Using Digital Technologies to Teach Mathematics by English Secondary School Teachers: the barriers, constraints, teaching and learning opportunities and training provided.

by

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Acknowledgements

I dedicate this thesis to my family, my husband Maurice, son Kevin and his wife Amanda, their boys Connor and Ewan daughter Julia and her husband Gordon and their boys Oliver and Isaac who provided welcome diversions. I also include my parents who taught me about the joy of learning, to be inquisitive and resilient, especially my mother whose encouragement kept me going. Unfortunately, my father passed away before this project was started. Through this work I hope younger family members will be inspired to 'aim high', even when seemingly impossible obstacles are placed in their way, to realise a change of direction could lead them somewhere more interesting and reveal hidden talents.

Of friends, I would especially like to thank Drs. Sue and Peter Johnston-Wilder who started me off on this extended project and supervisor Dr. Clare Lee whose advice, support and faith has helped me see this project through to completion. Thanks to the people who voluntarily took part in the questionnaires and interviews, and those whose encouragement supported me on this journey.

Author’s Declaration

Ideas developed during this study were reported and discussed in a session titled Mathematics Teachers and use of ICT at BSRLM day conference on 2nd June 2013 held at Sheffield Hallam University, Sheffield. Available [online] at: <http://www.bsrlm.org.uk/wp-content/uploads/2016/02/BSRLM-Speaker-Abstracts-2013-Jun.pdf> [Accessed 12 Jan 2015] p.6.

Study findings were also reported verbally and published at:
Parish, A., 2013. Developing Teachers' Resilience with Using Digital Technologies in the Classroom. In: ICERI2013 6th International Conference of Education, Research and Innovation. Seville, Spain. 18-20 November 2013. IATED, pp.2435-2445. Available [online] at: <https://library.iated.org/view/PARISH2013DEV> [Accessed 30 Nov 2013].

I hereby confirm that the work presented in this thesis is entirely my own. This thesis has not been submitted to any other university.

Abstract

This thesis aims to explore 'How English secondary school mathematics teachers could be better supported to integrate digital technologies into their teaching' by answering four sub-questions:

How were computers introduced into schools? Responses here present the history behind the present state of affairs. Using the voices of those involved when computers were first introduced, the origins of much that is "taken for granted" are explicated.

What barriers and constraints do teachers face teachers when using ICT? The usefulness and reliability of the hardware and software are key here alongside the ease of access to ICT. More subtle influences uncovered are the influence of a "top-down" approach which results in teachers' lacking autonomy and causes negative teacher beliefs about the merits of using digital technologies.

How do teachers use ICT in the teaching and learning of mathematics? The merits, or otherwise, of using digital technologies for teaching are explored, uncovering a lack of awareness of the benefits of using ICT or the wide variety of resources and applications available to benefit pupil learning. Only a limited number of resources are used and often inefficiently.

How could mathematics teachers training in the use of ICT for teaching be more effective? Teachers seem to "not know what there is to know" due in part to a lack of effective professional development. Findings here support ways teachers can be informed and supported outside the traditional professional development course.

Ideas were explored from the perspective of the teachers who might potentially benefit from using educational technology as a tool to increase learning. Research has explored the use and benefits of specific software and hardware but here the teachers themselves are given a voice on what influences them to choose to use digital technologies in their teaching or not.

Abbreviations

A Level	Advanced level
ACME	Advisory Committee on Mathematics Education
ATM	Association of Teachers of Mathematics
BASIC	Beginner’s All-purpose Symbolic Instruction Code
BECTA	British Educational Communications Technology Agency
BERA	British Educational Research Association
BSRLM	British Society for Research into Learning Mathematics
BESA	British Educational Suppliers Association
CAN	Calculator Aware Number
CAS	Computer Algebra System
CPD	Continual Professional Development
DES	Department of Education and Science, 1964–1992
DfE	Department for Education, 1992–1995
DfEE	Department for Education and Employment (DfEE), 1995–2001
DfES	Department for Education and Skills (DfES), 2001–2007
DfCSF	Department for Children, Schools and Families (DCSF), 2007–2010
DfE	Department for Education (DfE) 2010 –
GCE	General Certificate in Education
GCSE	General Certificate in Secondary Education
HTML	Hypertext Markup Language
ICERI	International Conference on Education, Research and Innovation
ICT	Information Communications Technology
IDM	Innovative Diffusion Model

INSET	In Service Training
INTED	International Technology, Education and Development
IT	Information Technology
ITT	Initial Teacher Training
IWB	Interactive whiteboards
MA	Mathematical Association
MEP	Micro-Electronics Education Program
NCETM	National Centre for Excellence in Teaching Mathematics
NGfL	National Grid for Learning
NNS	National Numeracy Strategy
NOF	National Opportunities Fund
OECD	Organisation for Economic Co-operation and Development
Ofsted	Office for Standards in Education, Children's Services and Skills
PCK	Pedagogical Content Knowledge
PGCE	Post Graduate Certificate of Education
QCA	Qualifications and Curriculum Authority
RECME	Researching effective CPD in mathematics education
RM	Research Machines
SATS	Standard Assessment Tasks
SCITT	School Centred Initial Teacher Training
SDL	Self-Directed Learning
SMILE	Secondary Mathematics Individualised Learning Experiment
SRL	Self-Regulated Learning
TAM	Technology Acceptance Model
TSM	Technology for Secondary/College Mathematics

UCAS	Universities and Colleges Admissions Service
VLE	Virtual Learning Environment
VLP	Virtual Learning Platform

Chapter 1 Introduction

This thesis explores the use of Information Communications Technology (ICT) in the learning and teaching of mathematics in English secondary schools, giving voice through questionnaires and interviews to those who are, have been or would consider using ICT as teachers in mathematics lessons. I include calculators within the term technology, as some were developed to run mathematical software including spreadsheets and dynamic geometry, although the main emphasis is on use of computers and associated hardware in teaching mathematics. I also use the terms Information Technology (IT) and digital technologies to reflect the terminology of the period under discussion.

1.1 My motivation for the studying the use of ICT in secondary school mathematics

Like some of the more mature participants in the study my history began in the early 1980s when computers began to be introduced into homes and schools. At that time software, including operating systems, were loaded from tapes and the screen was monochrome. Software was very limited; there was no internet or email. Such computers as were in schools were often assigned to mathematics or science teachers; mathematics teachers frequently became the first Information technology (IT) advisors. Home computers in the early 1980s were rare; they were relatively expensive and, as there was little commercial software, many owners learnt to program in BASIC (Beginner's All-purpose Symbolic Instruction Code) using short routines from resources such as user magazines. The computers in secondary schools were usually from one manufacturer such as Research Machines (RM), Acorn (the BBC micro-computers) or Sinclair. These brands were funded by a government initiative aiming to raise the profile of the British fledgling computer industry. At that time only teachers with a particular interest in technology used the machines that were available in schools. Such people thought, as I did, that there was potential for these machines to revolutionise education, particularly in the teaching of mathematics.

My first experience of computers in schools was in 1980 at a 470-pupil secondary school with one RM 380z. Moving to another school in 1985 demonstrated hierarchical power with the head teacher discouraging staff engagement with IT and barring them from attending courses. A change of head teacher in 1987 resulted in IT being embraced, using fund raising to purchase extra computers. Here I managed school funds using Newman College's database (Quest) and spreadsheet (Grasshopper), but quality educational software was lacking. In taking charge of IT development I experienced working with the full range of teachers, the self-motivated, enthusiasts, those lacking in confidence, sceptics and reluctant users. These experiences led to my belief that a strong and supportive community benefits the development of IT for teaching and teachers should not be expected to 'teach themselves'.

In 1997 a move to a middle school with a supportive community and head teacher gave me purchasing power for software and calculators thus ICT was embedded in the mathematics schemes of work using the National Strategies frameworks (Appendix A6.2). However many established staff in the school were not routinely using ICT. I planned training in subject-specific activities that fitted easily into teaching so staff could identify immediate purpose in the ideas. Good staff relations, peer support and funding for resources provided by the school seemed to be effective and the use of ICT developed in all curriculum areas.

Moving to an 11-16 high school in 2003 I found fewer digital resources and less use of ICT. Many of the mathematics staff, were willing to learn so training enabled development in ICT use. In contrast at the next school (14-18 upper school) using ICT was actively discouraged by the head of department. Prescribed textbook-led schemes of work contained no ICT activities and there were no departmental computers. Whilst the majority of the mathematics staff used the interactive whiteboard for display purposes there were only occasional use of available software or graphics calculators. Only the head of department attended ICT external courses, but did not cascade information nor encourage other teachers to develop ICT skills. I noticed she struggled with technology herself; hence it seemed to me her own stance affected her ability to disseminate technological information.

Despite £200 million for training being provided by the government (Younie and Leask, 2013) many mathematics teachers were not using ICT. I wished to explore why teachers were not using it, as by 1998, ICT offered so much potential. I was interested in whether the barriers were resources, support from colleagues or professional development, lack of experience or personal beliefs about the benefits of ICT. I felt that there must be ways of working that would encourage more engagement with ICT by teachers. I found using ICT in the learning of mathematics powerful, lessons more interactive, a wider variety of resources could be accessed, complex situations modelled, challenging mathematics accessed, and confidence in problem solving built. Where students had learning differences ICT allowed the manipulation of mathematical concepts and figures and work to be produced of a higher standard. I believed teachers could be creative, whether producing their own resources or finding ‘ready-mades’ on the internet.

Two activities gave me clues to the difficulties that teachers with less confidence and experience found when using ICT (discussed in chapters 6 to 8). As a member of the Qualification and Curriculum Agency’s consultation teams for secondary mathematics I found there was an appetite to include ICT within the mathematics curriculum prior to 2014 but this was met with resistance from government ministers responsible for the final version. Secondly, I used my experience to run conference software workshops demonstrating how ICT can be used to learn the mathematics curriculum but these individual workshops were short ‘tasters’ and I felt that ‘one-off’ sessions would not enable teachers to become authoritative users. Thus, I saw a different approach was needed allow teachers to fully integrate ICT into their teaching.

1.2 Finding an approach that works

To experience a learner’s experience on a course and when self-teaching I attended two three-day Technology for Secondary/College Mathematics (TSM) courses (2012 and 2013) and attempted to learn new software. In chapter 8 TSM courses are further mentioned. When on a course there can be ‘information overload’ which results in learners not being able to put all newly learnt skills into practice soon after the event. With self-learning the problem is persevering. As a learner, I noted a variety of emotions, from feeling ‘in-control’ when something worked, to frustration and annoyance when it did not, only if the task interested me would I retry later. Table 1.1 Situations, emotions and consequences experienced when undertaking tutor led training, illustrates some of the scenarios I experienced. In some tasks I supported other learners; often, by working together, we were enabled to experience success. Explaining to others helped consolidate methods and understanding. I gave those activities that would be useful in the future more attention and I was more likely to practice these ‘new-found’ skills, if frustrated I was unlikely to persevere.

