

Through the process of analysing all the data, these and other examples, made it became evident that characteristics of tasks that were not being captured, all shared a common feature that could be described as having *focus*. These characteristics of tasks were described as focusing the students on learning mathematics, helping to focus the classroom teaching, and focusing on the mathematical skills that the teachers wanted to develop.

Throughout this study, the initial TADT framework expanded into the modified TADT framework, which also further expanded as the teachers' experiences of using tablets to teach mathematics was better understood. As I described previously, the aim of this framework is to build on existing research, but also incorporate the experiences and perspective of the teachers in the study. As different teachers who teach different topics in mathematics at different school and countries, may have different factors that impact their use of technology, or different features of tasks that they value in their classrooms. Having a living framework is important to be able to capture the teachers' experiences, which is the essence of this study. The final TADT framework that has been developed in this study is presented in Table 25 below. Because of space restrictions on a page, the final TADT framework, with complete definitions that have been given through the thesis, are presented together in Section 4.7.2.

This final TADT framework is not intended to evaluate or measure teachers use of, and views on, tablets. Having an open-ended interview style in this study was indicative of this desire to move away from an assessment of what teachers are doing. Rather, the framework is a tool to guide conversation and development of using tablets, and other mobile technologies, in the teaching of mathematics. The framework can be used as a conversation starter and a guide that teachers can discuss and alter as their development progresses. The implications for teachers and future research of this framework are discussed in more detail in Chapter 5.

Table 25 Final TADT framework

Use of Tablets (Values in brackets Indicate Desired Use of Tablets)	Instrumental Evolution		Material
			Connect
			Enhance
			Extend
	Characteristics	Efficiency	Resources
			Classroom management
			Instant formative
			Teacher multiplied
			Increased exposure to subject
			Speedy access
		Engagement	Instant feedback
			Creative
			Student as teacher
			Visually enticing
		Focus	Individualised learning
			Customisable
			Teacher focus
			Visualisation
			Skills focus
	Views		Tablet self-efficacy (positive/negative)
			Perceived ease of use (positive/negative)
			Perceived usefulness (positive/negative)
	Factors		Time
			Resources
			Technical issues
			Mathematics missunderstood
			Support
			Management
			Classroom management
	Knowledge Exchange		Conversations in which help was offered or knowledge was exchanged

4.6 Portrait of a Teacher - Alex

The focus of this study is on teachers and how they use and view mobile technology in teaching mathematics. To help understand the teachers' experience, it is important to try and step in their shoes. Although every teacher is unique, the way they use and view technology, and possibly changing their use and views, is different. I do not claim that this study is generalisable, or that any one teacher can be held up as an example of what teachers generally experience. However, there are significant insights to be gained from understanding individual teachers. In this section, I would like to share the story of one of the teachers who participated in this study.

I chose to tell the story of Alex for two main reasons. First because despite Alex being an example of an enthusiastic teacher who is keen to use technology in teaching, her experiences of using tablets in teaching have led her to stop using them. This is reflected in her negative views expressed in the initial interviews (Table 7) as well as in the group meetings (tables 16 to 19) where she expresses more negative views than the other teachers apart from Charlie, who has not started to use the tablets at all. The second reason why I want to focus on Alex's story is because she is most impacted by the development of a learning network through the group meetings. The observation data in Table 10 shows that following the first group meeting, when Alex had the first observed class, she started using the tablets, for five different tasks. This is astonishing as she said in the initial interview and first group meeting that she has given up on using tablets but would like to learn how to. Alex was very inspired by the other teachers in the first group meeting, which is reflected in the fact that she participated in the most knowledge exchanges in the meeting, with five different conversations as shown in Table 16. These two key reasons investigating Alex's story highlights some of the outcomes of this study.

Alex is an enthusiastic and dedicated mathematics teacher in her mid-twenties, who joined my study because she wanted to learn how to use the tablets to teach mathematics. She is an avid user of technology in her personal life and she feels that technology has great potential in her professional life, to help her students learn mathematics. She has experienced first-hand the transformative power of technology in her own learning, when she was given a laptop in early secondary school to help manage her dyslexia. The impact this had on her own studies has made Alex an avid proponent of educational technologies, and she was excited to learn, two years prior to the start of this project, that her school would initiate a one-to-one tablet programme in her school. Although she was not a particularly advanced user of technology, she does not code or use complex programs, she was certain that having tablets would help her improve her mathematics classes and help her students learn.

Unfortunately, Alex's high hopes had dwindled away over the year and a half before she joined this study. She had stopped using tablets in her lessons altogether, and her self-efficacy had plummeted. She reflected on her experience when the tablets were first introduced in the first group meeting:

> I used it a lot, I was very excited when the project started because of my own background and education. I had a laptop in school since I was 6 because I'm dyslexic and it made me fulfil my potential. So I have an agenda to be able to facilitate better learning with technology. I was then trying to engage the year 7 students last year and just got totally frustrated because it was too difficult. Everyone was saying it will improve behaviour in your classes and it just didn't. it was a behavioural nightmare. I think with the class I had last year, I had two Year 7 class last year, and one of them had more behavioural needs than the other and I just couldn't do it with the tablets because I couldn't give any instructions that they would listen to and be able to use what I had. I got very disheartened and I started saying things like using technology is just not worth it and I almost gave up at that point. I have used it one to one with this boy in year 11 but again it's not quite what I want it to be.

Before joining the group meetings in this study, Alex felt ashamed to seek help from her colleagues because she thought everyone else seemed to be successfully using the tablets in their teaching, and she felt she had somehow fallen behind. It was not because Alex was not trying. At the start of the programme she did try to find good apps to use in her lessons and she diligently prepared her lessons knowing that the technology may falter, but she was prepared. She attended the professional development that the school had arranged and she initially sought the help of the technology manager who was responsible for overseeing the tablet implementation. Alex even went outside her school and joined a facebook group for mathematics teachers where ideas were shared. She also joined a National Institute of Wales Mathematics Teachers forum where she hoped to get good ideas, but recently that became a fee based resource and she had to abandon it. At the start of the first group meeting she made her feelings clear when she said: "You're going to find out that I'm quite negative towards them, because I don't see any point of replacing existing technology with new technology." Even so, she knew the tablets had potential and latter in that meeting she said that although she did not know exactly how, but she did "have some goals that I would like to do. I would like to teach a lesson where they would learn something independently. But that's a huge step in having the right resources and time."

It was certainly not for lack of trying, but the hurdles kept tripping Alex along the way, until she was exhausted, frustrated, and felt helpless. She had countless technical issues in her lessons, ranging from the loosing Wi-Fi connection to programs not working, she had new classroom disruptions to manage, ranging from students distracted by their tablets to not having their tablets or forgetting their passwords. In addition, Alex also found it challenging to find the type of programs that would help her teach mathematics, and help her students learn. She tried to find information to give her ideas, but she felt blocked on several fronts as she described:

> I've looked for blogs and I haven't found anything. But I' m also really bad at research. I'm dyslexic and I usually pass my phone to my sister and ask her that I really want to find out about. Six weeks later she comes back with a bunch of blogs.

Alex was trying in several ways to overcome the factors inhibiting her use of tablets, but the frustrations built up and she did not feel she had support to deal with these challenges. She started thinking she was the problem, she was not capable of using the tablets, and therefore she started using them less and less. At the first group meeting she said that using tablets as a teacher is "a bit like being a roman engineer, in that you try something and if it works you refine it and if it falls down you destroy the plan and never use it again." Alex had destroyed the plans and was trying to find a new way of using it again.

As I started this study, Alex was eager to participate. She felt that this might be a way for her to learn to finally use the tablets in her teaching. She eagerly jumped into the project and was very open about her challenges, feelings, and opinions. Her frustration was evident, but a remarkable thing happened in the first group meeting. As I watched the teachers participate in the meeting, I was taken aback by how vibrant the conversation was. It seemed almost like a valve had been released and the teachers were excited to share their experiences, thoughts and feelings with their colleagues. From what they were saying, it became clear that they very rarely had the opportunity to talk to other teachers who taught their subject, and have a chance to learn from each other. Alex, this meeting marked a turning point. She later talked about the realisation that, actually, she was not the only one having difficulty using tablets, and those other teachers she thought had easily adapted this technology, were actually struggling with the same concerns she was. Not only did this realisation raise her spirits, but it also gave her the confidence to try using the tablets again. From that first meeting, Alex learned from the other teachers about some programs she could try, and tips on how to use them in the classroom. She used these ideas soon after the meeting and even met with one of the teachers to help her get started.

There was something else that emerged from that first meeting for Alex. Hearing the concerns other teachers had, she started getting an idea.

> Alex: Just thinking about what these guys are saying. Jordan, imagine a world where you didn't have to research for digital worksheets that you could write your own. So I can write the questions that I want my class to answer
>
> Jordan: Just a static question and they type in an answer?
>
> Alex: Yes, they type in answer and then they know if it's write or wrong
>
> Jordan: Maybe you can use Socrative so maybe it's worth us thinking about how we can do that and they can do it self-paced
>
> Alex: But just listening to you I can't help thinking it would be great if we could create our own
>
> Jordan: Yes yes!

From this one meeting, Alex picked up on a need that she and the other teachers were experiencing and already started to test her idea with the other teachers. She knew her boyfriend was a good programmer, so she asked for his help. Together, they designed the program and within a few weeks he made it. Alex was thrilled to see her idea coming to life and she knew this would be a great help for her and the other teachers. She approached the technology manager at the school and asked how she could install this on the tablets. This is how the arduous process began to implement the program. She was told to go to the finance group and have them pay for the licences needed, as part of the program was using a ready to use platform. Over the course of the study, Alex described the ins and outs of this process, trying to get the school to approve and install the program. It was not a matter of funding, as the license was quite inexpensive, and it was not a matter of other teachers not supporting her idea, because they were enthusiastically waiting for her program to be available. Yet, over the months of this study, Alex grew more and more frustrated at the hurdles she had to jump over. Before the tablets were taken back by the school, Alex was still trying to get the school to install this program, and may have continued to do so until she was successful, but all the tablets were recalled in the school.

Her desire to innovate went beyond even designing one program. She was innovating in any way she could, whenever she saw a need. Having previously learned about the idea of flipped classrooms, Alex saw that this might benefit her Year 12 students. This year group did not have tablets, but Alex saw that they all had personal smartphones and home computers. She used this to send them emails with links to videos or reading material for the concepts they would be learning in the following class. She went through a few iterations of this, as she noted that students often did not even watch a video at home if there was no accountability for doing so. Alex started assigning questions related to the material she emailed, which students needed to answer for their homework. This resulted in many of her students preparing for the class and during the lesson she focused on solving problems, rather than regurgitating material they could view or read on their own.

Throughout this study, Alex was a very active participant in the group meetings, sharing ideas, asking for suggestions on her challenges, and learning from all the teachers. During the six months of classroom observations and group meetings, she went from not using the tablets at all in her teaching, to being a dynamic and innovative user of tablets in her classrooms. She started to learn how to better manage the students and the flow of the lesson with the challenges presented by the tablets, she learned new classroom management techniques to use to manage the disruptions caused by the tablets, she became more comfortable with the technical issues that came up in the classroom, and she learned many new ways of using tablets to help her teaching. During the six months participating in this study, the tablets that she previously rejected because of the difficulty she had integrating them into her classes, she not only regularly used the tablets in her teaching in a variety of ways, but it also became a seamless part of her practice. This became clear to her when, towards the end of the study I went to observe her lesson, and she had forgotten that I was coming. When she met me, she realised that even though she forgot about my arrival, she had already planned into her lesson several different tasks using the tablets. What was previously an effort, to try and plan a task using the tablets for when I will come to observe, had become a natural part of her lesson planning. This was also not simply using tablets for the sake of using them, as she often reiterated that she never wants to use technology for the sake of it, which was part of the reason she had stopped using tablets before, not having found any meaningful ways of using tablets.

Alex was using tablets regularly and in ways that she saw as value added. She also felt very comfortable with the many interruptions that still plagued the use of tablets. She managed students swiftly in minimising any distractions they may have caused with the tablets, she easily asked for students to help when the technology failed and she need to fix it, and she confidently dealt with students how had missing tablets. Her dedication even extended to giving her personal laptop, tablet and smartphone to students who did not have, tablet and also quickly grouping students to share tablets.

This transformation was not only in the way Alex used the tablets, but also in her views. Although she always felt that the tablets had potential to help teaching and learning in mathematics, her confidence in using them effectively was shattered. Over the course of these six months her confidence soared. Not only did she use tablets naturally in her lessons, and designed her own program that she went to her school to try and implement, but she was also brimming with new ideas. She said that she sees so much potential for tablets and the programs she could create. Although she does not know how to code programs, she reached out to different resources to try and bring her ideas to fruition.

With all the positive changes that Alex had gone through, her level of frustration grew again by the end of the study. The many factors, outlined in the post observation interviews and group meetings, that hindered the teachers' development and use of tablets were chipping away at her enthusiasm. With the removal of the tablets, I wondered how she would continue using them once they are reintroduced in the following academic year as class sets. I wondered how she would use them and how she will continue to innovate. Would the frustrations again outweigh her enthusiasm and initiatives? Would her view of herself and her abilities be strengthened or diminished? I never found out the answers to these questions, but from what I understand Alex no longer teaches at that school and she actually left teaching altogether. I do not know what her reasons were, but I can imagine her frustrations and the roadblock overtook her enthusiasm.

There are three key messages that I think are worth taking away from Alex's story. Firstly, the ideas that use and views of new technologies do not grow in isolation. It is hard to reach out for help, especially when there are misconceptions about everyone else's ability. It is also hard to take in what has been taught to us and learn to use it on our own. Having a network of peers to support and learn from is what reignited Alex's enthusiasm and enabled her to learn to put to use what she learned about tablets form other sources, and also learn from her own peers.