Table 1.1 Situations, emotions and consequences experienced when undertaking tutor led training

Situation	Emotion/Feeling	Consequence
Task very familiar	Boredom	Attention deviates, go off task.
New task appropriate level	Expectation, engagement	Listen and try.
Task too hard/does not make sense	Frustration, lost, de-motivated	Attention deviates, go off task.
Task successful	Good feeling, engagement	Try another task.
Task partially successful	Puzzlement, engagement	Attempt trouble shooting.
Task fails	Annoyed at time ‘wasted’	Displacement activity, give up.
Tutor talks/demonstrates for long time	Where is ‘hands on’?	Attention deviates, go off task.

Situation	Emotion/Feeling	Consequence
Talk/demonstration in sections and gives short task between	Involvement, engagement	Make effort to complete sections in time.
Tutor gives out worksheet without explanation	Where am I going on this one?	Start, interest level according to degree of initial success.
Tutor has sufficient helpers (could be other learners at a different stage in the process)	Supported, engagement	Will ask for help or acknowledgement they are on the correct pathway.
Tutor on own	If successful at tasks OK If help needed – frustration. Feel pressurised to keep question short, which might not solve problem.	Too demanding for tutor, learners will only ask for help if really seriously stuck, all learners may not be helped, so waiting for 'turn' and therefore get less out of session.
Tutor good communicator and approachable	Comfortable, engagement	Get something out of session no matter how task went.
Tutor makes it obvious that they are experts, remote	Tense, threatened	Avoid asking questions and seeking help.

An alternative to attending courses is self-teaching. In researching software available to mathematics teachers, I purposely looked at software I had never used, but were mentioned in the questionnaires and interviews, simulating the situation of ‘heard or read of’ but not used or taught. I am largely self-taught and a reasonably confident, competent user of ICT. As preparation for the data handling element of this thesis I attended an afternoon session on using NVivo. Unfortunately, the session did not go well, the demonstration was hampered by a poor internet connection, software and hardware problems and I was unable to use NVivo immediately. Firstly, I was not able to download NVivo straight after the session to practice (computer incompatibility), secondly, my own data was nor accessible so I had to use a sample project that bore little resemblance to my work. To begin I needed to learn NVivo’s ‘language’ and terminology. To emulate self-teaching I used QSR International’s YouTube channel and some of their demonstration videos but the amount of information took some absorbing and needed to be watched several times. Eventually, I learnt to use NVivo software at a very basic level using a mix of experimentation, video and on-line documentation so made a test project from my previously manually coded data. These personal examples illustrate some of the problems faced by teachers and how learning to use software requires motivation, commitment and perseverance.

1.3 The Research Questions

My experience in schools and as a trainer led me to the initial question ‘How, when and why do mathematics teachers use ICT in their teaching?’ The research question was developed following analysis of the data and the literature review to ‘*How could English secondary school mathematics teachers could be better supported to integrate digital technologies into their teaching?’* as the literature suggested the ‘how, when and why’ but there was also an issue regarding non-use of ICT.

As this study was in progress other studies such as Researching effective CPD in mathematics education (RECME) report National Centre for Excellence in Teaching Mathematics (NCETM) (2009) and the digital technology report (NCETM, 2010) were published. Earlier work such as that published by Cox et al., (1999) highlighted issues before digital technology was widely available, giving me a background to the situation around the time of the National Opportunities Fund (NOF) project and the introduction of the internet into schools.

I decided to use a chapter for each of the sub-questions, including the first one that presented a background in 2017. The sub-research questions are:

Research question 1 (Chapter 5) - How did teachers experience the introduction of ICT into teaching mathematics and what support did they receive in using it?

Research question 2 (Chapter 6) - What are the barriers and constraints teachers experience when using or contemplating the use of ICT?

Research question 3 (Chapter 7) - How do mathematics teachers' use ICT in their teaching?

Research question 4 (Chapter 8) - What training have teachers had in the use of digital technology?

Research question 1 briefly explores how early hardware and software were provided and training given to teachers to put the current situation into the context of the early introduction of computers in schools; the impact of decisions and approaches made at that time which are still evident today. Although there was great enthusiasm for introducing technology for learning mathematics in the 1980s, there were other demands on schools and teachers for both finance and time. Rogers (1983) described these early enthusiasts as early adopters and innovators. While researching the historical aspect I visited and interviewed staff at the Centre for Computing History in Cambridge (www.computinghistory.org.uk/) to appreciate the constraints of early computer technology while the internet provided me access to earlier research articles, including timelines of computer development in education. To supplement this information all interviewees were asked to recall early experiences of computing at school and/or home to put their approach into a historical context.

Barriers and constraints are the focus of the second research question which examines the situation in more recent times and identifying what the teachers' perceptions of barriers and constraints, some originating from teachers themselves; hence the third research question looks at teaching and learning in terms of the teachers and their beliefs about using technology to teach mathematics. Currently there is a huge resource available, so inspection of some of the resources that participants used is included to ascertain the range of software being used in classrooms.

The fourth and final research question investigated how the ICT-using participants learnt their skills, whether there was any commonality in terms of how they learnt to use ICT, their beliefs and pedagogy to investigate how training effectiveness could be improved.

The discussion in chapter 9 draws together findings from the research questions, seeking to answer the central question, ‘How could English secondary school mathematics teachers be better supported to integrate digital technologies into their teaching?’.

1.4 Structure of the thesis

The thesis is divided into three parts. The first part consists of chapters 1, 2, 3 and 4. Chapter 1 is the introduction containing the background to the thesis, the research questions and the structure. Chapter 2 is the literature review and chapter 3 discusses the theoretical framing. Chapter 4 covers the methodology and methods used. The findings from the questionnaires gave me guidance for delving deeper into some aspects arising from the questionnaire in interviews. The data from both questionnaires and interviews has been used in the following chapters.

Part 2 consists of chapters 5 to 8 setting out the background, findings, analysis and conclusions arising from the questionnaire and interview data for each research question. Chapter 5 focuses on the background of how ICT was introduced into schools. As reported by various authors, including Ofsted, (1995); Stevenson, (1997); Hammond et al., (2009b), provision of hardware, training and access to resources have been an ongoing issue since the first computers were placed into schools.

Chapters 6–8 focus on the situation post-2000. Chapter 6, considers problems met by teachers when using or contemplating use of digital technology, formally known as IT and ICT, and considers constraints and barriers met by mathematics teachers imposed at different governmental, institutional, departmental and personal levels. This chapter also considers the role of curriculum and examinations their impact on what the teachers are expected to teach.

Chapter 7 looks at beliefs and attitudes about using ICT for teaching and learning at a more personal level than the previous chapter. Whilst there is much literature available on the constraints that teachers feel (e.g. National Centre for Excellence in Teaching Mathematics (NCETM), 2010), there is less about the teachers themselves, their experiences and beliefs. The trainee teachers, teachers and undergraduate students were asked about their experiences of using ICT and whether, in their opinion, it enhanced teaching and learning. Interviewees were asked to describe their teaching style to identify whether they adopted a constructivist or transmissionist approach to teaching to identify whether known users identified with either end of the spectrum with the aim of determining whether this was an influence on use of digital technologies.

Finally chapter 8 arises from question 4. If teachers are expected to use ICT with classes of pupils, they need to feel safe and competent. One of the questions put to teachers was about their perspective on their competence when teaching in different situations. The questionnaire asked about training, and what form it took, responses included those from a small sample of initial teacher training tutors. Participants were asked about their preferences when taught to use ICT. This chapter considers teachers as adult learners; learning theories are applied to adult learning including the stories of two CPD providers who deliver ICT specific training who describe their learning journey and how they have changed their style as they became more experienced presenters in the vignette. There I feature a course they ran (with others) as an example of one specifically designed for teachers interested in using technology in mathematics teaching to ascertain if there is a useful model of training or support for people who are not confident users of ICT. Courses are not the only form of learning support and looking at the support ICT users have leads to alternative systems for other teachers with the aim of developing digital technology resilience amongst secondary mathematics teachers (Parish, 2013).

Part 3 of the thesis consists of two chapters, chapters 9 and 10 and draws together the conclusions from chapters in Part 2, including a discussion about the introduction in the early 1980s. Faced with a large number of teachers still not using ICT as a teaching resource, the problem continues; how might more mathematics teachers become skilled in the use of ICT. By looking at the decisions by interviewees to use ICT, examples of how they use it and the resilience they show, suggestions are made of routes by which higher uptake could be achieved within the financial constraints that exist for all schools. The thesis concludes by examining teachers as learners and types of CPD, recommending an approach to CPD rooted in complexity theory and developing resilience amongst teachers (Parish, 2013).

1.5 What gap in knowledge does this thesis explore?

There have been many explorations of the use of ICT for example Ofsted reports (2002, 2004, 2006, 2008) which concluded that ICT was not used to the extent that may have been expected or that Ofsted considered would be optimal in mathematics. There have been other studies showing how teachers used digital technologies (Becta, 2004, 2008, 2009) and why they might use it (Hennessey et al., 2005; NCETM, 2009; NCETM, 2010). Some studies have explored how software might help in the learning of mathematics, such as portable technology (Hennessey, 1999), Grid Algebra (Hewitt, 2016, Lugalia, 2015), dynamic software including Geogebra (Hohenwarter and Fuchs, 2004) and Cabri, (Laborde, 2000), 3D visualisation (Oldknow and Tetlow, 2008) and content-free software such as Logo (Papert, 1993, Noss and Hoyles, 1992). Other studies have illustrated the effect of curriculum orders and examination syllabi on teaching and learning and 'systemic subject cultures' (Kryacou and Goulding, 2004; Ruthven, et al., 2004) and the adoption of texts as schemes of work (Haggarty & Pepin, 2002) written to cover the curriculum orders and examination syllabi as schemes of work, such as the Oxford Framework series (Capewell, et al., 2002) and Cambridge Advanced Level Mathematics for OCR (Quadling, & Neill, 2004). Optimal use also includes hardware, in his report on the work of British Educational Suppliers Association Rossi (2015, p.8) reported that interactive whiteboards had been introduced into schools but in order to reduce costs it was without teacher training so they were being used as ‘glorified projector screens’.

In all these studies the teachers’ voice has been absent. We know that teachers do not make optimal use of ICT in teaching mathematics (NCETM, 2010; Hennessey et al., 2005) but there is little literature on why this is the case. There are assumptions about what prevents teachers making effective use of the training that has been offered (such as TSM and national opportunities funded NOF (Kirkwood et al., 2000)) but no-one has asked the teachers themselves what has prevented them seeking training through courses or self-training. We also know a great deal about how schools have been introduced to digital technologies, the history and the challenges that have ensued (Loveless and Ellis, 2001; Pimm and Wilder, 2005) but how do the teachers themselves see that history and the effects it has had?

This study uses the teachers voice to explore all these ideas and therefore it fills a gaping void in what the literature already presents.

Chapter 2 Using ICT to teach mathematics in English secondary schools

This chapter consists of six sections. Literature relating to how computers were introduced into schools, why they were introduced, what that introduction hoped to achieve and associated government-led initiatives (2.1), an overview of the types of resources available and how technology may be integrated into mathematics teaching (2.3) and the barriers and constraints to including digital technologies when teaching secondary mathematics (2.3).This is followed by sections looking at literature pertaining to three constraints in detail, school related (2.4), teacher related (2.5) and professional development (2.6).

The current position regarding the use of computers in secondary mathematics education in England has not suddenly arisen. Since the introduction of computers into schools in the 1970s there have been many government policies and practices and technological developments that have impacted on schools' use of digital technologies.

Use of ICT in mathematics lessons has been low for some time; the ImpaCT 2 report (Harrison et al., 2002) showed that in KS3 66.68% of teachers said they used ICT in lessons hardly ever or never, compared to 11.15% saying most or every week. In KS4 ICT was used even less with 81.94% of teachers saying they never or hardly ever used ICT and 3.24% used it most or every week. The Mathematical Association commented that 'Inspection evidence consistently shows very little use of appropriate technology tools in mathematics teaching at all levels' (Mann and Tall, 2002, p. 5). Ofsted (2002) reported that although many teachers are competent in the use of generic software, 'good, consistent and progressive use of ICT in mathematics is only in a small minority of schools'. One third of mathematics departments made very little use of ICT for learning, despite National Curriculum documents including references to ICT and government funding. Evidence suggests that teachers are using ICT as a tool to teach mathematics is still at a low level (Andrews, 1999; Becta, 2004; Ofsted, 2008; NCETM, 2010; Joint Mathematical Council of the United Kingdom (JMC), 2011).

It may be tempting to lay the blame for this limited use on teachers, however the decision as to whether to use technology is based on 'personal choices and professional satisfactions interacting with organisational, political and social contexts within which people work' (Cuban, 2001 p.152). Hence the whole context of the education system must be amenable if ICT use is to be actively encouraged.

2.1 The introduction of computers into schools

Cuban (2001) stated that while teachers embraced technology such as overhead projectors and video recorders which had proven reliability, computers continued to be regarded as 'add-ons' with inadequate technical support, unreliability and system complexity causing anxiety when using IT. Companies made faster and flashier machines and software but their focus had little to do with what teachers wanted.

2.1.1 Early days, pre-1989

Mainframe computers were available in the 1960s, but computers only became part of Primary and Secondary school resources in the1980s (McKinsey, 1997 p.8). Early programs were written by students and teachers, printed onto a tape or cards and sent to a local college or LEA facility for processing. It was not until the 'Computers in the Curriculum' (CIC) project in 1972, funded by the Schools Council that software specifically for education started to be developed. Smaller, more portable technology including scientific calculators appeared in the 1970s (Pimm and Johnston-Wilder, 2005). From 1979 there was major investment in computer access, computers were given via Local Education Authorities (LEAs) through government initiatives although there was no clear educational rationale set out for how this was to be done (Hammond et. al., 2009b p.17). The timing of the "Microelectronics Education Program" (MEP) (1980 to 1986), "Micros in Schools" (1981), and the "Technical and Vocational Initiative" (TVEI) (1983-1997) initiatives coincided with the government's desire to boost the UK computer industry, leading to government departments other than education also providing funding (Hammond et al., 2009b).

The government commissioned Cockcroft Report (1982) on the teaching of mathematics devoted chapter 7 (pp. 109-207) to computers and calculators, believing that: '... their increasing availability at low cost is of the greatest significance for the teaching of mathematics' (Paragraph 327). In considering the future, Cockcroft Report (1982) Paragraph 373 commented:

> 'We are therefore in a situation in which increasing numbers of children will grow up in homes in which calculators and microcomputers are readily available, in which there is access to a variety of information services displayed on domestic television sets and in which the playing of 'interactive' games, either on microcomputers or by means of special attachments to television sets, is commonplace.'

The authors realised how calculators and (micro)computers could be tools to assisting and improving the teaching of mathematics, also they noted the under-use of the technology in schools and lack of good quality mathematics software. The Cockcroft committee looked to the future, referring to the computer as an aid (paragraph 404) with the ability for achieving interactivity and graphical representation.

Pre-national curriculum developments in the use of technology for mathematics were led through enthusiastic educationalists keen to promote the use of digital technologies described by Rogers (1983) as innovators in his 'Innovative Diffusion Model (IDM)', venturesome in that they 'desire the hazardous, the rash, the daring, and the risky' and willing to accept setbacks (p.248). This model was also used by Cuban et al. (2001). Hodgson (1995) described this early core of enthusiastic teachers as 'multiplicative agents', who were expected to pass on their knowledge to colleagues. Roger's early adopters were more cautious but engaged with the technology. Later these early groups would be described as 'missioners' (Glover and Miller 2001a) as they tried to 'spread the word' including publishing in the Association of Teachers of Mathematics' (ATM) journal MicroMath. Teachers were able to try new ideas and be creative. The enthusiasts and IT-motivated began to develop skills, materials and ideas for their own use in classrooms and to share with colleagues and beyond. The Secondary Mathematics Individualised Learning Experiment (SMILE) and Newman College produced learning resources, including software for the BBC and Research (RM) machines, mostly written by practising teachers (Gazzard, 2016 p.73; Govier, 1997).

From 1986 Local Education Authorities (LEAs) were directed to take responsibility for in-service teacher training. There was a danger of insufficient funding (Humphries, 1985) and limited software development, and it was considered that existing resources would suffice. In 1988, the National Council for Education Technology (NCET) was formed with the brief to provide support materials and purchasing advice (McFarlane, 2002). Three types of mathematical software appeared, those that facilitated drill and practice, such as ‘Find the Rhino’ co-ordinate practice from MEP, and those that developed thinking skills, including puzzles released by SMILE (Pimm and Johnston-Wilder, 2005; Hammond et al., 2009b) and content-free such as Logo. Authors such as Papert (1980); Noss et al. (1987); Tall and Watson (1987) aimed to enthuse teachers to use IT to engage learners with a problem-solving approach.

2.1.2 After the introduction of the National Curriculum

From 1988 initiatives began to impact on teachers’ agency in their classrooms: an inspection regime (Ofsted, 1992); the National Curriculum (1988); the National Grid for Learning (NGfL) and the National Strategies (both 1997). The National Strategies provided a detailed scheme of work including activities and teaching approaches diminishing teachers’ freedom to organise teaching and learning in their classroom. Mathematics at Key Stages 2 and 3 continued to offer chances to use technology (DfEE, 1997; DfEE, 2001) as illustrated by Figure 2.1 (DfEE, 2001 p.9).

Figure 2.1 2001 criteria for Y8 data handling

254–5 • Collect data using a suitable method, such as observation, controlled experiment, including data logging using ICT, or questionnaire.

256–67 Processing and representing data, using ICT as appropriate

256–61 • Calculate statistics, including with a calculator; recognise when it is appropriate to use the range, mean, median and mode and, for grouped data, the modal class; calculate a mean using an assumed mean; construct and use stem-and-leaf diagrams.

262–7 • **Construct, on paper and using ICT:**
- **pie charts for categorical data;**
- **bar charts and frequency diagrams for discrete and continuous data;**
- **simple line graphs for time series;**
- **simple scatter graphs;**

identify which are most useful in the context of the problem.

Integrating ICT into mathematics in Key Stage 3 (DfES, 2003) followed, providing more advice including pedagogy and advantages of using ICT (pages 2-3), areas where ICT could be used (page 9) and the ICT resource to use with teaching objectives (pages 17-19). Commercial educational software was marketed, including graphing packages developed to support pencil and paper methods (Ruthven et al., 2008); dynamic geometry programs with the release of Cabri ll in 1994 (Pimm and Johnston-Wilder, 2005).

Prior to the introduction of the National Strategies, Ofsted’s review of IT inspections carried out in 1993 and 1994 (Ofsted, 1995) indicated that hardware was ageing badly; desktop machines were often used ineffectively (often in computer rooms) with too many students working together at one screen. Jarrett (1998, p.2) suggested that: ‘Portable equipment enables the study of maths to move out of the classroom and to incorporate fieldwork investigations’ so providing a way forward to increase access however constraints in the form of small screen size and the need to constantly re-charge or replace batteries hindered this. In 1995-6, only 7% of secondary schools had access to portable technology (DfEE, 1997) although this increased due to the National Council for Educational Technology (NCET) "Portable Computers in Schools" pilot scheme, evaluated by NFER (Stradling et al., 1994). The British Educational Suppliers Association (BESA 1997 report (Rossi 2015) stated that nearly a fifth of school spending on technology resources was assisted by government support and funding. Although there were many PCs in schools, impact on educational standards was not clear, although it was recognised that developments in hardware and software offered greater facilities for teaching and learning and could be used as an information source for pupils as well as an instrument for producing work (Stevenson, 1997). The McKinsey Report (1997 p.27) stated: 'There is evidence that many teachers lack the training, support, communications and therefore proficiency to be fully effective in the use of IT, and also a comment about the amount of training teachers should receive:

> 'By the time teachers have received 60 or more hours of training, and up to two years' experience, they are usually fully comfortable with the technology and able to integrate it into the curriculum. When they have gained several more years' experience, they often start to devise their own approaches using technology as a flexible tool'.

Stevenson (1997) recommended several remedial initiatives including setting up the National Grid for Learning (DfEE, 1997); changes to the National Curriculum for England for implementation from 2000; renaming IT to ICT (information, communications, technology) adding elements such as broadcasting and telecommunications. The British Educational and Communications Technology Agency (Becta) was set up in 1998 by the government to support schools purchasing hardware and software. Becta's initiatives focussed on resource provision; two were aimed at individual teachers 1996-2003. One was the Laptops for Teachers scheme (Hammond, et al., 2009b) 1996 -1998 whereby some teachers could purchase laptops at discount from approved suppliers and the National Opportunities Fund (NOF) training to equip teachers with skills to be confident and competent using ICT for teaching (Kirkwood, 2000; Pimm and Johnston-Wilder, 2005; Hammond et al., 2009b).