Secondly, innovation and initiative cannot be encouraged without thoughtfully supporting it. It was not enough for Alex to be enthusiastic and having good ideas. Even having the initiative to bring those ideas to fruition were not sufficient. She needed the support of her colleagues and she would have needed more systematic support from her school. Although the school encouraged innovation and initiative by organising special tablet days to display the ways teachers used them in the classroom and celebrating teachers who did interesting things. Alex was recognised in the school for using tablets in a unique way when she used the tablet to take pictures of problems students solved and projecting them on the board for the class to solve. There needs to be more systematic support for these teachers, as the integration of the program Alex designed demonstrated. The factors that inhibit teachers' use of technology needs to be addressed. Some of these factors can be addressed by the school and others are more far reaching. However, if the factors teachers face are not taken seriously, it will be a matter of time before they stop using the technology. At the end of the day, teachers want to teach well, and using tools that inhibit their teaching will not succeed.

Thirdly, the value added by a technology to the teaching of mathematics is not always complex or innovative. Alex used the tablets in very simple ways, such as using email to send students material to prepare for the next lesson. The classroom, and learning in general, is a complex system. Alex, and the other teachers, often used tablets to facilitate the learning by simplifying and enabling the mathematics to take centre stage. The framework that emerged from this study tries to capture the spectrum of characteristics that teachers value in tasks used to teach mathematics.

Alex is only one teacher, and not necessarily an average teacher, if there is such a thing. But, stepping into Alex's shoes, I hope to give meaning and more context to the data that was presented throughout this thesis. Understanding her experience, can hopefully provide a more grounded understanding for teachers' experiences using technology more generally.

4.7 Further Discussion and Reflections

Following the analysis of the different data sources and individual teachers, the TADT framework emerged from the research. In this section I look at the framework overall and reflect on the tablet program that it emerged from and the data it represents. In the following three subsections I first present and discuss a combined table of all of the data in this study on the final TADT framework. In the second subsection I provide the final TADT framework with all the definitions and discuss how it contributes to the existing research in this field. Drawing on all the data and analysis in this study, in the third subsection I critically reflect on the overall tablet program as experienced by the mathematics teachers in this study.

4.7.1 Combined Data Results

Having presented in Section 4.4 the final TADT framework that emerged from this study, it is important to recode all the data with the final TADT framework in mind. The results of all the data sources, presented on the final TADT framework, are presented in Table 26 below.

In addition to the analysis and observations that I have presented throughout Chapter 4, a few more observations can be made when seeing the data presented together. As previously mentioned, the numerical representation of the data is not intended to be a direct comparison between teachers, rather a highlight of trends and what is important to teachers.

Looking at the individual interviews, post observation interviews, and the group meetings, it is striking how many more factors and characteristics of use of tablets the teachers mention in the group meetings. Particularly in terms of the tasks that have characteristics of focus, there are many more mentions of this characteristic in the group meetings. This once again brings to the forefront the importance of having group meetings in a school, to discuss factors impacting teachers and also the ways in which to use the tablets. Even more, it is in the group meetings that teachers really go into depth of discussing the way they would like to use tablets in the future. This type of conversation can help teachers discuss ways of making these type of uses possible in their classroom. They can learn from each other about how to use tablets in the ways they desire and also combine their knowledge in finding the best resources for the uses they intend.

Looking across all the data, it is a clear indicator that the group meetings can really propel the learning and use of tablets forward. Not only is desired use of tablets significantly discussed, but with the increasing number of knowledge exchange conversations as every meeting, there is indication that there is momentum for the teachers to move forward in developing the way they use the tablets in teaching mathematics.

Table 26 Combined data results

Individual Teacher Interview

Use of Tablets (Values in brackets Indicate Desired Use of Tablets)			Jordan	Sam	Alex	Charlie	Total
Instrumental Evolution		Material	5	5	4	1	**15**
		Connect					
		Enhance					
		Extend					
Characteristics	Efficiency	Resources	1	1	2		**4**
		Classroom management					
		Instant formative					
		Teacher multiplied		1			**1**
		Increased exposure to subject					
		Speedy access		2	1		**3**
	Engagement	Instant feedback	1				**1**
		Creative	1				**1**
		Student as teacher					
		Visually enticing	1	1			**2**
	Focus	Individualised learning	1				**1**
		Customisable					
		Teacher focus					
		Visualisation					
		Skills focus					
Views		Tablet self-efficacy (positive/negative)	1		1/3	2	**2 / 5**
		Perceived ease of use (positive/negative)		1	1		**1 / 1**
		Perceived usefulness (positive/negative)	1	1 / 1	1 / 2	1	**4 / 3**
Factors		Time	1	1	2	3	**7**
		Resources	1	2	1	2	**6**
		Technical issues		1	1		**2**
		Mathematics missunderstood		1	1		**2**
		Support					
		Management	2	1	1	1	**5**
		Classroom management	4	3	3	1	**11**
Knowledge Exchange		Conversations in which help was offered or knowledge was exchanged					

Observation and Post Observation Data

Use of Tablets			Jordan (Classes Observed) 1	Jordan 2	Jordan 3	Jordan 4	Jordan 5	Sam 1	Sam 2	Sam 3	Sam 4	Alex 1	Alex 2	Alex 3	Alex 4	Charlie 1	Charlie 2	Total
Instrumental Evolution		Material	3	2	1	1	2	1	6	5	4	5	4	7	2			**43**
		Connect			1			1			1						1	**4**
		Enhance																
		Extend																
Characteristics	Efficiency	Resources	2	2	1	1	2	1	3	2	2	3	1	4	1		1	**26**
		Classroom management	2	1					3	4	2	4	2	5	1			**24**
		Instant formative					1	1	1	1	1		2	1				**8**
		Teacher multiplied	1															**1**
		Increased exposure to subject						1			1						1	**3**
		Speedy access	1						2	2	3	4		2	1			**15**
	Engagement	Instant feedback	1	1		1			2					3			1	**9**
		Creative			1								2					**3**
		Student as teacher								1		2						**3**
		Visually enticing								1		1					1	**3**
	Focus	Individualised learning															1	**1**
		Customisable																
		Teacher focus	1						2				2	3			1	**9**
		Visualisation			1								1					**2**
		Skills focus																
Views		Tablet self-efficacy (positive/negative)	2			1	1				1	1	1		2	1	2	**6 / 6**
		Perceived ease of use (positive/negative)	1		1/1	1		2							1		1/1	**4 / 5**
		Perceived usefulness (positive/negative)	1	1	2	3/1	4	4	3	1	2		1/2	2	1		2	**27 / 2**
Factors		Time	1	1				1						1			2	**6**
		Resources			1			2		1	3			1	3		1	**12**
		Technical issues	1	1		1		1	1	2		1						**8**
		Mathematics missunderstood																
		Support												1				**1**
		Management	1														1	**2**
		Classroom management	2	1			1	3	3	2	1	2			1	1		**17**
Knowledge Exchange		Conversations in which help was offered or knowledge was exchanged																

Group Meetings Data

Use of Tablets			Jordan (Group Meetings) 1	Jordan 2	Jordan 3	Jordan 4	Jordan Total	Sam 1	Sam 2	Sam 3	Sam 4	Sam Total	Alex 1	Alex 2	Alex 3	Alex 4	Alex Total	Charlie 1	Charlie 2	Charlie 3	Charlie 4	Charlie Total	Total
Instrumental Evolution		Material	3		1	(2)	4(2)	6	1 (1	(1)	(1)	7 (3)	4	2 (4	2 (1)		8 (5)		(2)	(2)	(1)	(5)	**19 (15)**
		Connect			(1)	(1)	(2)			(1)	1	1 (1)			(1)	1	1 (1)			(1)	2	2 (1)	**4 (5)**
		Enhance																					
		Extend																					
Characteristics	Efficiency	Resources				1		2				2								(1)	1(1)	1(2)	**3 (2)**
		Classroom management																					
		Instant formative													1		1						**1**
		Teacher multiplied						(1)				(1)											**(1)**
		Increased exposure to subject									1	1			(2)	1	1(2)						**2 (2)**
		Speedy access																					
	Engagement	Instant feedback			1		1	1	(1)			1 (1)		(1)	1		2(1)			(2)	3	3(2)	**7 (4)**
		Creative																					
		Student as teacher																					
		Visually enticing							1	1		1 (1)		(2)			(3)				1	1(1)	**2 (5)**
	Focus	Individualised learning	(2)				(2)			(1)	1	1(1)	(1)		(1)		(2)	(1)		(1)	2	2(2)	**3 (7)**
		Customisable						(1)				(1)	(1)				(1)						**(2)**
		Teacher focus																					
		Visualisation				(1)	(1)		1			1		1 (2	(1)		1(3)			(1)	(2)	(3)	**2 (7)**
		Skills focus				2	2		(1)		1	1 (1)		(1)	(1)	1	1(2)				(1)	(1)	**4 (4)**
Views		Tablet self-efficacy (positive/negative)											1	2/2	2		2/4	2	2	1		5	**2 / 9**
		Perceived ease of use (positive/negative)			1		1	1		1		2			1		1			2		2	**6**
		Perceived usefulness (positive/negative)	1			4	5	2	2		2	6	2/2	1		2/1	5/3	1	2/1		3	5/1	**21 / 4**
Factors		Time			1		1	1	1			2	2	1			3	1		1		2	**8**
		Resources			2	2	4	1	1	1	1	4	2	2	5	1	10	1	1	1	2	5	**23**
		Technical issues	2		3		5		2	2		4	1		2	2	5	1		1		2	**16**
		Mathematics missunderstood	1		1		2			1		1					0			1		1	**4**
		Support	1		2	1	4	1		1	1	3	1	3		3	7			1	3	4	**18**
		Management	2		1		3					0	1		1		2					0	**5**
		Classroom management					0		3			3	2	1	1		3	1	1			1	**7**
Knowledge Exchange		Conversations in which help was offered or knowledge was exchanged	4		13	2	19		13	14		27	5	15	12	1	33	1	12	14	2	29	**33**

4.7.2 Teacher Adoption of Digital Technologies (TADT) Framework

Throughout this study, I iteratively built upon existing research to develop the TADT framework. In this section, I discuss in detail the four distinct parts of the TADT framework, including how each contributes to the existing literature in the field. I break this discussion down into the four distinct parts of the TADT framework – Use of Tablets, Views, Factors, and Knowledge Exchange.

The final TADT framework is presented in Table 27 below. Because of the size of the framework, the definitions of each part need to be presented in separate tables. This separation also represents the ways in which the TADT framework can be taken apart and used separately, both by researchers and by teachers examining their practice. This framework is intended for both researchers and practitioners to use in the process of understanding how mathematics teachers use tablets in their classroom. The resulting framework is pulled together from different areas of literature and expanded from the outcomes of my research. The framework incorporates different aspects of teachers' experience in using tablets, which addresses Ruthven's (2013) concern that there is a need for more research on the concrete ways that teachers develop the use of technology in teaching. Both researchers and practitioners can use the TADT framework as a centrepiece that frames and encourages reflection and discussion about the ways in which tablets are being used in mathematics education. This is intended to be a living framework, which researchers and practitioners can add to and refine as they record the way more teachers are integrating tablets into their teaching. The remainder of this section highlights the contributions that each of the four parts of the framework makes to the existing literature.

Table 27 An outline of the TADT framework

Use of Tablets (Values in brackets Indicate Desired Use of Tablets)	Instrumental Evolution		Material
			Connect
			Enhance
			Extend
	Characteristics	Efficiency	Resources
			Classroom management
			Instant formative
			Teacher multiplied
			Increased exposure to subject
			Speedy access
		Engagement	Instant feedback
			Creative
			Student as teacher
			Visually enticing
		Focus	Individualised learning
			Customisable
			Teacher focus
			Visualisation
			Skills focus
	Views		Tablet self-efficacy (positive/negative)
			Perceived ease of use (positive/negative)
			Perceived usefulness (positive/negative)
	Factors		Time
			Resources
			Technical issues
			Mathematics missunderstood
			Support
			Management
			Classroom management
	Knowledge Exchange		Conversations in which help was offered or knowledge was exchanged

The *Use of Tablets* part of the framework is comprised of two different sections, the *Instrumental Evolution* and *Characteristics* of the use of tablets, as defined in Table 28 below. *Instrumental Evolution* is drawn from the work of Laborde (2001). On the TADT framework the four segments are presented in steps of increasing complexity. As I described in Section 4.3.3 and 4.5, it became clear in my study that teachers were using the tablets in ways that they found to be valuable but those features were not captured by other frameworks, which most often focus specifically on technologies that change the ways student interact with mathematical concepts. These other, equally valuable uses for tablets can be categorized into three distinct parts, in that they provide *engagement*, *efficiency*, and/or *focus* to mathematics teaching and learning.

Aspects of *Efficiency* and *Engagement* are characteristics that Ertmer et al. (2012) found teachers considered when using technology in their classroom. Research also has shown that *engagement* and *efficiency* are important contributions that technology can add to education, even going as far as for Jones and Knezek (1993) to state that *efficiency* is the purpose of technology in education. Kirkwood and Price (2014) reviewed how technology enhanced learning is interpreted in higher education literature; they use the Higher Education Funding Council of England's definition of efficiency as "existing processes carried out in a more cost-effective, time-effective, sustainable or scalable manner" (p 8). This relates more to the organisational aspect of using technology in their study, but my definition of *efficiency* in this study is narrowed down to the element of being time-effective, particularly in the classroom use of technology. I define *efficiency* in this study as a categorisation for tasks that help make the class proceed more smoothly, allowing more time and resources for the learning of mathematics.