According to Rossi (2015) not all government initiatives involving ring-fenced money and giving approved lists of suppliers were successful. Although efforts were made to increase participation and provision through funding for schools to have a broadband internet connection, improvement to, and increasing, hardware provision, initiatives were, at times, at odds with what teachers saw as necessary.

NOF focussed on aspects of teaching such as administration rather than subject teaching. Rossi (2015) commented that NOF training often did not match the needs of teachers and lacked follow-up support. As with other initiatives, NOF seemed imposed from above (Preston, 2004a); there was no formal recognition of the courses or funding to release teachers. With each government initiative, the curriculum became more prescriptive, more outcomes-based than processes-based (Nuffield, 2009) with more top-down central control, training focused on delivery, meeting targets and assessment.

With the closure of the independent Qualifications and Curriculum Development Agency (QCDA) in 2010 and Becta in 2011 the Education Secretary and the Department for Education (DfE) gained total control over the curriculum (Gilliard, 2011). The use of digital technologies in mathematics was placed in the supplementary curriculum guidance rather than being statutory and the use of calculators was actively discouraged. Many mathematics teachers may have thought that ICT was no longer recommended for teaching.

2.2 Digital technologies as a resource for teaching mathematics

2.2.1 Potential advantages

The advantages of using technology in mathematics lessons were recognised from the early 1980s. a group of HMIs commented on the use of scientific calculators in the sixth form (DES 1982 p.29):

> ‘In A-level work there was a very widespread use of the pocket calculator as a substitute for mathematical tables. It was disappointing to find much less use being made of them in other examination courses in mathematics. The fact that some examination rubrics would not allow their use during the actual examination was often interpreted to mean that they cannot be used at any time during the course. Much valuable mathematics activity can be derived from the use of these devices beyond the more obvious purposes for which they are used at the present time.’

Within mathematics, ICT facilitates the ability to access more complex concepts (National Council for Educational Technology (NCET) 1995; DfES, 2003; NCETM, 2010), whether exploring and using formulae, processing data or developing geometric concepts. The use of specialist software allows learners to draw geometric figures quickly and accurately. Data handling and collecting, from primary or secondary sources becomes both possible and interpretation becomes possible. Mann and Tall (1992) pointed out that ICT can be used for teaching most mathematical topics, providing an additional tool for the teacher to impart information through demonstration and exploration. Modelling engineering and science situations and scenarios becomes possible without having deal manually with large amounts of arithmetic (Selinger, 2001). This allows opportunities for pupils to develop understanding of how mathematics affects many everyday events. Monaghan (2004) suggested not all teachers know how to use the specialist software to support their work. The ATM produced low cost guides for Cabri, Geometers Sketchpad and GeoGebra dynamic software (Johnston-Wilder et al., 2007; 2007b; 2007c) and videos of Grid Algebra (accessible on YouTube) to support teachers. The benefits of using ICT successfully have been suggested as: more efficient working practices by students, including the quality of work produced; developing problem solving strategies; applying mathematical ideas to the 'real' world and acting as a stimulus and motivator (Oldknow and Taylor, 2003; Ruthven et al., 2004; Webb and Cox, 2004; NCETM, 2010). Other authors including Clements (2000) and Sutherland (2004) highlight the potential of spreadsheets and dynamic geometry for manipulation of information to explore problems while giving rapid feedback to support the construction of knowledge. Once teachers are able to see the possibilities, feel secure in their knowledge of the hardware and software, they are more likely to develop a positive attitude and be prepared to adapt their teaching (Cox et al., 1999). The availability of the internet has allowed access to internationally-developed open-source programs with on-line manuals and wikis such those of as GeoGebra for sharing resources (Geogebrawiki.wikispaces.com, 2017).

Not all reactions to introducing technology have been positive. The introduction of calculators into primary schools led to debate about their effect on standards

(Paton, 2014) with some reports, for example by the London Mathematical Society (LMS) (1995) and National Institute of Economic and Social Research (NIESR) (Prais, 1997) suggesting lower performance of English pupils in international studies is affected by use of calculators, rather than mental methods, in the early years. This was contradicted in other studies including the Calculator Aware Number (CAN) project 1986-1989 (Shuard et al., 1991; Ruthven, 1990; Ruthven et al., 1997).

2.2.2 Mathematics specific software

In Australia Forgaz (2002) found that the range of mathematics specific software used was limited, generic software and the internet being most commonly used, while only dynamic geometry, and a graphing package were mentioned as mathematics resources. Similar research results were found by Becker et al. (1999) in USA. An extensive list of generic and mathematics specific software that could be used in mathematics classrooms was suggested in the NCETM (2010) report. Key content-free mathematics software included Logo, geometry, graph drawing packages, spreadsheets and statistics packages. No mention is made of computer algebra systems (CAS). Several pieces of software have facilities for more than one element, while GeoGebra is more inclusive piece of dynamic mathematics software, encompasses all apart from Logo and includes a CAS interface (Hohenwarter et al., 2008). Although CAS is available on graphics calculators and included in GeoGebra according to Hoyles et al. (2004 p.315), it provides ‘an unprecedented symbolic means of expression for mathematical abstraction as a process’. They also noted that CAS is ‘embraced by professional users of mathematics’; although CAS software such as DERIVE, Mathematica and Maple are available and used in other countries the English secondary curriculum is currently not designed to accommodate examination questions based on CAS (Monaghan, 2000; MEI, 2008). Logo and derivatives are no longer included in the mathematics curriculum having been moved into the domain of computing. Appendix 7 describes available software in 2016.

2.2.3 Integrating digital technologies into teaching mathematics

The National Strategies for Mathematics (DfEE, 1997; DfEE, 2001; DfES, 2004), provided some assistance, especially at primary level, by suggesting suitable ICT opportunities. Assistance was included in an optional resource for secondary schools, Improving Learning in Mathematics, (Swan, 2005), with examples of using ICT to teach topics and applets on CD and DVD. Neither of these, however, negated the time taken for teachers to familiarise themselves with the software or increased their enthusiasm for using ICT which Hodgson, (1995) suggests is an important factor in how teachers integrate ICT. The intention to use ICT is also reflected in the Technology Acceptance Model (TAM) developed by Davis (1989) and discussed in chapter 3.

Oldknow and Taylor (2003) suggested three principles should be applied in addition to resource availability. Firstly whether ICT use supports good practice, secondly the relationship between the planned teaching and learning objectives and thirdly that it should allow the teacher or pupil to achieve something they could not do without the use of ICT or that it is more efficient and effective. Skemp (1979) outlined three modes of building and developing concepts, experience tested by experiment, communication tested by discussion and creativity tested by internal consistency. Mathematics teaching has always been based on communication, but the computer provides a resource to develop the other two methods by allowing experimentation (quicker processing and adaptation) followed by a discussion where mis-concepts can be identified, students being encouraged to verbalise their thoughts and ideas.

In an analysis of accounts of successful integration of computer use in mathematics, science and English lessons, Ruthven et al. (2004) identified seven major themes. The first they called ‘Effecting working processes and improving production’ with teachers referring to the pupils’ speed in completing activities such as data handling. Second was ‘Supporting processes of checking, trialling and refinement’ that supported pupils in improving their trial and improvement skills. The third theme of ‘Enhancing the variety and appeal of classroom activity’ included pupil enjoyment and seeing a different way of doing things such as taking out some of laborious repetitive tasks. A fourth heading was ‘Fostering pupil independence and peer support' and included teacher comments about pupils being free to explore and find out things for themselves and also to help their peers. They identified that pupils with difficulties were enabled to present good quality work with computers making this their fifth theme. They suggest that alleviating problems with writing and drawing and correcting mistakes removed disincentives and enabling pupils to take a pride in their work as well as build conceptual understanding. Their sixth theme ('Broadening reference and increasing currency of activity') is applicable to mathematics, using access to real data sets with a final theme 'Focusing on overarching issues and accentuating important features' included speeding up subsidiary tasks such as data handling, and being able to give clear visual representations.

A survey of teachers in the United States who had integrated ICT into their teaching by Hadley and Sheingold (1993) suggested that most teachers agreed with statements that referred to the computer becoming a tool for children, a means of expanding and applying what has been taught, and raising pupil's motivation through making the subject more interesting. They also commented that teachers felt they were able to set goals that were more challenging, the ability to present more complex material and tailor work to their students. In earlier work by Means and Olson (1997) teachers commented on being able to include more authentic and complex tasks, increased motivation and self-esteem of their students who were engaging more with each other and using peer-to-peer teaching. Monaghan (2004 p.344) cites an instance in his project of a group of pupils, having completed a task on quadratic graphs, being told by the teacher to 'reflect those graphs in the x-axis' and pupils succeeded in the task without further guidance. However Cuban (2001) commented that teachers they interviewed (in the USA) were not changing their teaching style to be more student-centred approaches with 'little to no use in math'.

Apart from computers schools were also given funding for data projectors, interactive whiteboards (IWB) and a virtual learning environments/platforms (VLE/P). Interactive whiteboards have represented a major investment by schools and potentially the best example of integration of digital technology as the use of a digital projector and computer are also required. Miller et al. (2004) raised the issue that most of the mathematics teachers in their study using supported didactic approaches were only using a limited number of presentational forms and manipulations, using the interactive whiteboard as a visual support. Teachers who had had access to whiteboards longer were using manipulations, to develop a sense of interactivity. While there is evidence that interactive whiteboards improve presentation and consequently motivation, Miller et al. (2005 p.105) commented that:

> '…neither of these add to teaching effectiveness unless they are supported by teachers who understand the nature of interactivity as a teaching and learning process and who integrate the technology to ensure lessons that are both cohesive and conceptually stimulating'.

Authors including Glover and Miller (2001a); Smith et al. (2005); Kennewell et al. (2009) suggested that an IWB provides advantages over static white or black boards although it appears that mathematics teachers are not making full use of them (Glover and Miller 2001a). For teachers the IWB enabled more interactivity in the classroom although reports including Ofsted (2008) and NCETM (Miller et al., 2008) suggested they were more likely to be used for presenting ideas using presentation software or as a 'textbook on the computer' potentially resulting in didactic teaching, rather than 'on the board, on the desk, in the head' (Miller et al., 2008). While connecting a computer to a projector offers the teacher a means to display pre-prepared work that can be annotated in class, show video or use the internet, the IWB also allows for hand annotation, via the computer or inbuilt keyboard and the ability to save this for another day, the introduction of the interactive whiteboard (IWB) gave mathematics teachers opportunities to change their pedagogy and deliver more interactive lessons. Glover et al. (2007) described three types of practice:

- firstly 'supported didactic' with the interactive whiteboards viewed as direct replacement for blackboards and static whiteboards a 'pen' or finger being the input method)

- secondly ‘interactive’ where it is used to demonstrate using, for example Power Point and Excel with some use of the inbuilt tools
- thirdly ‘enhanced activity’ where the board is used interactively to ‘promote discussion, explain processes, develop hypotheses or structures then to test these’.