Some studies have also suggested that tablets have a positive influence on students' *engagement* in mathematics (Hilton, 2016), although the research on the impact of technology, and particularly mobile technology, on students' *engagement* in mathematics is limited (Fabian, Topping & Barron, 2016). In this thesis, I base my definition of engagement on Ruthven's (2009) description of engagement as it "relates to securing the participation of students in classroom activity" (p 3). I further narrow the definition of *engagement* as a categorisation for tasks that help to capture and sustain the attention of students so that they focus more intently on learning mathematics.

What the TADT framework contributes to the literature is that it represents a more holistic integrated view of the different ways in which tablets contribute to the mathematics classroom. It combines the values from frameworks such as Laborde (2001), which categorises the use of technology in increasingly more complex ways of interacting with mathematics, but also recognises that those same tasks also have characteristics that contribute in several other ways, and may include aspects of *engagement* and *efficiency.* The TADT framework also contributes to the literature by including *focus* as an additional characteristic of tasks. *Focus* is defined as helping students *focus* on specific mathematical skills and help the teachers *focus* their efforts in teaching mathematics.

Table 28 The TADT framework – Definitions for the part related to the *Use of Tablets*

Instrumental Evolution		
Material	Definition: The task is different using a tablet than a paper/pencil task because of the tool being used, but not in the mathematical thinking required.	Example: Worksheet on a tablet that provides the answer is the same as a textbook with answers in the back.
Connect	Definition: The task using a tablet helps students make connections in their mathematical thinking that would be more difficult to understand with a paper/pencil method.	Example: Quickly graphing multiple equations using a graphing program on the tablet allows for visualisation of what changes in an equation mean to the graphical representation.
Enhance	Definition: The task using a tablet requires more mathematical knowledge than if it were solved using paper/pencil methods.	Example: Constructing a square using a dynamic geometry software requires specific knowledge of the properties of the shape, such as the angles and properties of the sides, rather than simply drawing the shape.
Extend	Definition: The task is only possible using the tablet and not possible using paper/pencil.	Example: 1. Using programing logic to solve a problem or create something. 2. Using the drag mode of a dynamic algebra software to understand the properties of shapes.
Efficiency		
Resources	Definition: The task uses the tablet to reduce the need for additional supplies such as paper, manipulatives, and other physical objects.	Example: PDF version of test solutions eliminates the need to make photocopies for every student.
Classroom management	Definition: The task reduces disruption in the classroom and enables the teacher to orchestrate the classroom as intended.	Example: 1. Students not having to go to the board to write solution for entire class. 2. Reduced need for physical resources that are limited and need to be collected and stored.
Instant formative	Definition: The task allows the teacher to instantly receive answers from students to a set of questions.	Example: An electronic mathematics quiz that helps the teacher to identify the level of mathematical ability of each student or polling the class about how confident they feel about the lesson.
Teacher multiplied	Definition: The task allows the role of the teacher to be replicated several times, alleviating the teacher from having to repeat information.	Example: Having a video of an instructor explaining a concept, allows the student to return to the instruction part of the lesson and not have to ask the teacher to repeat parts of the lessons.
Increased exposure to subject	Definition: The task enables students to interact with more mathematics than would otherwise be possible.	Example: Graphing multiple equations using a tablet allows students to see the relationship between a graph and an equation as they do not need the lengthy time to draw each graph by hand.
Speedy access	Definition: The task increases the speed to access resources.	Example: Accessing electronic worksheets or websites using a link or scanning quick response (QR) code.
Engagement		
Instant feedback	Definition: The task provides students with immediate answers to mathematical problems they complete.	Example: Electronic worksheets indicate if an answer is wrong, or provide answer, allowing students to proceed in their work with a sense for of their abilities.
Creative	Definition: The task allows students artistic freedom in building or representing their mathematical thinking.	Example: Students take pictures of shapes they build with blocks and create presentations of the 2D images they take of the front and side views of the shape.
Student as teacher	Definition: The task facilitates students presenting and explaining work to the other students.	Example: Taking a picture of student work to project on the board, or using a program that projects individual student's tablet screen on the board, allowing students to demonstrate their work to the class.
Visually enticing	Definition: The tasks esthetic and/or interactive nature makes it pleasing for the students to use.	Example: Games that require students to practice mathematical skills such as numeracy.

Table 28 The TADT framework – Definitions for the part related to the *Use of Tablets* – Continued

Focus		
Individualised learning	Definition: The task allows the student to progress to questions that are determined by their previous results, enabling each student to practice the mathematical skills they require.	
	Example: Game that determines the following mathematics question based on student's previous results, allowing the student to practice skills required for the questions they got wrong.	
Customisable	Definition: The task is such that it can be altered by the teacher to suite specific students and/or lessons.	
	Example: Digital application can be customized by the teacher, such as the questions on a digital worksheet, or parameters allowed in a program where students can build three dimensional shapes.	
Teacher focus	Definition: The task allows the teacher to spend more time teaching and helping students who are most in need of assistance with mathematical concepts.	
	Example: Having an electronic worksheet that provides instant feedback to students reduces the number of requests for the teacher to check student work.	
Visualisation	Definition: The task demonstrates mathematical concepts in a non numerical fashion.	
	Example: Allowing students to see the way graphical representation of equations changes with modifications of formula.	
Skills focus	Definition: The task removes the need for certain skills to allow the student to practice a specific skill.	
	Example: Graphing equations allows student to focus on the subtle differences in the graph when changing parts of the equation, rather than on the skill of drawing an accurate graph.	

The *views* that teachers hold about the use of technology in teaching and learning has an impact on the way they can learn and implement new technology in their teaching. Recognising these *views* and reflecting on them, provides insights and opportunities to explore these *views* and possibly how they can change. This part of the framework, which is defined in Table 29, was influenced by the work of Chiu and Churchill (2016) who built the framework on beliefs by combining the three separate definitions, as explained in Section 2.3. The contribution to this literature made by the work in this thesis is that the TADT framework incorporates teachers' *views* into the larger picture of how tablets are integrated into teaching mathematics. Putting teachers' views into a framework along with the way they use technology, brings the teachers' experience of using technology to the forefront. Having a framework such as the TADT framework – which can be used to investigate the way tablets are used in teaching mathematics – that also incorporates in the same framework the teacher' views on using tablets, makes a clear connection between technology use and the view teachers hold. Not separating the *use* and *views* of the technology helps to make it clear for researchers and practitioners that teachers' experiences in the use of technology is an important aspect to consider.

Table 29 The TADT framework – Definitions for the part related to *Views*

Views		
Tablet self-efficacy	Definition:	Teacher's views on her "capabilities to organise and execute the courses of action required to produce a given attainment" (Bandura, 1997, p.3)
	Positive Example:	I know how to use tablets to teach my mathematics class
	Negative Example:	I am not confident in using the tablets in my class
Perceived ease of use	Definition:	Teacher's views on the ease of use of tablets in teaching mathematics
	Positive Example:	I find it easy to teach with tablets
	Negative Example:	It is difficult to find the programs I want to use on the tablets
Perceived usefulness	Definition:	Teacher's views on how useful tablets are to teach mathematics
	Positive Example:	I think there is great potential for using tablets in my teaching
	Negative Example:	It is more trouble than it's worth to use tablets in my classroom

Factors outside of a teacher's control are recognised widely in research literature as having an impact on teachers' use of technology. As outlined in Section 2.4, research has identified a variety of different factors that impact the way teachers use technology in the classroom. Moersch (1995) defined five problem areas of computer usage in education that included staff development deficiencies, computers being used for isolated activities unrelated to instructional themes, computer usage was removed from classroom teaching, computer usage sustained the existing curricula rather than being a catalyst for change, and technology plans failing to establish a link between the need for technology and identifiable instructional priorities. Franklin (2007) identified additional barriers to success, which included too much curriculum needing to be covered, a lack of time, and emphasis on high-stakes tests. Other researchers have also cited the lack of effective teacher training on the use of classroom technologies as factors that impacted teachers' use of technology (Guha 2003; Mentz & Mentz 2003; Tsitouridou & Vryzas 2004; Thomas & Palmer 2014). Ertmer (1999) categorised factors in two distinct groups of first-order barriers (ex. resources, training and support) and second-order barriers (internal to the teacher, such as confidence, beliefs about how students learned, as well as the perceived value of technology).

There are many types of factors defined by different researchers, some specific factors have overlapped, such as the lack of time and insufficient training for teachers. However, the research reviewed have often pointed to factors that are not necessarily the ones teachers articulated as having an impact on their choices, such as their beliefs about technology. Although all factors need to be understood, the TADT framework focuses on factors that teachers express as those impacting their decisions of if, and how, they use technology in the classroom, are also understood. Highlighting the *factors* that teachers specifically address as impacting upon them is another way that the TADT framework puts the focus on the teachers' experience of using technology. By incorporating factors as part of a framework that specifically looks at the way teachers use technology, also brings to the forefront the different elements that need to be addressed.

The factors used in the TADT framework were partially drawn from research, but were built up from what teachers in the study said were factors impacting their use of tablets. These factors are defined in Table 30 below. This framework is also designed for future researchers and practitioners to reflect on these factors and expand on them with their own findings.

Table 30 The TADT framework – Definitions for the part related to *Factors*

Factors	
Time	Time available to prepare or learn to use tablets
Resources	Resources, software or hardware, available to use tablets
Technical issues	Issues concerning technical challenges with the hardware, software, or infrastructure
Support	Support provided to the teachers from the leadership or technical team
Classroom management	Classroom management concerns caused by the use of tablets

Knowledge Exchange, as shown in Table 31, is defined in the framework as conversations in which help was offered and knowledge was exchanged. This part of the TADT framework draws on the extensive literature that teaching networks, where teachers learning from each other, have been found to be extremely useful by many teachers in developing their professional practice (Trust, Krutka, & Carpenter 2016; Dawson 2012). In the TADT framework the *knowledge exchange* is captured by counting each time help is offered and knowledge is exchanged between teachers. By not capturing the context of the information exchanged, the focus is on the exchange between the teachers rather than judging or evaluating the help or knowledge being exchanged. The key contribution to the literature is to bring the existing knowledge, that learning networks are important for teacher development, into a framework that looks at the use of technology in teaching. Where other research has focused on the need for teachers to learn and develop their practice in networks of their peers, the frameworks for teachers learning in network and frameworks capturing the way technology is used, have not been combined. Combining these is intended to both highlight and promote the research backed conclusion that learning among teachers is an important aspect of the way technology is used in teaching practice.

Table 31: The TADT framework - Definition for the part related to *Knowledge Exchange*

Knowledge Exchange	Definition: Conversations in which help was offered or knowledge was exchanged.
	Example: Anne "After a week of searching for an app that would dynamically demonstrate the properties of a circle, I finally found one." Tim "What is it called? I have been searching for one to use in my next class." Anne "I'll send it to you."
	Example: Ken "I tried to use the graphing app on the tablets but I wasn't able to graph more complex equations." Sarah "I found a way to do that last week, let me show you."

The TADT framework captures a more holistic picture of the different ways tablets can be used to contribute to the teaching and learning of mathematics from previously developed frameworks. In addition to the different uses of technology, the TADT framework also combines other important aspects of using technology in the classroom, which include the *views* teachers hold, the *factors* that impact them and their continuous learning from each other. Having a framework that represents these different aspects of incorporating tablets into mathematics education recognises and measures the different elements that contribute to the way tablets are used in mathematics classrooms. This holistic view considers the landscape in which the technology is used, addressing what Joubert (2013) suggested is the reason why research has had minimal impact on the use of digital technologies in the teaching. Joubert (2013) suggested that research agendas do not always fully take into account the landscape in which the technology is used.

4.7.3 Reflections on Possible Improvements to the Tablet Programme

Throughout this study, I sought to understand the teachers' perspectives and use of tablets in teaching mathematics, aiming to address the overarching question of *how* they use and view tablets in teaching mathematics, and *why* they make the choices they do. Reflecting on my findings in this study, and what I learnt about the way the school implemented the tablet programme, there are two key changes that I feel would greatly improve teachers' experiences in future tablet programmes. These changes involve the school: (1) designating more time for the teachers to learn to use the tablets and to reflect on their practice; and (2) providing subject specific support to the teachers. Although time and support are scarce resources in teachers' already extremely busy schedules, they are critical elements for successful changes in practice. Adding any form of technology to the school structure, requires teachers to learn and alter their own way of teaching and managing their classroom. However, as it has been stated before, change in any type of instructional practice takes significant time to implement (Dwyer et al., 1990; Laborde, 2001). Without allowing for enough time to learn and reflect on practice and subject specific support the resources put into the programme may go to waste.

As I found in this study, without the necessary time for teachers to learn to integrate technology into their teaching, the use of the technology can quickly of be squeezed out by other demands placed on them, as was the case with Alex. She started using tablets enthusiastically when they were first introduced, but a year into the programme, when she joined this study, she was hardly using the tablets. Although there were several reasons why Alex almost stopped using the tablets, a big reason was that she encountered many difficulties that she did not have the time or confidence to overcome. In analysing the data, I believe that the school could have supported her, and the other teachers, by carving out more time for the them to learn to use the tablets. The importance of good professional development is well known (Ertmer & Ottenbreit-Leftwich, 2010; Opfer & Pedder, 2011). Although there were professional development sessions where teachers were shown how to use the tablets, there was no time provided for reflection and continuous learning, both of which have been shown to be critical for the learning process (Steeg, 2016). If teachers were given more time, on an ongoing basis, to learn and practice using the tablets, search for resources, and reflect on their own practice, they may have made more use of the tablets in their teaching. As Gunn and Hollingsworth (2013) have found, change in teachers' practice is only possible through "thoughtful and systematic implementation of critical knowledge, skills, and strategies" (p. 204).

Time would also have been important for the teachers to be able to meet and learn from each other how to use the tablets. Learning with their peers has been shown to be essential for teachers' development (Trust, 2012; Trust et al.,2016). In this study, it was also clear that the teachers benefited from meeting with other teachers who taught their subject, not only to learn about new ways of using the tablets, but also to discuss subject specific questions, classroom management concerns, and gain confidence through sharing their context specific experiences.

Subject specific support is the second change that I would recommend in future implementations of technology into teaching. Although the school in this study had technology specialist who helped teachers find ways of using the tablets in their lessons, as well as subject champions who were identified as successful users of tablets in each subject group, there was not enough focused support on subject specific use of the tablets. One of the key factors inhibiting teachers' use of the tablets, that emerged in this study, was the lack of understanding on the part of those providing the training and technology support about the specific mathematics uses for the tablets. Particularly as tablets have an extensive collection of applications, many that are meant specifically for mathematics education, teachers found it both challenging and frustrating to find the right program to fit specific needs in the mathematics class they were teaching.

As outlined above, my recommendation for the future integration of technology into teaching, would be for schools to deliberately carve out time for continuous professional development, which also includes time for teachers to reflect and learn on their own, as well as to constructively work with their peers. In addition, I would suggest that the school leaders be sensitive to subject specific needs and provide expertise to the teachers that is in their field of teaching. Although the school in my study tried to provide support to the teachers from different angles – from having technology specialist in the school, to external professional development, and identifying technology champions in each subject that teachers can approach – in my opinion, the glue that would bind together these efforts would be designating more time for teachers to learn, while being sensitive to the needs of each subject. Creating opportunities for the teachers to learn together in groups with their peers (teachers of similar subjects and year groups) would greatly increase their learning process, as was shown in this study. In the following quote, Alex expressed some of the reasons why she was looking forward learning in a group with her peers during this study, which also reflects some of the feelings held by the other teachers.

> I am hoping through doing this I can spend some time literally in a room with people who are also trying to teach maths with iPads. Because of my timetable this year I don't spend any time on this site and I teach in a vacuum. For me this is literally the time I get to interact with people and prioritise these thoughts. The other thing too is that it's also about how I know I learn. I learn through teaching people, talking to people about things. I learn through someone saying 'I will show you now'. I don't learn, or I'm not willing to try things, when someone sends an email summary.

Considering the vast financial expenses that a school makes in implementing new technology, both for the technology as well as for the professional development, providing opportunities for the teachers to meet among themselves, to talk and learn from each other, would likely be the least expensive initiative. Making it a priority for teachers to be able to meet and learn from each other would greatly increase their learning process and ability to integrate the new technology into their practice. Providing the opportunities for teachers to continuously learn from each other might be the least expensive, but most critical part, of implementing new technology into classroom-based teaching and learning.

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5
CONCLUSION

5.1 Introduction

In this chapter I conclude the study and provide my thoughts on implications and directions for future research. In Section 5.2 I address the research questions that guided this study. In Section 5.3 I outline the limitations of the study and in Section 5.4 I discuss implications and directions for future research. Finally, in Section 5.5 I make my concluding remarks.

5.2 Addressing the Research Questions

Through the analysis of the data, the stories that emerged, and addressing the two research questions, this thesis has provided a better understanding of how teachers experience the introduction of a mobile technology into mathematics education.

The first research question is as follows:

1. How do teachers develop over time (if at all) their use of and views on tablets in the teaching of mathematics?

As outlined in Chapter 2, it takes a long time to see changes in the way teachers use technology, unless there is some form of intervention. In this study I wanted to find out how teachers could develop their use of tablets in teaching mathematics without an intervention, but by adding something that could possibly be replicated at other schools, without the need for a researcher being present. For this reason, I incorporated the group meetings where the teachers could learn from each other in how they use the tablets. Both Alex and Charlie said that they were not using the tablets. Although Alex was very enthusiastic when they were first introduced, a year on, when this study started, she was hardly using them in her lessons. It was the introduction of the group meetings, where the teachers talked about their experience, challenges and successes, while sharing knowledge on how to use the tablets, that they all started to develop their use. Even Jordan and Sam, who both said were using tablets fairly regularly in their lessons, actually further developed their use over the course of this study. All the teachers noted that meeting as a group influenced them by learning new ways of using the tablets, improving their self-efficacy through the support of the other teachers and by sharing their challenges, and having time to reflect on how they used the tablets and how they could improve.

Although the group meetings helped the teachers to develop their use of the tablets in their teaching, the development did not follow an expected path. How the teachers developed their use of the tablets did not align with the progressively more complex uses of tablets that Laborde's (2001) framework suggests. For example, Charlie, who used the tablets the least, directly jumped to a more complex use of the tablets. What became clear in this study, was that teachers used the tablets in a lot of different ways, and the characteristics that the teachers valued in these tasks did not fit the characteristics that a lot of research in this field values. Although some tasks may have appeared to be serving a basic purpose in terms of the mathematical complexity, the tablets were actually used in ways to help manage the classroom and the time in a way that helped the teachers advance their mathematics lesson. This realisation led me to expand on the initial framework I developed based on previous research to look at the way technology is used in mathematics teaching, so that it included a more holistic list of characteristics that teachers valued in the use of the tablets. This framework helps to shed light on characteristics of the tasks for which tablets are used for in the mathematics classroom and can also possibly serve as a tool for teachers to use when thinking about ways to use tablets in their lessons.

To address the factors that may influence the teachers' use of and views on tablets, the second research question is the following:

2. What factors contribute to teachers' considerations of how, and why, they use and view tablets in the teaching of mathematics?

Throughout this study, many factors emerged that contributed greatly to the teachers' considerations of how, and why, they used and viewed tablets in their teaching of mathematics. Resources, particularly the lack of resources that met the teachers' needs, was a frequently cited factor by all the teachers. Mainly this was due to the overwhelming number of programs and applications available on the tablets that did not quite match the needs the teachers had for specific aspects of the mathematics lesson. Technical issues, either with the school's wireless infrastructure or within programs, often caused frustration for the teachers. Some teachers, like Jordan and Sam learned to manage some of these technical issues, but that was not the case for all teachers. Having to prepare an alternate lessons, in case technical difficulties might prevent the use of tablets, was a burden faced by all teachers. Teachers found it difficult to prepare two versions of lessons as they were already limited in the time they had available. Time was also an inhibiting factor in terms of having to find resources. Classroom management, regarding issues that emerged because of the tablets, was also often sited. Issues such as students not having the tablets because they either forgot them at home, did not charge them, or the school had removed the tablet from them for bad behaviour, caused management issues for the teachers. The distraction the tablets caused in the classroom, such as the need for students to be constantly touching their tablet, even when it was off, also caused classroom management problems. Other disruptions caused by the tablets were issues such as students forgetting their password, having trouble logging into a program, or not having downloaded a program that was required for the class. All of these, and many other issues, caused disruptions that the teachers had to manage. Although it is often stated that technology becomes less of a distraction once it becomes a regular part of the school life, this research started a year after all the students were given tablets that they had for all their classes and were able to take home with them. Lack of support for the teachers, particularly subject specific support, in using the tablets and addressing challenges, was also a factor that teachers frequently said limited their use of tablets.

In addition to external factors, one of the main internal factors that greatly influenced the way teachers considered using the tablets, was the teachers' views regarding their own self-efficacy. Particularly as teachers faced challenges in using the tablets, the negative impact that had on their self-efficacy greatly influenced their use of the tablets. Alex, who was keen to use tablets from the time they were introduced, found that her self-efficacy suffered so much that she almost entirely stopped using tablets.

Although many different types of factors emerged from this study, through the analysis it became clear to me that there are two overarching factors that incapsulate the others. By addressing these two factors, it is possible to address most of the others. The two factors are *support* and *time*. If teachers are given the time and the appropriate thoughtful support they need to continuously learn to use the tablets in their specific context, then a lot of the other factors would disappear. Finding appropriate resources is an issue that can be addressed both at the school level as well as in the greater education technology industry. At the school level, it would be easier to find resources if teachers were given additional time as well as support from experts and their own peers. On an industry level, there is a gap in curating education technology resources. The information is disparate and there is no central source for well curated resources to address the needs teachers face in the classroom. This is a complex issue, with different teachers having different needs both for themselves and for the particular groups of students they are teaching. It is not sufficient for a list of resources to be developed, that is just one step, it is important for structures to be in place that make it easier for teachers to continuously learn to use tablets in their teaching of mathematics.

5.3 Limitations

Conducting research in a school setting presents some challenges. It is certainly not a limitation to have research situated in schools, because it is precisely the challenges presented by the normal running of a school that is an important part of the research. However, the challenges can limit the amount or consistency of the data that is gathered. Schools are very busy places where diversions and distractions emerge constantly. My aim in this study was to answer the research questions within a natural school environment, and allow the forces brought about by the normal running of the school to act upon the study. My hope was that by trying to maintain the regular classroom setting, aspects of this study could be applicable in other schools and provide valuable insights.

However, the limitations of having a study in a school environment are numerous, mainly due to some loss of control and some loss of data. Interruptions by students and faculty during class alter the lessons teachers planned, possibly using the tablets in different ways than they intended. Changes in the school’s schedule may alter the plans set out in the research and can limit the amount of data that is collected. Students being disruptive, or not bringing their tablets to class, can alter the lesson the teacher had organised and the way she intended for the tablets to be used. Failures in the technology infrastructure also cause teachers to have to change their plan and methods of teaching. In addition, the lack of control over the topic and timing of the material that teachers need to cover, may not be the topic for which tablets are most useful. These are just some of the factors in a school setting that may impact the results of the study. However, this is also exactly what needed to be captured as the study investigates how teachers use tablets in a school setting, not a controlled and artificial environment.

The number of teachers in the study would have ideally been slightly higher. Although the design of the study was to have few teachers that I could study in depth over a long period of time, rather than more teachers with less time, I had originally anticipated to have five or six participating teachers. However, because of time restrictions and interest in the project, only four individuals committed to and completed the study. The danger of having any participant leave the project half way through was very real, but luckily did not occur. Having more voices in the study would have made for richer data, but that is a limitation that had to be accepted.

Changes in school structure and policy are also limiting factors in this project. This is an aspect of working in a school setting, however in this project it was a significant influence on its own. In June 2015 I still had a month and a half left of fieldwork. At this time there was a sudden change in the school tablet policy. The school leadership made a decision that removed tablets from individual students and organised the devices into classroom sets that teachers could borrow for specific classes. This was a major change as it was central feature that every student could take home their tablets and have ownership over the devices. This change meant that suddenly all tablets were recalled in order to be refurbished for use in the next academic year. This meant that I could not collect any data for a month and a half and the number of group meetings with the teachers was further reduced from five to four. This change reduced the amount of data that I was able to collect in this study.

With the limitations of time and the unforeseeable circumstances that altered the intended design of the study, I would have liked to be able to meet with the teachers and have them interact with the framework that was developed. It would have been valuable for them to see the framework, discuss their use of tablets in their teaching with regards to the framework, and to have their professional opinion about the framework. Having the teachers use the framework, and provide their insight on its design, would have further rooted the framework in the actual practice of the teachers. It would also be valuable to see how using the framework as a point of discussion among the teachers, as a living and changing artefact, might further develop their own practice. Unfortunately, because the tablet programme was abruptly changed by the school, in a way that removed all the tablets for the remainder of the year, it was no longer possible to have the teachers use the framework. This is something that can be explored in future studies.

Although these limitations all have some impact on the data that I collected, they also represent the limitations any initiative might face in an actual school setting. Accommodating and acknowledging these limitations makes the results of the study more valuable and relevant to other school settings that likely face some similar challenges.

5.4 Implications and Directions for Practice and Research

In this section I outline three key implications and directions for future practice and research. The three areas of focus are: understanding teachers' use of technology, creating learning networks in schools, and providing teachers with curated list of resources for using technology.

5.4.1 Understanding Teachers' Use of Technology

There is a need for more research to understand how mathematics teachers use mobile technology, such as tablets, overall not just specific programs. Particularly as tablets are encompassing features of several other technologies and physical resources, as well as being used for a variety of subjects, the possibilities of how to use these devices in education is seemingly endless. There is a need to understand how teachers use these tools in their mathematics lessons and how some of the non-mathematics specific tools might be useful to support mathematics teaching. There is significant research focused on how teachers can use mathematics specific programs – such as GeoGebra, Cabri, or graphing calculators – to present knowledge in new ways, but there can be great value in using non-mathematical programs to support the mathematics classroom. It would be valuable to further investigate how pedagogy, as well as technology, can be directed to make classroom activities more efficient, engaging, and helping students focus on the educational aspects of the activities. I would have liked to continue this research for a longer period of time to investigate these issues, unfortunately the school withdrew all the tablets before the study was finished and returned it to the students and teachers many months later.

The final TADT framework that I developed in this study is something that I would like to incorporate in the kind of future research I outlined in the previous paragraph. By extending the time of the study and the number of group meetings, it would be valuable to present the framework to the teachers during the group meetings. My intention is for this framework is to be a living artefact that would be used by researchers and teachers as a way of thinking about using technology in the classroom. Using the framework as a source of discussion may provide teachers with ideas on how to use technology in their teaching, it may provide a framework for how they think about the technology in their teaching, and it can be something that they could modify to accommodate the context in which they are working.

5.4.2 Creating Learning Networks in Schools

Developing a learning network within a school, such as the group meetings used in this study, can be the glue that holds together all the other valuable resources and investments that schools make in the implementation of technology in teaching. Having a technology manager in the school, external professional development, and purchasing resources for the tablets, would all be more valuable if teachers had the opportunity to discuss their use, and experience of using technology in their teaching, and develop their skills. Having this type of forum allows teachers to process what they learned in professional development classes, help them learn to use the electronic resources that the school purchased, and discuss the benefits and opportunities of the initiatives introduced by the technology manager.