Oldknow (2005) also identifies three levels of IWB usage:

- low interactivity where the IWB is used as a display tool, for example using a PowerPoint presentation
- medium interactivity where software is controlled from the front of the class for example in discussions
- high interactivity where students are able to interact, for example when using dynamic geometry.

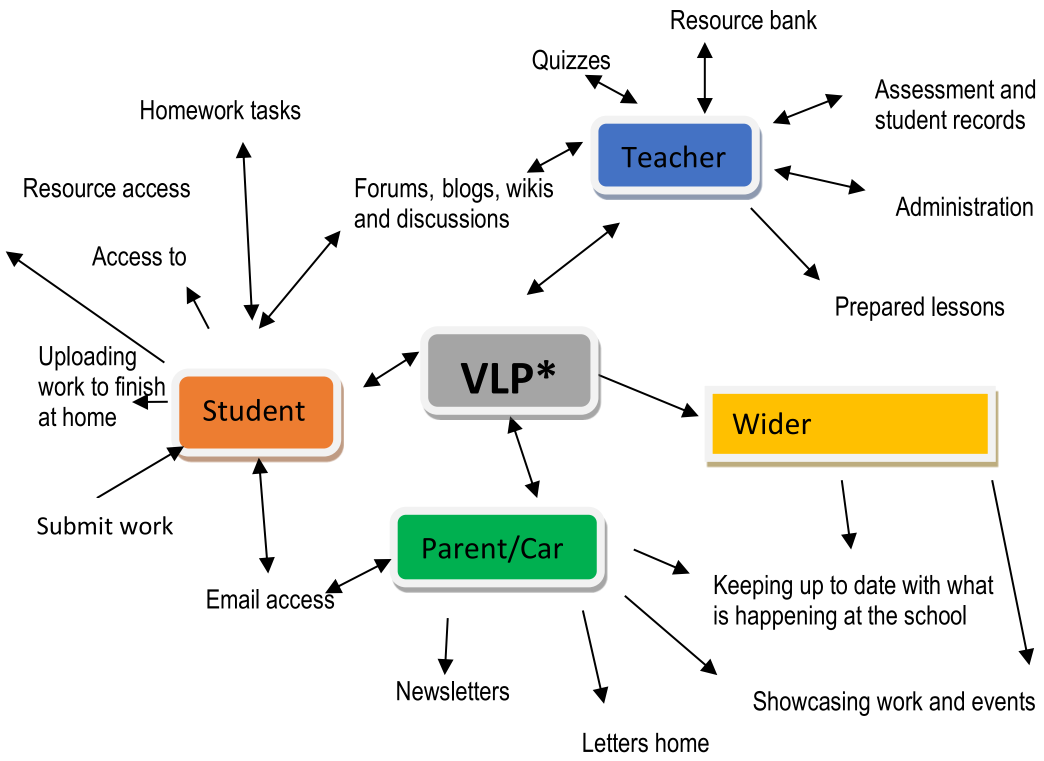
Oldknow, (2005) adds that the use of a wireless keyboard, mouse or tablet (not to be confused with a tablet computer) also enables interaction to take place from elsewhere in the classroom, including the pupil’s seat, allowing the teacher to move around and avoiding disturbance as students move to the front of the room, a problem in some classes. Comments from teachers themselves regarding use of IWBs quoted by Oldknow (2005, p.31) included:

> ’…the system represents a considerable advantage over just a plain whiteboard, or over a digital projector and a static screen ... the learning curve for the user is not steep ... you can use the system as a conventional whiteboard ... review material ... links can be prepared beforehand ... scribbling can be saved and/or printed out ... annotate over other packages ... adds significantly to the quality of presentations’.

In addition to IWBs schools were encouraged to set up VLPs with government funding (DfES, 2005). VLPs offer teachers opportunities to share work with other teacher, to give students access to work outside the classroom and provide communication channels between school, home and the public face of the school (Jewitt et al., 2011; Barker and Gossman, 2013). There are different forms of VLP and schools choose how they wish to set them up, some prefer to use one that includes administration tools, whilst others keep the VLP exclusively for curriculum use. There are also commercial or open source frameworks where schools build their own, for example Moodle (moodle.org, 2017) (Jewitt et al., 2010; Cope, 2013).

Where schools did not have a VLP, they could use an intranet system, with some of the features of a full VLP. Figure 2.2 compiled from Jewitt et al. 2010; Cope 2013 and provider's websites shows some ways schools have incorporated them, illustrating how an effective VLP can act as a communications hub. In many establishments, however the use of the VLP is limited (Ofsted, 2009).

Figure 2.2 Uses of a virtual learning platform



* VLP Virtual Learning Platform

2.2.4 What might affect integration into mathematics lessons?

Although National Curriculum documents have included references to ICT, and government funding through initiatives such as NGfL and Becta has been available, evidence suggests many teachers have not been using ICT as a tool when teaching mathematics (Andrews, 1999; Ofsted, 2008; NCETM, 2010; JMC, 2011). According to Smith et al. (2008a p.42) reasons given for not using ICT by many secondary teachers, were about organisational issues.

> 'A high proportion (41 per cent) said that they found ICT difficult to access in their schools, and 29 per cent said that they did not think ICT was time-effective a lot or some of the time.'

Cox and Marshall (2007) pointed out that there are unanswered questions about the effect of ICT on learning, both in the short and long term. The case for change has not been made to such an extent (OECD, 2015, p.3) that mathematics teachers see the reason for changing to use more ICT in the classroom, how it fits with their present practice and how to implement the change. Cox and Marshall (2007) also mentioned that other factors within schools, such as school intervention schemes, will potentially affect the result of research data. They remarked that many of the findings were based on standardised test results rather than research specifically looking at the types of ICT used, hence do not evaluate changes in the cognitive processes of the students. There are other implications for integration of ICT into mathematics teaching (Harrison et al., 2002); teachers' knowledge of the software, their inclination to use ICT, their training needs, and the availability of resources. As McLoughlin and Oliver (1999) commented, using ICT can change the role for both teachers and pupils, with teachers delegating some responsibility for learning to the pupil. This is an action some teachers may not feel comfortable with, especially in the high-stakes English environment where schools are judged on the number of pupils attaining a certain level in examinations. Hennessy et al. (2005 p.172) pointed out how teachers in their study felt that 'ICT must take second place to guiding students to examinations'.

For schools that follow a textbook-led scheme of work, many texts commonly used in schools, including Nelson's Key Maths series (Barker et al., 1995; 2000a; 2000b) and The School Mathematics Project Interact series (SMP, 2003) have few ICT examples for pupil activities as 'new technology' is regarded as a supplementary tool rather than a fundamental tool to be integrated into teaching. The books tended to focus on preparation for passing examinations with a more prominent place in planning (Haggerty and Pepin, 2002). This was a point also made in Rodd and Monaghan's (2002) study on the use of graphics calculators in Leeds schools.

2.3 Barriers and Constraints

Schools and teachers face barriers and constraints when using or intending to use digital technologies as highlighted in a number of reports including that by NCETM (2010) and authors such as Jones (2004); Bingimlas (2009). School related issues arise from external forces including government (national and local) and academy sponsors expectations, plus internal influences including management attitudes, school ethos and availability of resources.

2.3.1 External forces

Policy-makers have a direct impact through dictating what they fund, statutory national curriculum and examination syllabi. Since 2010 the Government changed the way state schools are run and financed, by encouraging the formation of Academies and 'Free' schools (*Education Act, 2011*), which are directly funded by, and answerable to, the Department for Education rather than the Local Authority as was previously the case for all schools (Academies Act, 2010). Whilst maintained schools (community, foundation and voluntary aided or controlled) were told to follow a national curriculum, (DfE, 2014, p.4), other schools including those run by academy chains, free schools and private schools did not. The only stipulation was that they should have a broad and balanced curriculum including English, mathematics, science and religious education, any entitlement to ICT was removed. The importance of the school's ethos regarding incorporating ICT into the curriculum at management and departmental level is likely to be reflected in teachers' use for teaching and administration and access to training.

2.3.1.1 Funding

Whereas funding was previously given to Local Authorities to distribute after they had taken out appropriate funds for the services they offered, including bulk purchasing and advisory services, government funding is currently (2017) given directly to academies and 'Free' schools who have the option to 'buy-in' services such as those previously offered by local authorities including ICT support and teacher training. Two support organisations were also closed, Becta was closed in January 2011 (Gov.uk, 2012) and replaced in 2015 with a list of 21 suppliers who offered services and solutions for hardware and generic software (Crown Commercial Service, 2015) but excluding teaching support and Teachers TV channel in April 2011 which had provided support for classroom teachers with on-line videos of software being used in classrooms and training. Although a group of academies may provide services previously provided by local authorities; provision can no longer be considered to be consistent even within one local area.

2.3.1.2 Curriculum influences

The since the introduction of the National Curriculum in 1989 (DfES, 1989) the government has been involved in providing study programs for schools. Following the Cockcroft Report the first National Curriculum 1988-1989 was introduced and included an 'entitlement for all' highlighting IT links throughout the curriculum (e.g. Mathematics Attainment Target 5 Number/Algebra Level 6 stated 'use spreadsheets or other computer facilities to explore number patterns'). Facilities to train all mathematics teachers in applications such as Logo and early databases/spreadsheets were not activated reducing the potential of these strong mathematical programs to improve the teaching of mathematics. The curriculum also included BASIC programming but did not suggest how this should be implemented.

The mathematics curriculum subsequently underwent revisions in 1992 and 1995 reducing attainment targets. The mathematics content changed little; in each version there were references to the use of computers and calculators in the requirements for number, algebra, data and shape as well as using and applying mathematics. (DES, 1989; DfE, 1991; DfE, 1995). The 1999 Mathematics National

Curriculum (DfEE, 1999a) highlighted links to other subjects, including ICT; the use of 'should' indicated the intention teachers should regard that link as a statutory requirement but links to ICT were more commonly expressed as 'could' with no specific references to ICT in the level descriptors. The document also contained a generic section on 'Use of information and communication technology across the curriculum' where it was suggested that 'Pupils should be given opportunities to apply and develop their ICT capability through the use of ICT tools to support their learning in all subjects' (DfEE, 1999a, p 84). The National Numeracy Strategies (NNS) (DfEE, 1999b; 2001) contained examples for incorporation of ICT into teaching as mentioned in 2.1.2. NNS promoted 'whole class' direct teaching at both primary and secondary (Key Stage 3) levels. Unfortunately, the examples were not aligned with the National Curriculum; content was based on expectations for year groups rather than National Curriculum levels, although it was stated that following the strategies was not a legal requirement, there was an expectation that teachers should follow them. In 2003 the DfES wrote of Key Stage 3 (DfES, 2003, p 1):

> 'During the key stage, pupils should be taught the knowledge, skills and understanding through … tasks focused on using appropriate ICT [for example, spreadsheets, databases, geometry or graphic packages], using calculators correctly and efficiently, and knowing when it is not appropriate to use a particular form of technology.'