Through this study, it became clear that giving the opportunity for teachers to work together, to develop their use of tablets, greatly impacted how much they used the tablets, their level of innovation, and it also improved their self-efficacy. Alex and Charlie are good examples of this. Alex stopped using the tablets before this study started, as is detailed in Section 4.6, and Charlie never got the courage to start using the tablets. During the first group meeting Charlie and Alex spoke at length on why having a learning network would be valuable to them. This is one example of many in which teachers highlighted the value they saw from having dedicated time to discuss and learn from each other.

> Charlie: When you go to any of the trainings I feel completely and utterly overwhelmed. I watch it all going on and I'm not in the room, I'm on the ceiling, and I'm watching it all going on and I'm thinking 'oh my god I would never be able to do that'. So it's just nice to be able to hear that not everything is absolute instant hit.
>
> Alex: I am hoping through doing this I can spend some time literally in a room with people who are also trying to teach maths with iPads because of my timetable this year I don't spend any time on this site and I teach in a vacuum. For me this is literally the time I get to interact with people and prioritise these thoughts.

Although there are many different professional learning networks online for teachers, fostering this type of network in a school provides many advantages. To begin with, it incorporates teachers who otherwise would not find such a network online. In order to participate in such an online community, someone would need a certain level of engagement with technology. Having this network within a school, includes everyone who wishes to participate, not only those who are more comfortable using technology.

Time is another factor that would greatly inhibit many teachers. As was found in the study, teachers are greatly restricted by the amount of time they have to prepare their lessons. Without easily accessible and pre-arranged group meetings, finding time to engage in online communities is unlikely to happen for many teachers.

Relevant context is another important reason to have learning networks for teachers in schools. As previously mentioned, different school contexts have different obstacles and opportunities in the way technology is used in the classroom. Having teachers from the same school, who know the same students, meet regularly and learn from each other, means that they have the same cultural reference and context in which they apply the technology.

For all these reasons, having a learning network for teachers within a school can provide a glue for all the other resources that schools provide to support the technology used in teaching. Teachers can leverage their different skills and knowledge to each develop further their use of technology in teaching mathematics.

One important direction for future research would be to investigate how the group meetings could develop over time and how the knowledge exchanged in the meetings might impact the way teachers use technology. It would be valuable for future research to incorporate more group meetings over a longer period, and for group meetings to also increasingly focus on specific mathematical topics. This may enable teachers to design innovative uses for tablets that can help students to interact with mathematics in ways that would not be possible without a tablet. This approach, with teachers exchanging knowledge in group meetings, might result in significant changes in relation to instrumental evolution, as well as other aspects of the framework.

I hope this study will have an impact on the structure of teacher development in schools. The group meetings indicated that there is a real need for schools to dedicate time for teachers to meet as a group and discuss their practice. For teachers to be able to share their knowledge and learn from each other is critical in helping them use the technology My study has shown that there is a significant change in the teachers' views of tablets and the way that they use them. One of the key factors that inhibit use of technology in schools is that teachers do not have time to explore and develop lessons that use the technology. Schools spend significant resources on technology, the supporting structures, and the professional development to train teachers to use the technology. Strategically leveraging the knowledge and imagination of the teachers in the school can make the difference between a successful integration of technology or wasting valuable investment on technology that will quickly fade into the back of the classroom. Providing the type of group meeting structure that was in this study, could be the glue that holds together all the other investments they have made in technology.

5.4.3 Curating Tablet Resources for Teachers

The greatest factor inhibiting teachers' use of tablets in my study was resources. Everyone agreed that there was an abundance of resources available, but the concern was the quality, usability, price, and disparate sources of countless resources. This factor impacted the amount of time teachers had to spend to find what they needed and also the self-efficacy was hindered as they got lost in a sea of apps, webpages, and programs. When, during a group meeting, we tried to find an app to suit a particular need teachers were discussing, Charlie summed up the frustration teachers face in the when she said that apps are "incredibly time consuming to find. We probably just spend 15 minutes demonstrating that we are lost in a world of a million apps, or no apps."

Having a curated list of useful apps, websites, and programs that teachers can use was a desire expressed in different ways throughout the course of the study. The teachers have never found a good forum to curate material online, but they also expressed the need for this to be a role that the technology manager could fill. They particularly made it clear that it was critical for anyone who did this, to be very sensitive and knowledgeable about the specific subject needs. The challenge is to know what mathematics teachers need and have specific understanding of what features programs need to have.

Although the teachers specifically mentioned that they would like the technology manager to help them curate the apps available to them, this role could also be taken on by the software industry. It would be useful to have a reliable and well-informed resource where mathematics teachers could find programs that best suited the topic they were teaching. In addition to curation, it might also be beneficial to build into programs clear teaching guides that include the rational for the design of the program that helps students learn mathematics. This type of guides may help teachers select programs more effectively and also learn ways of implementing them in their class. This type of material, that aims to promote teacher learning alongside student learning, is often referred to as *educative*. An example of such an educative material was used to help teachers teach proof in mathematics (Stylianides & Stylianides, 2014) by providing annotated PowerPoint slides with the annotations detailing what to do as well as why/how to do it. These types of instructions, included in programs and apps, could greatly aid teachers in how they use technology. This is only one part of the greater ecosystem required for integrating technology into teaching, which includes professional development, resources, and infrastructure, among others, but it could be a significant contribution to helping teachers find and use the resources they would like.

5.5 Concluding Remarks

This study, by being situated in the natural school setting and focusing on the teacher, provides insights to help integrate technology into mathematics education in the school setting. By focusing on teachers with different levels of experience and comfort in using technology to teach mathematics, this study highlights the ways they use tablets in their lessons, their views on using tablets and the factors that impact their decisions. Through regular group meetings that fostered a learning network, the teachers focused on reflection and exchanging knowledge about their use of tablets, and in this process their use and views of using tablets developed. Over the course of the study, a variety of uses for tablets, that were valued by teachers, emerged. This is reflected in the TADT framework that I developed in this study. This framework is intended to not only look at teachers but also be used by teachers in ongoing learning networks that may help them further develop their use of technology in mathematics education.

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Appendix 1: Chronological Story of Relationship Building

Prior to my first visit to the school I was fortunate to have foundations of my relationship with the teachers and the school being set. In addition to the school having the characteristics necessary for my project, my two doctoral supervisors at the time, who each had professional relationships with the school, kindly introduced me to their contacts. One of my supervisors introduced me to the school and the information technology (IT) director, while my other supervisor introduced me to the head of mathematics and to Jordan. Jordan was a mathematics teacher who became a central contact in this study. I will discuss these relationships in more detail in the paragraphs that follow.

I visited the school for the first time when one of my doctoral supervisors invited me to accompany him on a visit. He was working on a different project with the school and was going to meet with the IT director who was in charge of implanting tablets at the school. This was a great opportunity for me to meet the IT director and learn about how the school was using the iPad tablets that it had introduced six months prior. We arrived at the school and were greeted by the IT director. He was a lively and passionate individual eager to discus the tablet program that he helped implement. He seemed to believe strongly in the power tablets held to help students learn by engaging them, providing individualized learning experiences, and offering the opportunities to learn any time of the day. His job was to manage the infrastructure that was required to run tablets and also help the teachers find learning tools that they can use in their classrooms. He organized some professional development opportunities for teachers as well as assisting individual teachers to help them find ways of using tablets in their lessons. As I met him in July 2014, it had only been six months that the students were using tablets in their lessons. Teachers were each given iPad mini tablets the previous summer, but they were not used until January 2014 in the classroom. The students received their iPad mini tablets before going on their winter break in December 2013 as a way for them to get used to the devices by the time they returned to school.

During that first visit to the school I toured the facilities and the IT director discussed at length the integration process of tablets. I saw the computer rooms and heard stories about the challenges teachers had booking space for their classes to use the computers. I visited classrooms that looked like many others that I have seen. There were whiteboards at the front of the class and projectors pointing at them from the ceiling. Overall there was minimal technology, but the walls were full of artwork and educational posters. It was a warm and lively environment.

During this tour, the IT director told stories about how tablets were received by the school. He described the students exhilarated at the each receiving new iPad minis that they could take home, however the reception was more mixed among parents and teachers. He described some parents as enthusiastically embracing that their children should use leading edge technology to learn any time anywhere. However, other parents questioned the added value it would offer considering the high cost. Other parents worried about screen time and possibly loosing control of what their children did online. Teachers were similarly split. The IT director described some teachers are trailblazers and pushing for innovative ways to use tablets, whereas others worried about the distractive and time-consuming nature of the devices. He said some teachers who hesitated at first had already started to see the benefits of the devices, but it was still a divisive topic among the faculty.

The IT director was in the process of organizing an iPad Day where all the teachers would use tablets in their classrooms. Along with teachers from each subject area, who were enthusiastic tablet users, the IT director developed lessons for tablets that each teacher was to use. The aim of this day was to help expose all teachers to what a lesson might be like using tablets. I was invited to join this day and observe several mathematics teachers.

Returning to the school on the iPad Day, I observed several Year 7 mathematics classes using tablets during their lessons. Each class had around twenty to thirty students, some classes had tables clustered in groups of four and other classes had traditional row seating. Throughout the day the teachers used tablets to control slideshows, work on logic problems, and show videos. There were a variety of tasks and students seemed to be engaged in the activities. There were some infrastructure issues during the day, particularly with the network getting overloaded and failing, but the teachers found ways around the challenges. Throughout the lessons I sat among the students and observed. Overall the students were well behaving and buzzing with excitement. They seemed to be immersed in the lessons, worked well with their tablets, but also some students were quite distracted flipping in and out of programs on their tablet, or taking pictures. This day was a wonderful opportunity to meet some of the mathematics teachers and see tablets being used in class. I had many nice conversations with teachers and heard about their experiences as they have adjusted to using tablets in their teaching over the past six months. The teachers were curious to hear why I took an interest in the school and about my project. As these were very early meetings, I focused on my past experiences and how I came to be interested in this topic. I discussed the overarching questions I hoped my project would answer, but also made it clear that the exact details of the project would develop as I became more familiar with the teachers, the challenges they faced, and the ways they were using tablets in their teaching. I felt the atmosphere of the school to be very positive and vibrant, with teachers and student enthusiastically moving about the school. This was certainly not in any way meant to draw any conclusions about the way tablets were used in the classroom; as I previously mentioned, this was part of an acclimatization process for me and to become familiar with the school environment and the teachers at the school.

During the iPad Day, one of the teachers whose class I attended was named Jordan (names of all teachers have been changed). Jordan was very enthusiastic about using tablets in lessons and was identified as a technology champion in the school. We quickly connected as we discussed our shared interest in the use of technology in mathematics education. I told Jordan about my background and experiences teaching mathematics. I also expressed my desire to learn more about how technology was used in mathematics classrooms and how teachers developed their skills. I asked many questions and Jordan kindly shared a great deal of insight and experiences. We found quite a bit of common ground and had a wonderful conversation. As I expressed my desire to visit the school on a regular basis and see how teachers used tablets on a daily basis, Jordan generously offered to organize my visit and introduce me to other teachers.

I returned on several occasions to the school and Jordan helped organize these visits. Jordan arranged for me to observe several Year 7 mathematics classes being taught by a variety of teachers. Through these meetings I connected with teachers who also invited me back to the school to observe more classes. Gradually spending more time in the school, and meeting teachers, I became more naturalized into the environment. I easily came to the school, signed in at the reception and waited in the staff room for the teacher I was meeting to arrive. I watched teachers rush in and out of the staff room, I overheard conversations and slowly became a familiar face among the teachers and students. Occasionally I felt the apprehension as I told a teacher that I was researching at the university, and I saw the questioning looks that made me feel like an outsider. But as I was there to learn, not judge, and making that clear by the way I behaved, over an extended period of time, eased any tensions I experienced. I was always clear that I would not share raw information with the leadership of the school and my study was not making judgments on good or bad practice, rather it would explore how practice developed.

As I spent time in the staff room and the halls of the school I got glimpses into the daily life teachers had and I heard the off the cuff remarks that were made about tablets. One day as I sat in the staff room, one of the teachers bursts in the room by pushing the door open with his shoulders and balancing a coffee cup on his tablet, with his hands full of books. “Well, this is the most use I have yet found for these iPads” he explained to the room and no one in particular. There were some chuckles and sighs as it was obvious that that there were mixed feelings on the topic. There were also other times where I saw one teacher tell another about a great new app she discovered. The two would huddle over a tablet and explore the program and talk about how to use it in the next class. As in any school staff room, stories were often told about students that all the teachers knew. How little Jonny was found to be playing a game on the tablet rather than listening to the teacher, or little Sally was finally learning a topic using an app on the tablet that she has struggle to understand before. There were also stories about how a student discovered a fantastic way of learning with the tablet, or how another student had to have their tablet confiscated for bad behaviors and this caused greater inconvenience to the teachers who had lessons planed on tablets. One day there was a lot of buzz and frustration in the staff room as the teachers grumbled at the network having gone down and making the technology irrelevant. On another day I found a physical education teacher excitedly telling a group of other teachers what he saw at an educational technology trade show. “Look at these blocks” he explained “I can design an entire class with different stations so when a student gets near this block instructions and videos will pop up on their tablet to explain the exercise or game that they need to do. How fun!” The small group of other teachers huddled around his tablet as he showed pictures of this new device. “Hopefully I can convince the department to buy them, they would be amazing!” These are some of the types of conversations and sights that I witnessed as I sat in the staff room and walked the halls. There were mixed emotions, but after six months and even a year after tablets were introduced in the school they were still a topic of conversation.