An appendix, 'ICT in the Mathematics Framework' illustrated ICT opportunities was included. This document aimed to help teachers identify where ICT would support their teaching, focussing on three areas, pedagogy, mathematics and organisation. They highlighted how feedback enhances learning by encouraging an exploratory approach, enabling trial and improvement and iterative searches to be more efficient through the speed and accuracy of the feedback, allowing for changes to be made in stages (e.g. when using dynamic geometry) as insight is acquired into the task.

Drenoyianni and Selwood (1998) commented that teacher beliefs and the use of ICT need to be considered alongside their interpretations of official orders and requirements. Selwyn (1999) also noted conformity to external regulations and preparing students for examinations undermines pedagogy while Hennessy et al. (2005) suggested this also severely affects the use of ICT, with teachers adapting use of ICT to an expositional style of teaching. Since the National Curriculum for England (2000) (DfEE, 1999a) was introduced there has been pressure to use ICT within subject teaching, but as Hennessy et al., (2005) comment (p.157):

> '… classroom teachers have historically had little say in designing and implementing development plans for using ICT within their schools, and for defining its role within subject curricula'.

ICT consultants and tutors (not mathematics teachers) were the target audience for the ICT KS3 Strategy (DfES, 2004). Of the nine key concepts for ICT, four were appropriate to mathematics: using data and information sources, organising and investigating, analysing and automating processes, models and modelling. The document emphasised the need to develop skills for other subjects through ICT entitlement stating: 'Pupils who try to learn new areas of ICT at the same time as new mathematics content will often fail in both endeavours.' (DfES, 2004, p.8). The document further stated that it was not the role of the mathematics teacher to teach the ICT capability, which should be developed in ICT lessons and using ICT should not be seen as a bolt-on but fully integrated into lessons with purpose, adding value to teaching and learning. It was expected that the level of ICT use in mathematics would be met in the previous year's ICT curriculum, thus reinforcing capabilities acquired. As mathematics teachers were not included in the circulation of this information; they were not likely to implement the suggestions.

Four years later the mathematics curriculum had another change; Section 4 (Curriculum Opportunities) of the Mathematics Programme of study for Key Stage 4 (DfES, 2007a p.163) stated:

> 'During the key stage students should be offered the following opportunities that are integral to their learning and enhance their engagement with the concepts, processes and content of the subject. .....'

> *'g.* become familiar with a range of resources, including ICT, so that they can select appropriately.'

By way of explanation:

> 'Become familiar with a range of resources: This includes using practical resources and ICT, such as spreadsheets, dynamic geometry, graphing software and calculators, to develop mathematical ideas.'

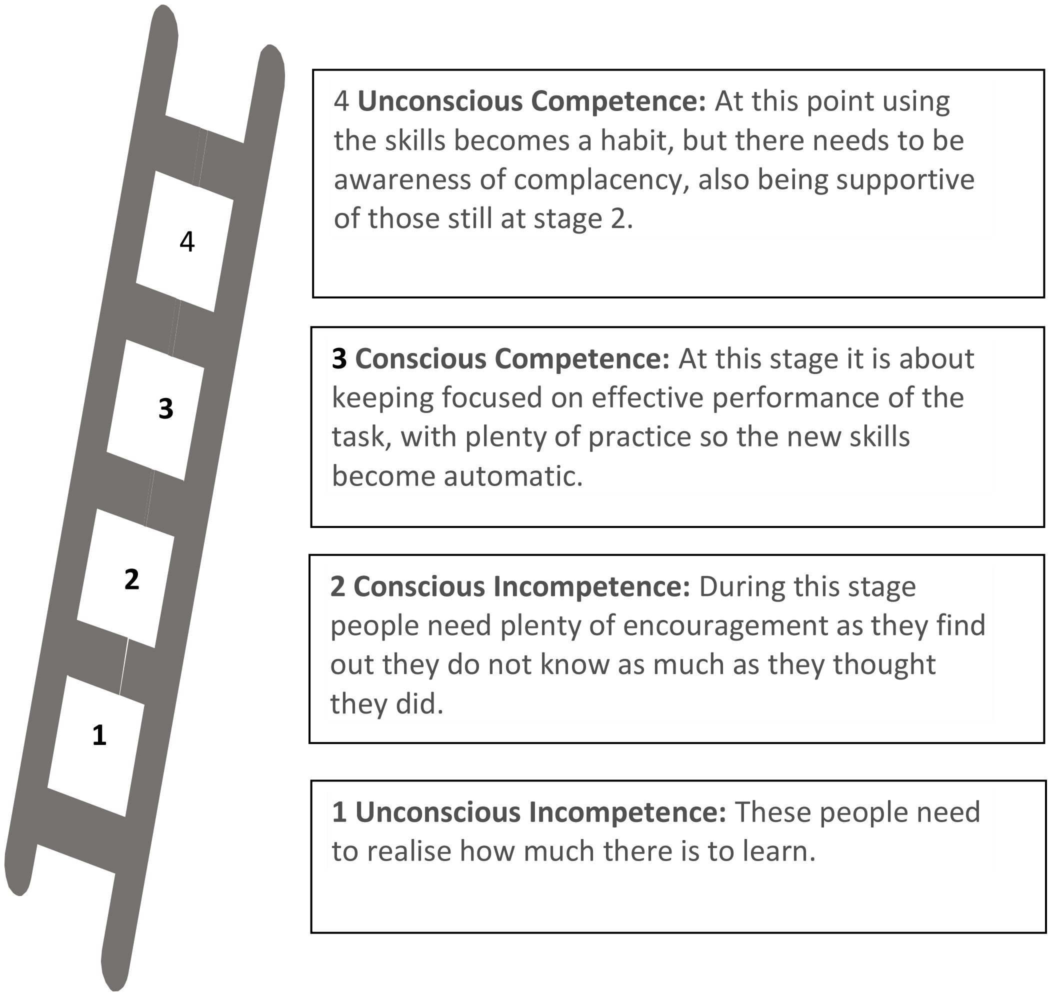
There was similar wording in the Key Stage 3 document (DfES, 2007a). By placing the ICT element in the explanation part of the document removed a statutory obligation. In mathematical processes and applications, attainment targets there was only brief mention of ICT at levels five and seven being a tool that 'could' be used. None of the other attainment targets referred to ICT. The National Curriculum revision included references (in the explanatory notes) to using ICT to support mathematics teaching and learning (pp.146-7) such as:

> **'Constructions, loci and bearings:** This includes constructing mathematical figures using both straight edge and compasses, and ICT.'
>
> '**Presentation and analysis:** This includes the use of ICT.'
>
> **'Become familiar with a range of resources**: This includes using practical resources and ICT, such as spreadsheets, dynamic geometry, graphing software and calculators, to develop mathematical ideas.'

Hennessy et al. (2005) suggested a centralised curriculum reduces professional autonomy, and in mathematics, further delegation of the responsibility to teach ICT within subjects rather than as a discrete subject, requires teachers to develop technical skills, such as the use of spreadsheets.

Smith et al. (2008a) reported that in-school training was positively received, the value depends on how far those offering the training are on the 'Conscious Competence Ladder' (attributed to Dubin, 1962) and whether they, or the participants realise, the potential of ICT resources (Figure 2.3). This seems unlikely to change as out-of-school of training is costlier, necessitating greater funding being given to or found by schools.

Figure 2.3 Conscious competence ladder



The manner in which the curriculum is presented creates constraints regarding lesson planning. Webb (2002) suggested that there whilst there is agreement about what is to be taught between the various examination boards, specifications give little guidance regarding the pedagogical skills needed to teach the content, whether this be in ICT as a subject or ICT within other subjects (DfEE, 1999c). Kyracou and Goulding (2004) in their report on the NNS mentioned that the three-part lessons affected how teachers taught lessons, particularly in the interpretation of interactivity. Whilst their study was concerned with the primary strategy the same style and ideals were apparent at Key Stage 3 and ICT was mentioned in the document as a tool and as resource for pupils. The NNS itself posed some conflicts for teachers as lesson planning was often presented as a weekly script, including a set time to complete a topic. This led to teachers having to consider whether using certain teaching strategies, including using ICT, or allowing further work, e.g. consolidation of concepts (Kyracou and Goulding, 2004) would mean the topic would over-run and whether they could justify this. They also suggested that difference between 'interactive whole class teaching' and 'whole class teaching' was not fully understood, leading to widespread use of closed questions and didactic teaching. The introduction of the NNS into KS3 increased teacher's workload (Barnes, et al., 2003 p.47) as they tried to fit existing resources and meet demands for improved standards, leaving little time to develop material for lessons. Their comment that, 'The continued inflow of multiple initiatives into schools was also a concern, and in many instances cut into the time available for focusing on the teaching and learning of mathematics' is still relevant.

In an attempt to raise the profile of ICT across the curriculum the government did, as part of their secondary strategy for school improvement, produce documents relating to the use of ICT in Mathematics, such as "ICT across the curriculum – ICT in mathematics" (DfES, 2004) and "Using interactive whiteboards to enrich the teaching of mathematics" (DfES, 2007b) but, again, it was up to the individual teacher to study and implement the content. Following the Key Stage 3 National Strategy for Mathematics (2001 to 2010), (DfEE, 2001) with its suggestions and examples for use of ICT (Appendix A6) Swan headed the Standards Unit Mathematics team to produce materials for teachers, including professional development resources, with the aim of improving learning in mathematics through a focus on interactive teaching (Swan, 2005). Section 5.8 (p.50) covers the role of the computer and says, 'computers, data projectors and interactive whiteboards open up new ways to enhance the learning process' stating they are interactive, provide instant feedback, are dynamic and link the learner to the real world. Many teachers did adopt a more interactive style, (DfE, 2011) but the curriculum also emphasised areas such as quick recall, brisk pace, meeting learning objectives and fast lively teaching (Tanner, et al., 2005) suggesting a conflict with allowing thinking time for interaction by, and with, pupils. Kyracou and Goulding (2004), in their report on the NNS, stated it was difficult to judge what effect the introduction of the strategy had as there had been changes to the curriculum made before that date, also it was difficult to measure the added value (or otherwise) of ICT usage as there was the students’ responses to delivery of the strategies, examination curriculum, and government policies to be taken into account. The withdrawal of the national strategies in 2011 and changes to the national curriculum in 2014 potentially gave schools flexibility as how to deliver the new curriculum and delivery guidance through the new Hubs network and the National Centre for Excellence in Teaching Mathematics (NCETM) (Roberts, 2014). Priorities for teachers in upper secondary schools has always been to enable students to pass examinations.

Selwyn, (1999) suggested that, for many teachers, subject pedagogy was dictated (especially at A level) by the nature of the qualifications being taught and the final examination. Ruthven et al. (2004) found that following curriculum orders exerts considerable influence on professional practice. Some schools interpret them literally, while others more loosely. They noted that teachers were asked to adopt the good practices of others, describing the effects as *’systemic subject cultures’* resulting in mathematics departmental schemes of work often based on commercially produced materials. Following the PISA report in 2013 there was a move to emulate mathematics teaching in Singapore and Shanghai (Merttens, 2015) with an emphasis on teaching Mastery in key stages 1 to 3.

In spite of suggested opportunities for the use of ICT by authors such as Oldknow and Taylor (2003); Ball and Ball (2001) to help teachers include ICT in their lessons, with suggestions for its use, some including a disc with activities; these were not always written as schemes of work leaving teachers to study and adapt the ideas and activities to their own needs. Ofsted (2008 para. 54-60), reported from a survey of 192 English schools 2005-2007 a decrease in pupils’ opportunities to use ICT with learning potential ‘too rarely realised’ and ‘not supporting pupils’ preparation of their future lives’. In 2009 Becta produced further guidance in association with the MA and the ATM showing how some pupils had used ICT (Becta, 2009). More recent research (NCETM, 2010) indicated that the situation had not changed much over time and added that a spectrum of use was to be found in schools, ‘ICT is rarely used by anyone, teacher, learner in any format to pupils having free access to support their learning’ (NCETM, 2010, p.11).

In 2010 the incoming Conservative and Liberal Democrat coalition government decided to radically reform the English education system and rewrite the national curriculum (*Education Act, 2011*) including replacing the new primary curriculum which had ICT at the centre along with literacy, numeracy and personal development (Rossi, 2015). The BESA report (Rossi, 2015 p.10) reported that their 2012 survey revealed that teachers thought 'Michael Gove had no time for technology and was more interested in chalk and talk methods of teaching with memorised facts and dates'. Other recent changes in education policy mean that pupils still finish compulsory full-time schooling age 16 but now are expected to stay in education or training and to study some mathematics, at least part-time, within education settings (which include apprenticeships and traineeships) until they are 18 years old (DfE, 2015a, 2015b). ICT as a subject was to be discontinued in favour of computing as a subject for all four key stages. Criteria in the primary national curriculum indicates the use of Logo based programs for control technology in primary school (DfE, 2013a) but the school is free to choose other control software which may have a lesser mathematical basis.

In 2012 the Education Secretary, Michael Gove announced that calculators should not be used in primary schools until pupils had a sound grounding in mental methods for calculation. Much research has been disregarded by those in charge of approving the curriculum; for example, the Calculator Aware Number Project (in the 1990s) demonstrated that primary pupils who used calculators were more confident with manipulating number, especially mentally (Ruthven, 2009). Use of calculators in primary schools was discouraged, suggesting a return to a pre-calculator time with a more conservative, traditional curriculum. This is at odds with three recent reports, (NCETM, 2010; ACME, 2011; JMC, 2011) which all look at the benefits of using digital technologies as a tool to teach mathematics. ACME (2011 p.13) states:

> 'There is potential, by using mathematics-specific technology, to bring abstract mathematical ideas into the manipulable world (such as moving screen objects to substitute expressions as variables) and to experience the possible variation of mathematical objects through dynamic representations

> (such as conjecturing geometric relations and properties). While workplace uses of new technologies (such as structuring real data with spreadsheets, or creating and using databases and displays) might be learned when required in a particular context, the use of new technologies to advance mathematical knowledge is not embedded in classroom cultures; yet learners' outside lives and sources of knowledge are significantly influenced by current technology. One teacher commented: 'The world of the student is IT. And then they go to a school where IT isn't part of the world. It switches them off.'

The 2013 national curriculum document included the statement: 'All schools maintained by the local authority in England must teach these programmes of study from September 2016' (DfE, 2013b). Academies and Free Schools were still expected to prepare pupils for the same examinations as those who followed the national curriculum. Study of the new mathematics curriculum for 2014 and beyond indicated less emphasis on skills that require technology, with fewer explicit links to the use of digital technology. The mention of ICT there is in the National Curriculum (DfE, 2013b) could be summed up by the statement in the Key Stage 3 Mathematics programmes of study under the title Information and Communication Technology (ICT): 'Calculators should not be used as a substitute for good written and mental arithmetic. In secondary schools, teachers should use their judgment about when ICT tools should be used' (DfE, 2013b, p.2). Within the programmes of study, the only two references are in 'Number: calculation and accuracy' and 'Geometry and measures'. In these it is states: '[…] use a calculator and other technologies to calculate results accurately and then interpret them appropriately' (DfE, 2013b, p.6) implying that there is no need for mathematics teachers to develop knowledge or skills in using ICT for teaching beyond basic calculation, and 'Derive and illustrate properties of triangles, quadrilaterals, circles and other plane figures […] using appropriate language and technologies' (DfE, 2013b, p.8). The calculator debate continues and calculators are currently banned in tests for 11-year olds (DfE, 2012a; Stacey, 2012; 2014; Paton, 2014); non-calculator papers are included in GCSEs.

2.3.1.3 Testing, including examinations

In England the current state school structure requires that schools prepare their pupils for national tests at the end of Key Stage 2 in primary school (age 11) and in secondary schools at the end of Key Stage 4 (age 14-16) pupils sit General Certificate in Education (GCSE). After this there are further examinations (Advanced Level or vocational) until they reach age 18.

The testing regime which is currently statutory in England in itself can be seen to present barriers to the introduction of ICT. Hennessy et al. (2005) have suggested that examinations undermine the use of ICT, as working towards the tests plays an important part in what is taught. In England tests are paper based and the General Certificate of Secondary Education (GCSE) Mathematics (Paper 1) and General Certificate of Education (GCE) A level (Core 1) examinations prohibit the use of any technology, including calculators. The external examinations do not include elements relating to ICT use and restrict the types of calculators, including graphics and handhelds at post-16, allowed. Hennessy et al. (2005 p.170) wrote:

> 'Despite the widespread commitment to integrating ICT, it was clearly accompanied by a feeling of external pressure. This pressure relates to the requirement within the English National Curriculum to use ICT within subject teaching ...'

In their report Understanding the Score, Ofsted (2008) commented on the pressure put on teachers by managers to get as many students as possible past the GCSE C grade has had a detrimental effect on the teaching of mathematics, while Berliner (2011 p.288-9) commented that, 'pressure of the testing also results in teachers engaging in vast amounts of test preparation with their students' and 'one quite rational but troubling way to accommodate the ever higher test scores from students is by curriculum narrowing'. Berliner also pointed out that instruction in high stakes environments (i.e. pressure to attain a certain level) are often focused on drill such as memorization and mastery of rote procedures rather than developing understanding. Selwyn (1999) commented that subject pedagogy is led by the nature of examinations, which in mathematics has traditionally been exposition (whereby the teacher gives out knowledge, i.e. one-way) followed by practicing exercises. By its nature of being more interactive, the use of ICT in lessons is unlikely to be used to support the students to pass their examinations by teachers who espouse using a tried and tested teaching method. Demetriadis et al. (2003) however pointed to the adoption of use of ICT by teachers to an exposition style of teaching to support the teaching of examination content, in particular the use of an interactive whiteboard as a writing or display surface, for pre-prepared work using PowerPoint or Word, rather than making use of the interactive features.

2.3.2.1 Ethos and leadership

Personal beliefs regarding the use of ICT in teaching, pedagogy, and attitudes to change of people at all levels of management positions are regarded as having a major impact on the ability of teachers to use and develop ICT usage within subjects. Glover and Miller (2001b) categorised teachers' attitudes as missioners, tentatives and luddites in their approaches to technology. They applied these descriptors to not only the teachers, but also to those in school management. They described missioners as those who embraced the use of technology and supported others to do likewise by sharing their knowledge, while the tentatives were those who interested in developing their skills, but lacking the confidence to use it with pupils. The luddites were not interested and were comfortable with the way they had always conducted their lessons and were resistant to change. Cox et al. (1999) suggested that if schools, as represented by the senior leadership team or management, were not committed to using ICT, supportive of teachers attending courses, setting up systems ot allow others to learn from their experiences, the rest of the school would set up 'antibodies' to new ideas and other teachers would be less likely to change their practice. Becta's Harnessing Technology review (Becta, 2008, p.20) reported that there were still issues in building a good infrastructure to 'support flexible and extended learning' which meant teachers and learners were not receiving an up to date and reliable service. Where the leadership teams embraced ICT, funds would be made available for purchasing and training, with provision of quality technical support to enable even aging machines to function.

Whilst Glover and Miller's (2001b) research was concerned with interactive whiteboards, their comments they make are equally applicable to other forms of technology. Where missioners administer the school, staff members are encouraged to take ICT on board, however luddites act as a constraint and barrier as they would not be prepared to make the investment necessary. Lack of funding would affect the necessary training to use them interactively and with subject-specific software so staff could be aware of, and able to use, features appropriate for their subject. Where management consisted of tentatives or luddites not all classrooms would be equipped with interactive whiteboards (Glover and Miller, 2001b). In these situations, there would have to be negotiation where staff wished to use them. A similar situation arises with learning platforms and intranets which have also been widely introduced into schools. Teeman et al. (2009) suggested that while 79% had access to learning platforms only 40 per cent used it a few times a month or more. The departmental ethos regarding use of the learning platform or intranet can also be a constraint or an asset. To upload files for sharing, to set up groups and user areas takes time, an issue which Hammond et al.'s (2009a) participants highlighted as being a real issue at an individual level. Whilst an individual might see the merits of students having access from home, or elsewhere, sceptical colleagues will see this as a challenge to their way of working. As reported by Cox et al. (1999) and Fullan (1991) people do not always have a clear and coherent sense of the reasons for educational change, what it is and how to proceed, so if teachers see no need to question their current professional practice they may not accept the use of ICT in their teaching.