As I visited the school, I spent time observing Year 7 mathematics classrooms that were taught by a variety of teachers. As I mentioned before, in this part of the study I did not take notes or photographs, I simply went to the classrooms and observed. The purpose for this was twofold. Firstly, to develop a relationship with the teachers it was important to gradually develop my classroom presence. Although I am not there to make judgments or evaluations, taking notes would give that impression and it may hinder the quality of the relationship I can develop with the teachers. On the other hand, I also wanted to simply immerse myself in the classroom environment. Become familiar with the space, the routine and the manner in which tablets were being used. Becoming naturalized in the environment is a central role of the study that aims to capture information in the school setting.

As I visited classrooms I got used to the rush of students coming into the class, the routines some teachers had where the students automatically started practicing arithmetic as soon as they entered the class using an app on their tablet, and occasionally the distractions students found on their tablets. I saw some teachers smoothly moving between activities on the tablet to others deliberately making an effort to add one activity during the class in which the tablet was used. I saw how teachers scrambled to find ways to accommodate students who forgot their tablet, and scramble to fix technical errors that disrupted their lessons. I always offered to help with anything I could, and I told teachers before the classes began that I am happy to lend a hand any time they wish. I helped to hand out worksheets and also walk around during work periods to help struggling students with their work. The teachers graciously shared with me their thoughts, struggles, successes and experiences of transforming their lessons to include tablets. I learned about their lives, how they came to be teachers and what they hoped to do in the future. We talked about our weekend, how I felt about being back in university after having had a career, and how my experiences differed in the UK from those of my home in Canada. Throughout all of this, I slowly became a familiar face in the classroom. And essentially we developed a friendly collegial relationship.

In February 2015 I was invited to come to the school for a parents' evening. This was actually scheduled to take place in December 2014, but the school had rescheduled the event. This evening was particularly focused on the use of tablets in the school and demonstrating to the parents how they were being used in the classrooms. From what I was told, there were mixed feelings among the parents on having tablets used in the classroom. One year after the school introduced tablets, this evening was meant to showcase how they were being used in different classrooms. The evening started in the school auditorium where the head teacher gave an overview to the parents in the audience on how the tablet program has been progressing. The Head Teacher acknowledged both the challenges and the successes that tablets presented, and also shared some anecdotal stories. I have touched on the tensions that existed among faculty and parents regarding the introduction of tablets, but from what I could gimps, the leadership of the school also had diverse ideas on what would make the tablet program a success. The head of the school had changed after tablets had been implemented. Although it had been a year since tablets started to be used by the school, it was not completely clear what shape the program would take in the future. There were questions from the parents that showed the diversity in how they felt about the program. Following the presentation the parents were organized into different tour groups, as they were led to visit some of the classrooms. The classrooms were set up to demonstrate some of the best uses for tablets in that class. Teachers displayed work students have done, and demonstrated how tablets were helping their students learn. As I made my way through the classrooms I saw parents amazed at the lessons their children were exposed to and also questioning the validity of using tablets for other tasks. The evening displayed some of the most visually pleasing displays of how tablets were used and it also shed some light on the debates and tensions within the wider community on the topic using tablets in the classroom.

All of these experiences gave me context. Often they were not unfamiliar to the general discourse that can be found in the media on the topic of mobile technology in the classroom, but it situated the study and gave me a basis of common understanding that I shared with the teachers. As my relationship developed within the school, I asked some of the teachers if I could observe their class and try out an observation instrument I was hoping to use in the future. The results of these classroom observations are described in the following section.

Appendix 2: Classroom Observation Tool in Phase One

This is broadly adapted from Sears (2012) which was adapted from Horizon Research, Inc. classroom observation protocol developed for the Cases of Reasoning and Proving in Secondary Mathematics Project, with funding from the National Science Foundation (Award No. DRL-0732798)

PART I

A. Background Information

1. Date of Visit:
2. Teacher:
3. Class Period:
4. Total Number of Students:
5. Level of Class:

B. Outline of the Lesson:

1. List the stated goals for the lesson as described and/or provided by the teacher.
2. Briefly (2-3 paragraphs) describe the structure and flow of the lesson you observed [non-evaluative].
3. Describe how the tablet was incorporated into the lesson. For example, what programs were used, who used it, and how?

PART II . Classroom Culture

A. Ratings of Key Indicators

	Not at all				To a great extent	Don't know	N/A
1. Active participation of all was encouraged and valued.	1	2	3	4	5	6	7
2. There was a climate of respect for students' ideas, questions, and contributions.	1	2	3	4	5	6	7

3. Interactions reflected collaborative working relationships between teacher and students.	1	2	3	4	5	6	7
4. The climate of the lesson encouraged students to generate ideas, questions, conjectures, and/or propositions.	1	2	3	4	5	6	7
5. Intellectual rigor, constructive criticism, and the challenging of ideas were evident.	1	2	3	4	5	6	7
6. ______________________________	1	2	3	4	5	6	7

If you rated any of these indicators are 6 or 7, please provide an explanation in your supporting evidence below.

B. Synthesis Rating

Classroom culture interfered with student learning				Classroom culture facilitated the learning of all students
1	2	3	4	5

C. Supporting Evidence for Synthesis Rating

Provide a brief description of the nature of the lesson, the rationale for your synthesis rating, and the evidence to support that rating. (If available, be sure to include examples/quotes to illustrate ratings.)

PART III.

A. Detailed Lesson Observation

Please tick boxes as to what is happening during the class and specify when required.

Time into class (min)	Interruption	Instruction	iPad used	Mathematical tasks	iPad program used	Method of using iPad (whole class, small groups, individual, specific students)	Purpose of technology (intro task, teaching/ understanding, practice, reiteration)	NOTES
5								
10								
15								
20								
25								
30								
35								

40								
45								
50								
55								
60								
65								
70								
75								
80								
85								
90								

B. Description of Mathematics

List and describe the mathematical tasks that took place in the lesson and if/how the iPad was used for these tasks.

C. Description of Lesson Observation

Describe in more detail the flow of the lesson and the ways in which the iPad was used by the teacher and the students. Also comment on way the teacher generally interacted with the technology.

Appendix 3: Classroom Observation Tool in Phase Two

Period:		***Reminders:***
Teacher		*Pictures of board and iPads*
#Students:		*Handouts to be collected*
Level:		*Draw/photo of classroom setup*

Time	iPad used (✔)	iPad Program Used	Details Notes	Description of picutre taken
11:05				
11:06				
11:07				
11:08				
11:09				
11:10				
11:11				
11:12				
:				
:				
:				

Appendix 4: Fieldwork Safety, Risk Assessment form

Declaration

Please note: electronic signatures are not acceptable

Student Declaration

☐ I have completed the risk assessment relevant to my fieldwork.

☐ The information given on this form is correct to the best of my knowledge and I will ensure that it is updated as necessary (referring to the FCO website if relevant).

☐ I have familiarised myself with current university Health & Safety Policies (and university statement of safety organisation.

☐ I have also signed the travel insurance form!

Signed ____ **Date:** _________________

Supervisor Declaration

☐ I have read this risk assessment form and discussed it with the student

☐ I have completed the supervisor check list with comments as appropriate

☐ I am aware of my responsibilities to act as a point of contact for the student during travel

Signed (supervisor) ______________________ **Date:** _________________

Departmental Administrator

I have signed the insurance form! (please tick to confirm) ☐

DGS / HoD Approval

(HoD Approval required when region/area to be visited is deemed 'inadvisable' by the FCO)

Signed ___________________________________ **Date:** _________________

Fieldwork Safety, Risk Assessment and Insurance

This **entire** form **must** be completed by **all** students intending to carry out fieldwork. The Head of Department or their representative is required to approve all overseas fieldwork. It is mandatory to submit this form to the Higher Degrees Office **at least five weeks** in advance of carrying out your research. No travel should be booked until approval has been obtained by your supervisor and the Head of Department (or their representative). Please note that even if you're travelling to your home country on fieldwork, it still falls under university business and **must** be treated with equal consideration. **All signatures must be original.**

1. General information

First name	**Surname**
Nationality	**Supervisor**
Contact Address prior to fieldwork:	
Contact email prior to fieldwork	**Contact phone number prior to fieldowork**

2. Itinerary

Where is the fieldwork taking place? *Please be specific if you are visiting particular areas within a city, or region*. (For example, Cowley, not just Oxford).	
According to the FCO Website, the area I am visiting has been identified as:	Low Risk
Date(s) of visit *Please note, this form can only cover you for a single period. If you plan to return at a later date, you will have to submit another form.*	
Contact details during fieldwork: **Accommodation** *Please give as much as information as possible (address, contact name, phone, mobile phone, fax, email)*	
Contact details during fieldwork: **Placements / Local Contact** *Please give as much as information as possible (address, contact name, phone, mobile phone, fax, email)*	
If you are not a British national, does your own government advise against travel to the area you propose to visit	No
What activities will you be undertaking?	
What institutions will you be visiting?	
Will you be travelling alone at night, and what precautions will you take?	

3. Health/medical and emergency procedures

Have you taken advice from the University Occupational Health Service on the health risks associated with travel to your field site (http://www.admin.ox.ac.uk/uohs/at-work/travel/)?	Not Applicable
If no please state why:	
All accidents, incidents or near misses must be reported to Erica Oakes (erica.oakes@education.ox.ac.uk) at the Department of Education and your supervisor. Please check the box to confirm that you will ensure this takes place while you are on fieldwork: ☒	
Next of Kin: *Please state full name, address, telephone number, email and their relationship to you*	
Passport / visa numbers (overseas travel only)	
What first aid training have you received or what first aid is available to you?	
Will you need to take any first aid provisions?	
If you're visiting an area that is fairly isolated, what access do you have to emergency services and medical help? If relevant, please also provide details of emergency plans in place (e.g. for evacuation from the research area, or if there is an injury to a worker in a small team)?	

4. Training and or experience

Have you received any training for your overseas travel? Please give details.	Have you experience in similar work? Please give details.
Training Available from: https://www.admin.ox.ac.uk/safety/safetytraining/safetytraining/course/?crsID=104	

5. Supervision

A fieldworker will still be under supervision with regards to health and safety, even though the supervisor may not be present. Please provide details of your supervisor, or other nominated person, who you will contact on a regular basis to ensure your safety. The nominated person should be provided with the contact details of a person in the Department, in case of emergency etc. Specify contact period times (e.g. daily/weekly).

Name	**Contact Period (when and how often you will contact your supervisor)**
Address	**Telephone**
Email	
How will contact be made? You must ensure that this is possible (e.g. if reliance is put on a mobile phone, you must ensure there is adequate signal):	

6. Risk Assessment

A risk assessment must be carried out in order to comply with University Safety Policy. You will need to read UPS S3/07 Overseas Travel and UPS S5/07 Safety in Fieldwork.

Please remember to consider not only possible risks to your own health and safety, but also the effect that your work may have on other people or the environment.

The competency of external agencies hosting a fieldworker must be considered. Arrangements and responsibilities for the fieldwork must be agreed and documented as part of the risk assessment.

Hazard identified (please specify) **(see checklists in appendix to UPS S5/07)**	**Risk(s) involved and control measures to be put in place to minimise risk**	**Estimated level of risk**
Personal (e.g. lone work, first aid, violence, crime, travel, handling cash, transport)		Low
Physical (e.g. extreme weather, fitness and medical risks)		Low
Equipment (will you be taking a laptop, mobile, cash, internet access etc? These should be specified in your insurance form)		Low
Environmental and surroundings (e.g. pollution, waste, language barriers, local culture and awareness of this)		Not Applicable
Other		Not Applicable

7. Supervisor Risk Assessment check list

Supervisor to complete, then sign the front page of the form.

		Additional comments if relevant
I have discussed with the student the general risks associated with the planned fieldwork.	☐	
I have discussed with the student the potential additional specific safety issues and risks associated with this fieldwork, and appropriate measures to reduce them.	☐	
I believe that travel arrangements discussed are satisfactory and safe.	☐	
I have discussed with the student any specific health issues associated with the area they are		

travelling to and any issues regarding their research.	☐	
We have identified specific requirements for additional guidance and advice (indicate as necessary) and this is being sought by the student/researcher	☐	
I am satisfied that the student has adequately assessed the risks associated with the planned work, and agrees to carry out the work in a manner that reduces risks to health and safety to a satisfactory level.	☐	

Travel Insurance Application

Your travel insurance document provides cover for both you and your personal belongings while travelling on University business. Details of the limits of cover are set out on the Confirmation & Summary of Cover, available from www.admin.ox.ac.uk/finance/insurance/travel. Please note:

1. All travel insurance claims are settled net of a standard excess of £50.
2. Please list all personal items over £500 in value below. We strongly advise you not to take valuable items with you while travelling.
3. All **theft/lost property** claims must be supported by a local police/security report.
4. All **property damage** claims must be supported by an estimate for repair, detailing the extent of the damage and the cost of repair. If the item is beyond economical repair a quotation for replacement must be supplied with the claim. You may also be asked to supply a receipt for the original item.

Please complete the following information:

Full name of traveller	**Department**
Inclusive dates of travel *From* *To*	**Destination(s)** *(City & Country)*
Attach Completed Risk Assessment	

(See University Policy Statement S3/07 point 3 for further information)	☒
Name of Supervisor	**Name of Head of Department**
Home address & emergency contact no.	**Next of kin name, address & contact no.**
Accommodation addresses and contact numbers	
Reason for travel	
Outbound flight number	**Airport of departure** **Destination airport**
Inbound flight number	**Airport of departure** **Destination airport**
List of personal items >£500 value	
Item	**Estimated value**

Signature of Applicant: **Date:**

Cover will operate from this date in the event of a cancellation claim

Signature of Departmental Administrator: **Date:**

NOTES:

There is a maximum of £3000 cover for personal property (and in the event of a claim, there is a £50 excess). As a consequence, if you are taking a personal laptop (or any other electrical item) with a value greater than £1000, you should arrange all-risks insurance cover for the item personally (and declare this on your University travel insurance application form). Please check website at: **http://www.admin.ox.ac.uk/finance/insurance/travel.shtml** for any changes to this information. If you hire a car overseas for local travel you must arrange car insurance (comprehensive) locally. **Cover is NOT provided under the University travel insurance scheme.**

Please note, repatriation for medical reasons provides for emergency return to Britain and not your home country. The cover does not provide for medical treatment **in** Britain as it expects you to be covered under the NHS. If you are not covered under the NHS you should make your own insurance arrangements for medical treatment in this country. You should take details of the Emergency Medical Assistance contact numbers. Further copies can be obtained from the Higher Degrees Administrator. The details are also available on the University's Travel Insurance web page (see: **http://www.admin.ox.ac.uk/finance/insurance/travel.shtml)**. **Please ensure you have this information before you travel.** If you do need medical treatment overseas please ensure you obtain receipts. They will be essential for the claim which will be made to the insurers. (Please note the excess charges.)

Appendix 5: CUREC form (Application approved on 6th November 2014)

University of Oxford

CENTRAL UNIVERSITY RESEARCH ETHICS COMMITTEE (CUREC)

CUREC/1A Checklist for the Social Sciences and Humanities

The University of Oxford places a high value on the knowledge, expertise, and integrity of its members and their ability to conduct research to high standards of scholarship and ethics. The research ethics clearance procedures have been established to ensure that the University is meeting its obligations as a responsible institution. They start from the presumption that all members of the University will take their responsibilities and obligations seriously and will ensure that their research on human subjects is conducted according to the established principles and good practice in their fields and in accordance, where appropriate, with legal requirements. Since the requirements of research ethics review will vary from field to field and from project to project, the University accepts that different guidelines and procedures will be appropriate. Please check the CUREC website to ensure that you have the correct form for your project.

This form does not cover research governance, satisfactory methodology, compliance with the requirements of publishers when administering their tests or questionnaires, or the health and safety of employees and students. As principal investigator, it is your responsibility to ensure that requirements in these areas are met. Please carry out a risk assessment of the project, in consultation with all researchers involved, using the checklist and CUREC's other documentation.

The use of an asterisk in this form indicates a phrase defined in the glossary. The glossary and further information on the University's research ethics procedures are available from the CUREC website:

www.admin.ox.ac.uk/curec

This form is designed largely for research that falls within the Divisions of Social Sciences and Humanities and which does not involve a high level of risk to the subjects. Elite interviews, field work and oral history are included in the CUREC process. Please take a moment to read through it and if you have any questions or doubts as to whether it is the appropriate form, please review Section A or consult the CUREC website.

Note on anonymised data and audit: you do not need to obtain ethical approval for your study if:

- you are using previously collected **anonymised data** about people which neither you nor anyone else involved in your study can trace back to the individuals who provided them (e.g. census data, administrative data, secondary analysis). Please refer to the definition of *personal data in the glossary and FAQ A4 for further guidance; or
- you are conducting research on behalf of or at the request of a service provider that matches the definition of *audit in the glossary.

If your research is audit or uses prior-anonymised data, please check this box: ☐

You do not need to seek ethical approval from CUREC, and you do not need to complete any more of this form. However, please check with your department's requirements, as some departments require you to lodge this form with them.

Office use only: IDREC Ref. No. ___________________

Date of confirmation that checklist accepted on behalf of IDREC: // //

SECTION A	Yes	No
1) Are you using research methodologies commonly used in biomedical or behavioural laboratory sciences?		✓
2) Is there a significant risk that the research will induce anxiety, stress or other harmful psychological states in participants that might persist beyond the duration of any test or interview in which they are participating?		✓
3) Will the research involve human participants recruited by means of their status as present or past NHS patients or their relatives or carers?		✓
4) Does the research involve *human participants aged 16 and over who do not have *capacity to consent for themselves? See the Mental Capacity Act 2005		✓
5) Is the study to be funded by the US National Institutes of Health or another US federal funding agency?		✓

If you answered 'yes', please **stop** work on this checklist and

6. **for questions 1 and 2**, complete CUREC/1 instead (available from www.admin.ox.ac.uk/curec/);
7. **for questions 3 and 4**, submit your proposal to the appropriate NHS ethics committee (see www.nres.npsa.nhs.uk and www.admin.ox.ac.uk/researchsupport/ctrg for further information);
8. **for question 5**, or **if you answered 'yes' to questions 1, 2 or 4 and your research will take place outside the EU and is a biomedical study**, submit your proposal to OXTREC, which uses separate documentation. **Applications to OXTREC using this form will not be accepted.** If your research is not a biomedical study and does not have US funding, but will take place outside the EU, you may use this form to submit your application for approval to the Social Sciences and Humanities IDREC.

If you have answered 'no' to all questions in Section A, please complete Sections B-E. This form and any supporting materials should be typewritten.

SECTION B

****Principal investigator/ supervisor/student researcher (title and name):***	***Ms Kinga Petrovai***
Name of supervisor (STUDENT RESEARCH PROJECTS ONLY):	***Dr Gabriel Stylianides, Dr Chris Davies***
Degree programme, e.g. DPhil, MPhil, MSc (STUDENT RESEARCH PROJECTS ONLY):	***DPhil***
Department or institute:	***Education***
Address for correspondence (if different):	
Email and phone contact:	***kinga.petrovai@education.ox.ac.uk 07786 410969***

Title of research project:	***Tablets in mathematics education: A case study of integration practices***

Brief description of research methods and goals plus description of the nature of participants (including the criteria for inclusion/exclusion, method of recruitment), explanation of how professional guidelines and/or CUREC protocol(s) will be applied (if relevant) and expected use to which the results/data will be put. Please describe how you will obtain informed consent. Approx 400 words.
In my research project, I will explore year eight mathematics teachers' views and decisions relating to how they integrate tablets (iPad minis) into their teaching over the course of a year. The teachers, who will be recruited from one school, will participate in a community of practice, which will meet on a regular basis. The intent of the community is to explore, discuss, reflect, and share ideas on how to integrate tablets into their mathematics teaching. I will guide the discussion with leading questions and occasionally provide information from research, but the intent is for the teachers to learn from each other. I want to investigate if and how each teacher changes their views and practices in using tablets in their teaching and how they use the community of practice to support their teaching practice. Five year eight mathematics teachers will be recruited from a comprehensive school in the south of England, which has recently implemented a program that provides one iPad mini for every student. The teachers will have diverse experiences in both teaching and in using tablets as a tool for teaching. The common link between them will be the fact that they are colleagues at the same school and they have an interest in exploring how to use the tablet in their teaching. This group of teachers will form what is referred to as a community of practice. The project as a whole will be one case study. This case study will consist of the discourse in the community of practice and the information gathered from each individual teacher in that community. The community of practice will meet twice a term, which is approximately once every month. Each term I will interview every teacher once and I will observe one or two classes taught by each teacher. The teachers will select which classes I will observe. The main sources of data will be from the audio recordings of the community of practice meetings, classroom observations (see data collection sheet, Appendix A), individual interviews with the teachers (see interview protocol Appendix B), short three-minute interviews with teachers after each of the observed lessons (Appendix B), and two interviews with the head teacher and the school's technology specialist. In these interviews, teachers will identify their views on using tablets in their teaching, their views on participating in the community of practice, and their considerations and decisions in how they integrate tablets into their teaching. In the three-minute post lesson interviews with the teachers, they will be asked to identify what they thought was a success and a challenge in how they taught with the tablet that class, and what they would like to change for next time. In the interviews with the head teacher and the technology specialist, they will be asked to identify their views on using tablets in teaching at the school and their considerations and decisions in how they try to integrate tablets into the school. All the interviews and community of practice meetings will be audio recorded with the use of lapel microphone and hand written observation notes taken by the recorder. These data will be transcribed and used to analyse the discourse and also provide narrative background to the case. This research will be guided by protocol SSD/IDREC/2009/P15.1. Section 13 of this protocol classifies the methods of this research as Group A activities and as such 'opt-in informed consent of the teacher is usually sufficient' (Protocol P15.1, section 13). Therefore clear information about the research will be provided to potential teacher-participants (see appendix C), their consent will be sought (see appendix D), but in addition their head teacher will be informed of the research, asked to consent to it being conducted in the school and asked if further consent needs to be sought under the school's ethics procedure (see appendix E).

List actual or probable location(s) where project will be conducted, if known:	One comprehensive school in the south of England. The school has already been identified and the teachers and administration have agreed to participate in the study.
Anticipated duration of project:	15 months
Anticipated start date:	17/11/2014
Anticipated end date:	19/2/2016
Name and status (e.g. 3rd year undergraduate; post-doctoral research assistant) of others taking part in the project:	2nd year DPhil student
Please indicate what training on research ethics the researchers involved with this study have received, e.g. the title of the online or in-person course, and date completed (online training available at www.admin.ox.ac.uk/researchsupport/integrity/):	I am certified to work with human subjects having successfully completed the Collabrorative Institutional Training Initiative in 2012 while I studied for the M.Ed. (Technology, Innovation, and Educaiton) at Harvard University. I also worked on two projects for which I needed to obtain approval from the Committee on the use of Human Subjects.

SECTION C

Methods to be used in the study (**tick** as many as apply: this information will help the committee understand the nature of your research and may be used for audit).

	Please tick
Interview	✓
Questionnaire	✓
Analysis of existing records	
Participant performs verbal/paper and pencil/computer based task	
Measurement/recording of motor behaviour	
Audio recording of participant	✓
Video recording or photography of participant	
Physiological recording from participant	

Participant observation	✓
Covert observation	
Systematic observation	✓
Observation of specific organisational practices	
Other (please specify)	

SECTION D

Have you read one or more of the following professional guidelines and do you undertake to use the principles listed there as a guide for your own work? Please note that this is not intended to be an exhaustive list. Links to the guidelines listed below are included on the CUREC website.

	Please tick
British Society of Criminology: Code of Ethics for Researchers in the Field of Criminology [www.britsoccrim.org/codeofethics.htm]	
British Educational Research Association Ethical Guidelines for Educational Research [www.bera.ac.uk/guidelines]	✓
Academy of Management's Code of Ethics [www.aomonline.org/aom.asp?ID=&page_ID=242]	
Association of American Geographers Statement on Professional Ethics [www.aag.org/cs/resolutions/ethics]	
Oral History Society of the UK Ethical Guidelines [www.oralhistory.org.uk/ethics/index.php]	
American Political Science Association (APSA) Guide to Professional Ethics in Political Science (Section H) [www.apsanet.org/content_9350.cfm]	
Political Studies Association Guide to Good Professional Conduct (see section on "Research") [www.psa.ac.uk/Pubs]	
British Psychological Society Code of Ethics and Conduct [www.bps.org.uk/what-we-do/ethics-standards/ethics-standards]	
Ethics Guidelines of the Association of Social Anthropologists of the UK and Commonwealth [www.theasa.org/ethics/guidelines.shtml]	
Social Research Association: Ethical Guidelines [www.the-sra.org.uk/guidelines.htm]	
Statement of Principles of Ethical Research Practice from the Socio-Legal Studies Association [www.slsa.ac.uk/content/view/247/270/]	
Statement of Ethical Practice for the British Sociological Association [www.britsoc.co.uk/about/equality/statement-of-ethical-practice.aspx]	
Other professional guidelines (please specify):	

SECTION E

Please put a tick in the yes/no column as appropriate to indicate your response.

	Yes	No
1) Will you obtain informed consent according to good practice in your discipline before participation?	✓	
2) Will you ensure that *personal data collected directly from participants or via a *third party is held and processed in accordance with the provisions of the Data Protection Act?	✓	
3) Does the research involve as participants *people whose ability to give free and informed consent is in question? (This includes those under 18 and vulnerable adults.)		✓
4) As a consequence of taking part in the research, will participants be at serious risk of rendering themselves liable to criminal prosecution (e.g. by providing information on drug abuse or child abuse)?		✓
5) Does the research involve the *deception of participants, as part of the investigation/experiment?		✓
If any of your answers above are in a shaded box, please indicate whether those aspects of your project are fully covered by the following.		
6) Research protocol(s) which has/ve received IDREC/CUREC approval? ***If yes, please give protocol number(s): SSD/IDREC/2009/P15.1 (Group A research activities)***	✓	
7) Professional guidelines that you will be following, as noted under Section D? ***BERA ethical guidelines***	✓	

If any of your answers in Section E are in a shaded box and are not covered by a protocol or by professional guidelines, please complete CUREC/2, available to download from the CUREC website. Then submit both this form (you need not complete section F) and the CUREC/2 to the Social Sciences and Humanities IDREC.

If all your answers in Section E are in the unshaded boxes or your answers in shaded boxes are covered by a protocol or professional guidelines, complete Section F and submit this form and any accompanying documents to the Social Sciences and Humanities IDREC or to the relevant officer/committee at departmental level (see notes and address below).

FINAL CHECK

Please check each of the following before submitting the checklist. Failure to provide this information could delay the start of your research.

Have you completed Sections A-E? ☒

Have you defined all technical terms and abbreviations used? ☒

If you have produced any documentation in support of your application (which might include questionnaires, participant information, consent forms/form or note of procedure for recording oral consent, advertisements and surveys), have you attached a copy of these? ☒

Are all pages (including appendices and attachments) numbered? ☒

SECTION F

You can submit this checklist by email and/or as a signed hard copy; if it is being sent by email only, the checklist, and any email from the head of department or nominee separately endorsing its submission, must be sent from a University of Oxford email address (i.e. as a minimum, the checklist and supporting documents must be submitted by the head of department or nominee indicating his/her approval from a University of Oxford email account).

Complete this section only if you do not need to submit form CUREC/2.

I understand my responsibilities as principal researcher/supervisor/student researcher as outlined in the CUREC glossary and guidance on the CUREC website.

I declare that the answers above accurately describe my research as presently designed and that I will submit a new checklist should the design of my research change in a way which would alter any of the above responses so as to require completion of CUREC/2 (involving full scrutiny by an IDREC). I will inform the relevant IDREC if I cease to be the principal researcher on this project and supply the name and contact details of my successor if appropriate.

Signed by principal researcher/supervisor/student researcher:………Kinga Petrovai…………………

Date:…23/10/2014………………

Print name (block capitals)……KINGA PETROVAI………………………………………………………

Signed by supervisor:……Gabriel Stylianides………………………(for student projects)

Date:…23/10/2014………………

Print name (block capitals)……GABRIEL STYLIANIDES………………………………………………

I understand the questions and answers that have been entered above describing the research, and I will ensure that my practice in this research complies with these answers, subject to any modifications made by the principal researcher properly authorised by the CUREC system.

Signed by associate/other researcher: ……………………………………………………………….

Print name (block capitals)…………………………………………………………………………

Date ………………

I have read the research project application named above. On the basis of the information available to me, I:

(i) consider the principal researcher/supervisor/student researcher to be aware of her/his ethical responsibilities in regard to this research;

(ii) consider that any ethical issues raised have been satisfactorily resolved or are covered by relevant professional guidelines and/or CUREC approved protocols, and that it is appropriate for the research to proceed without further formal ethical scrutiny at this stage (noting the principal researcher's obligation to report should the design of the research change in a way which would alter any of the above responses so as to require completion of a CUREC/2 full application);

(iii) am satisfied that the proposed project has been/will be subject to appropriate *peer review and is likely to contribute something useful to existing knowledge and/or to the education and training of the researcher(s) and that it is in the *public interest.

(iv) [FOR DEPARTMENTS/FACULTIES WITH A DEPARTMENTAL RESEARCH ETHICS COMMITTEE (DREC) OR EQUIVALENT BODY - PLEASE DELETE IF NOT APPLICABLE] confirm that this checklist (and associated research outline) has been reviewed by the Department's Research Ethics Committee (DREC)/equivalent body, and attach the associated report from that body.

Signed:…………………………………………..
(Head of department or nominee e.g Chair of DREC, Director of Graduate Studies for postgraduate student projects)

Print name (block capitals)…………………………………………………………………………

Date:……………………

If your research involves participants recruited by means of their status as current or former NHS staff, or the research will, in whole or in part, be carried out on NHS premises, use NHS facilities or assess NHS facilities or services, please see FAQ B3 (www.admin.ox.ac.uk/curec/faqs/).

Please check with your department about its procedures for the approval of CUREC forms. If your department indicates that the checklist should be submitted directly to the IDREC, please send it, together with any supporting documentation, to the following address(es), keeping a copy for yourself:

Secretary of the Social Sciences and Humanities IDREC Email: ethics@socsci.ox.ac.uk
University of Oxford Social Sciences Division
Hayes House, George Street
Oxford, OX1 2BQ
IDRECs and/or CUREC will review a sample of completed checklists and may ask for further details of any project
Revised March 2012

Appendix C – Information for teachers

UNIVERSITY OF OXFORD
DEPARTMENT OF EDUCATION

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general.enquiries@education.ox.ac.uk www.education.ox.ac.uk

Tablets in Mathematics Education: A case study of integration practices

Researcher: Kinga Petrovai

Supervisors: Dr Gabriel Stylianides and Dr Chris Davies

Invitation

You are being invited to take part in a research study. Before you decide to participate, it is important to understand why the research is being conducted and what your participation entails. Please take time to read the following information carefully. Please ask if there are any aspects of the project that are unclear or if you would like more information. Take time to decide whether or not you would like to take part in this research.

What is the purpose of the study?

This research will explore year eight mathematics teachers' decisions and development relating to how they use tablets (iPad minis) in their mathematics teaching. Through regular meetings as a community of practice with the other teachers participating in this project, teachers will have the opportunity to discuss what lesson would benefit the most from the use of tablets, share ideas and resources of how to use tablets, and reflect on their own experiences in the classroom. I will be the moderator for these meetings, however the content and direction will be guided by what the teachers bring to the meetings. Through observation of several classes taught by each teacher, as well as a 3-minute reflection interview after the lesson, I will also observe how the practice of using tablets in mathematics teaching may change over time. I want to investigate how tablets are used in mathematics teaching over a period of a year, during which teachers participate in a community of practice in which they discuss and reflect on their teaching.

Why have I been chosen?

For this study, I am looking to explore how year eight teachers, with a variety of different teaching and technical experience, use the tablet in their teaching. In order to form a community of practice, the teachers are to be selected from one school. The school is selected based on having implemented a one-tablet-per-student program in the past year. As a year eight mathematics teacher at such a school, you have been identified as someone who might be interested in participating in such a project.

What does participating in the research entail?

I am looking to put together a group of year eight mathematics teachers, who will meet twice or three times per term for approximately an hour, from approximately November 2014 to December 2015. All participants will mutually agree upon meeting times. These meetings will form what can be referred to as a community of practice. As a participant in these meetings, you will have the opportunity to discuss what lessons would benefit the most from the use of tablets, share ideas and resources about how to use tablets in teaching mathematics, and reflect on your own experiences using tablets to teach. I will be the moderator for these meetings, however the content and direction will be guided by what you and the other participants bring to the meetings. As a participant you will also select two or three classes per term that I can go to observe how you use the tablet in your teaching. Following the class I will ask you three short questions about how tablet worked in that class, what were some challenges, and what you would like to change next time. These brief interviews will take about three minutes and are not intended to interfere with you moving on to the next class. Each teacher-participant will be interviewed once each term at a time that is convenient for him or her. These interviews will be approximately 30 minutes in length and will focus on individual views and practices in the use of tablets in mathematics teaching and considerations in if, how, and why you as a participant use tablets in your teaching. The main source of data will include audio recordings and my hand written notes of the community of practice meetings and the interviews with each participant. The data will also include my hand-written observation notes during the classroom observations. Both the data storage and report in the thesis, and any other publications, will be anonymised for both the school and the teachers. Your personal data will be treated in total confidence and kept securely in a password-controlled server.

Do I have to take part? What are the risks and benefits of taking part?

It is your decision to take part in this study. You can decide to stop participating at any time. You do not need to answer questions that you do not wish to. Other than the time taken out of your day for the community of practice meetings and the interviews, there are no foreseen risks to taking part. The benefits for technology and mathematics education research are to help appreciate the ways in which teachers develop their integration practices of tablets in their mathematics teaching. I hope that participation will contribute to your professional development too through discussing your pedagogical thoughts and practices. In addition, by participating in this research, you will be helping to create some resources that your school may decide to incorporate in its scheme of work. However should concerns arise during the research that you feel cannot be discussed with me, please contact my supervisor Dr Gabriel Stylianides (gabriel.stylianides@education.ox.ac.uk). This project has been reviewed by, and received ethics clearance through, the University of Oxford's Central University Research Ethics Committee.

What will happen to the results of this research?

The results of this research will form the basis of an Oxford doctoral dissertation, a copy of which will be held in the library at the Department of Education. Some results may be published in academic journals or books concerned with exploring the use of technology in mathematics teaching. Both the data storage and report in the thesis, and any other publications, will be anonymised for both the school and the teachers. Your personal data will be treated in total confidence and kept securely in a password-controlled server. If you wish to obtain a copy of the published results, please let me know.

Who is funding and organizing the research?

The research is privately funded and organized as an independent doctoral research project in conjunction with the Department of Education, University of Oxford.

Contact for further information

Should you have any further questions about this research, please feel free to contact: Kinga Petrovai, Department of Education, 15 Norham Gardens, Oxford, OX2 6PY or via email: kinga.petrovai@education.ox.ac.uk.

What happens next?

If you are interested in being a participant in this study, please let me know by email within a week or receiving this letter. I will then contact your Headteacher to seek their consent and to confirm that no further consent is required other than yours. This being the case, I will then ask you to complete a consent form. From there a date for the group meeting will be set as well as dates for observation.

Thank you for your interest in this project.

Kinga Petrovai

Department of Education

University of Oxford

October 2014

Appendix D – Teacher consent letter

UNIVERSITY OF OXFORD

DEPARTMENT OF EDUCATION

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Tablets in Mathematics Education: A case study of integration practices

Researcher: Kinga Petrovai

Supervisors: Dr Gabriel Stylianides and Dr Chris Davies

Research Consent Form

Declaration of Consent:

☐ I have read the participant information sheet and have had the opportunity to ask questions about the study and receive satisfactory answers to questions.

☐ I understand that I may withdraw from the study without penalty at any time by advising the researchers, and any data already recorded will be discarded.

☐ I understand that this project has been reviewed by, and received ethics clearance through, the University of Oxford's Central University Research Ethics Committee.

☐ I understand that my personal data will be treated in total confidence, kept securely in a password-controlled server; and what will happen to the data at the end of the project.

☐ I understand how to raise a concern and make a complaint, and agree to participate in this study

- ☐ I agree to voluntarily take part in this research.
- ☐ I confirm that I have read the associated information sheet and understand the intent and purpose of this research.
- ☐ I agree that data captured by this research can be shared with the researcher's supervisors.

Name of Participant: ______________________________

Email: ____

Signature: ______________________________________

Date: _______________________

Appendix E – Letter to Headteachers

UNIVERSITY OF OXFORD

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general.enquiries@education.ox.ac.uk www.education.ox.ac.uk

UNIVERSITY OF OXFORD

(Head teacher name

School name and address)

(Date)

Dear *(Head teacher name),*

I am writing to enquire about conducting some research in your school. I am a doctoral research student at Oxford University, supervised by Dr Gabriel Stylianides and Dr Chris Davies. In my research project, *Tablets in Mathematics Education: A case study of integration practices*, I will explore how teachers use tablets (iPad mini) in their mathematics teaching and how their use of the tablet develops over the year (January to December 2015).

I have already informally approached (*Teacher names*) and they have stated that, subject to the school's agreement, they would be interested in participating in this project. The research would take place over one calendar year (2015), with some preliminary interviews conducted in November and December 2014. The research would involve the teachers participating in two, or possibly three, community of practice meetings in a term, which will be run at mutually agreed upon dates for about one hour at a time. There would also be one interview with each teacher per term, as well as one or two classroom observations for each teacher. What or how the teacher chooses to teach is up to their professional decision and I will not make any judgement about their teaching. My research focus is on the way teachers use tablets in their mathematics teaching and how their practice may change while participating in a community of practice. By participating in the research, your school would be contributing to a project that will deepen our understanding of mathematics teachers' use of tablets, with an intended impact on developing initial teacher education and continuing professional development. In addition, by participating in this research, your school will help to create some resources that you may decide to incorporate in its scheme of work. I hope that participation will also contribute to the teachers' professional development too through discussing their pedagogical thoughts and practices in using tablets in teaching mathematics.

The commitment from the school would be to allow me to meet with the participating teachers (Teacher names) as a group twice or three times a term for approximately one hour at a time, individually interview each teacher (Teacher names) once a term for approximately 30 minutes, and observe a few mathematics lessons per term as agreed with (Teacher names). The timeframe for this project is approximately from the middle of November 2014 to December 2015 I would audio-record the teachers during the community of practice meetings, as well as the interviews, using a lapel microphone recorder and take hand-written notes. I would also conduct a brief three-minute interview with the teacher following the observed lessons. I also wish to interview you and the technology manager twice during this project. These interviews would focus on your views about the incorporation of tablets in the teaching of different subject areas in the school, with particular attention to mathematics. These interviews would also be audio recorded as well as I will take hand-written notes.

Oxford University has strict ethical procedures on conducting ethical research with teachers, consistent with current British Educational Research Association guidelines. Following these guidelines, before beginning the research I sought the teachers' informed consent. Throughout the project they would be free to withdraw at any time. The ethical guidelines suggest that it is not necessary to seek the consent of parents and the assent of students for this type of research as the study will not focus on particular students. However, if you feel that further consent would be appropriate in your school context then please let me know. The teacher and the school would be made anonymous in all research reports. The data collected would be kept strictly confidential, available only to my supervisors and myself, and not used other than specified without the further consent of all involved being obtained. All tapes would be destroyed at the end of the research period, and kept in locked conditions until then. I have an enhanced CRB check as a Junior Dean at St Catherine's College, but if your Safeguarding Policy requires an additional CRB check, this can be arranged.

If you feel you would like to take part in the study, or need more information about what is involved, please contact me via email. Whether or not you feel it would be appropriate for your school to participate, I would be grateful if you would complete the pro-forma below, and return it to me in the stamped addressed envelope enclosed in this letter. Thank you for your time and attention. I look forward to hearing from you.

Yours sincerely,

Kinga Petrovai

kinga.petrovai@education.ox.ac.uk

Department of Education

University of Oxford

UNIVERSITY OF OXFORD

DEPARTMENT OF EDUCATION

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Tablets in Mathematics Education: A case study of integration practices

Researcher: Kinga Petrovai

Supervisors: Dr Gabriel Stylianides and Dr Chris Davies

Research Consent Form

Declaration of Consent:

(*School name*)

(School address)

(Headteacher name)

☐ We do not wish to participate in this project.

☐ We would like to find out more about this project.

☐ We would like to take part in this project.

Please return this form in the stamped addressed envelope enclosed with this letter.

Thank you for your help.