The departmental ethos and leadership also influences the use of ICT from the perspective of schemes of work. Andrews (1999) reported that some departments had no policy for using ICT in their schemes of work and that some Heads of Departments avoided the issue or were waiting for others to develop one. Andrews (1999) suggested that schools with: 'established policies' seemed either to be radical and forward-looking or to contain colleagues with well-developed and exploited skills. Lack of modelling of use of ICT by departments and the attitude that ICT is not part of the scheme of work means teachers joining the department will tend to 'toe the line' unless they are very confident and can justify their ICT use to others. This is particularly true of new entrants to teaching as highlighted by a study by Hammond et al. (2009a) following students who made good use of ICT in their NQT year. An element of 'strategic compliance' was noted by both Hammond et al. (2009a) and in a study by Flores (2005) in Portugal. For some new teachers a move towards teaching in a transmissionist manner was seen as maintaining greater classroom control while for others this will be to conform with the ethos and expectations of their school mentor and the mentor's beliefs on whether the use of ICT had a positive impact on teaching and pupil learning. Hammond et al. (2009a) followed thirty trainees after they had become newly qualified teachers. They looked at the effect of their former student's mentors and other staff in the school and the encouragement given to use ICT. Their results indicated a fall in the responses to 'felt encouraged to use ICT' from sixteen when trainees to ten as new teachers. Six out of the thirty reported that mentors and other teachers in the school were not encouraging, indicating that the part that colleagues play is significant, even when a teacher is prepared to use ICT.

2.3.3 Lack of support

Lack of support for teachers has been an issue since the introduction of digital technology in schools. Support reflects on school management and ICT strategy. At the personal level there is need for building confidence amongst all staff including senior management and learning support assistants if there is to be effective ICT use without increasing workload (PricewaterhouseCooper (PwC), 2004). On the technical front lack of support extends to provision of reliable equipment with schools budgeting for replacement hardware and software including emergent technology and training at all levels rather than expecting staff to 'learn by discovery' (PricewaterhouseCooper, 2004). Lack of support extends to maintenance of ICT hardware resources. Unreliable equipment leads to inefficient use of time as a reserve lesson has to be planned 'just in case' and/or teachers 'fixing' the problem instead of teaching. PricewaterhouseCooper, (2004) found that within schools, technical support is variable and in some cases the lack of a technician entails involving an ICT competent teacher being asked to problem-solve hence taking them away from their lessons or being asked to 'fix' the problem in break times or after school. As technology becomes more complex there is more need for highly-skilled technicians in small and large schools; this raises funding issues.

2.3.3.1 Access and reliability

Hodgson (1995) suggested that explanations for underuse of computers in mathematics classrooms include restricted availability of computers with good processing powers, a lack of quality software, and complexity of the user interface making it difficult for sustained use in classrooms. He pointed out that, when computers were introduced into schools, there was much debate on the type and number of machines, rather than pedagogy. Mumtaz (2000) also commented on access to ICT facilities suggesting that it is a problem but schools where good practice was found invariably had good quality ICT resources. This situation is not confined to England, in the USA Cuban (2001) observed that most teachers and students had far more access than previously, but classroom use continued to be uneven and infrequent. Where schools use computer suites, rather than departmental or cluster of computers, implementation of ICT examination courses strained access for other classes' access especially where timetabled against one of the ICT examination classes (Jones, 2004).

The reliability of equipment provided and variable technical support caused other access issues (Preston et al., 2000; Hennessy and Deaney, 2004). A number of authors including Jones (2004); Ofsted (2008); Becta (2008); NCETM (2010) identified the teachers' inability to access reliable ICT resources as a concern. Andrews' (1999) study of teachers in the Greater Manchester area found that access to computers for cross-curricular use was problematic because of the number of IT courses being run. The teachers in his sample suggested that mathematics teachers could avoid using computers. Andrews' (1999) study also highlighted access issues, block timetabling of classes made it difficult for all pupils in a cohort to get access to computers during their mathematics lessons. This is reiterated by Smith et al. (2008a) who hinted that the situation had changed little for mathematics classes in eight years while Ofsted (2008 para. 56) commented that, 'the lack of ICT facilities was due, in the main, to the growth of ICT as a discrete subject'. A computer suite was often booked far in advance and usually entailed prior booking for a whole lesson and moving the class to the suite even when access was only required for a short time (Tanner and Jones, 2003; Ruthven, 2008). They found that the computers become the point of interest rather than the mathematics, causing disruption to teaching and learning. Tanner and Jones (2003) pointed out that some schools were however making dedicated provision of computers for the mathematics department.

Access and the reliability of equipment is seen as a major impediment to the use of ICT to teach mathematics. Jones (2004) suggested that teachers' fear of things going wrong, such as equipment breaking down in a lesson or that they will inadvertently cause damage to the system deters teachers, especially the less confident. Cuban et al. (2001) pointed out that if this were a regular occurrence this has a negative impact on the teacher. Preston et al. (2000) also reported on the breakdown of equipment acting as a disincentive to using ICT. Lack of up-to-date-equipment did not help reliability as schools sought to increase the number of computers by retaining and using older ones to supplement more recent purchases (Ofsted, 2008). Andrews (1999) suggested that few schools had funds to employ computer technicians while Jones (2004) suggested that lack of preventative maintenance is a reason for breakdowns and schools should provide adequate technical support and Becta (2008) commented on the statistical link between enthusiasm to use ICT with students and the availability of technical help. Smith et al., (2008a) noted that this support is decreasing with only 80% of secondary schools in 2008 having a technician compared to 94% in 2007 in spite of an increase in the number of computers and that by 2008 technical support as a priority had fallen from 61% in 2007 to 37% in 2008 in the schools surveyed.

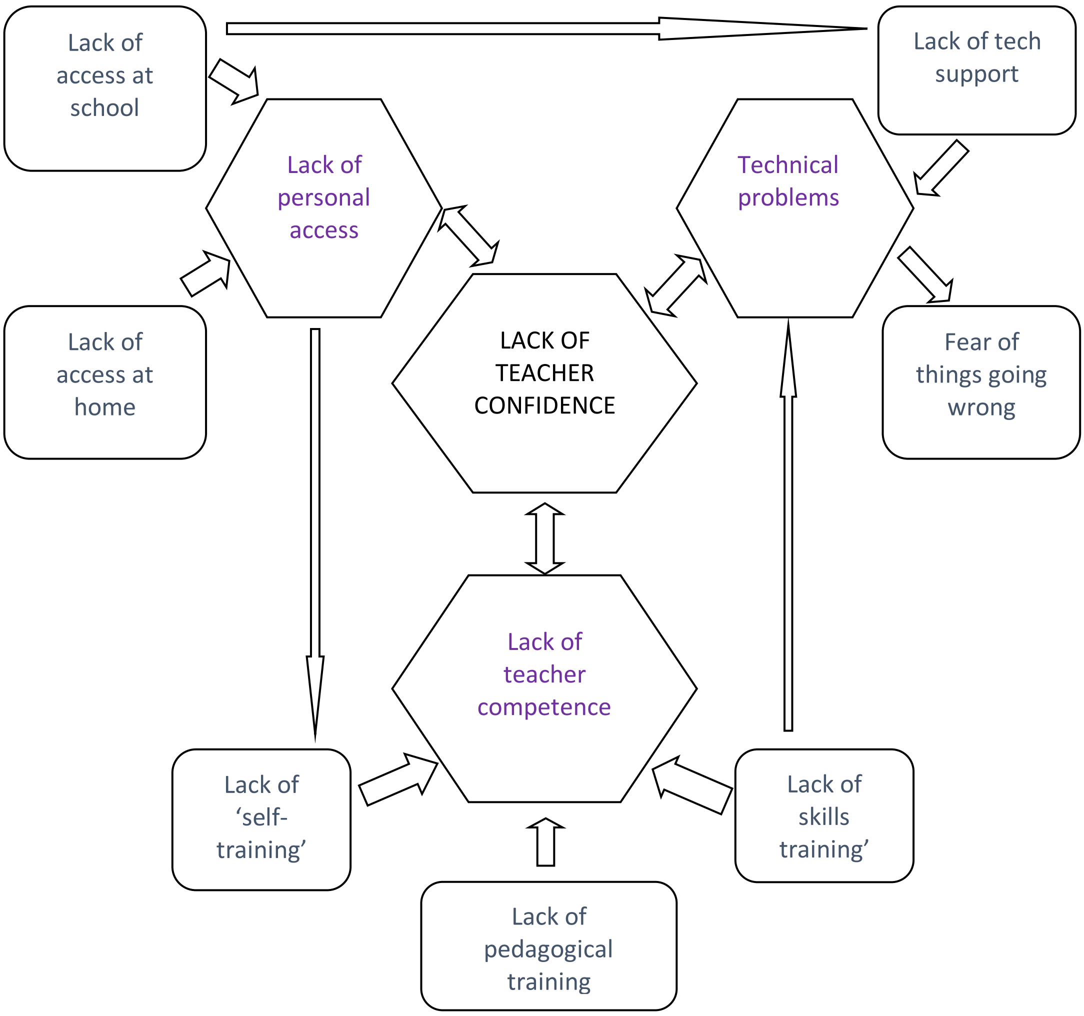
2.3.3.2 Lack of access to training

BESA has highlighted problems with training for many years (Rossi 2015). In 2014 they reported in their CPD Training in Schools research that the need for training had increased because of the wholesale changes to the curriculum and assessment plus the National Curriculum (2012) replacing of ICT by computer science, for which many teachers felt ill-equipped. Schools must recognise the diversity of skills amongst staff and that their training needs are not being adequately identified and met (PricewaterhouseCooper, 2004). Some staff do not have basic skills while others do not know all the capabilities of the ICT equipment or the potential of the software they have access to (see Figure 2.3). Morris (2012) commented that trainee teachers did not have to pass an ICT skills test but there was an apparent expectation that it would be part of teacher-trainees' school-based practice in the core subjects (literacy and numeracy). Morris pointed out a tendency to consider younger teachers more knowledgeable in the use of ICT; this has been shown not to be the case with regard to use in the classroom (Hobson et al., 2009). Conlon (2004) states there has been no large-scale training since NOF to update teachers with advances in technology; 'At least 80 hours of professional development are required before teachers can really begin to integrate technology into their teaching' (Conlon, 2004 p.134). Miller et al. (2008) discussed lack of training in how to use interactive whiteboards, and how to use the whiteboard to help ask open questions that demand thinking. They were concerned that more IWB-ready materials should be made available rather than teachers having to create their own. They suggested that teachers working together to create interesting resources as a method of developing skills and increasing awareness of the IWB's potential. Time to attend CPD and funding was recognised by Morris (2012) as being a barrier to personal development, with teachers needing time to consolidate skills and to explore resources. Approaches to CPD were often ad hoc with staff sharing experiences or using the cascade model. Meirink et al. (2009) reported that teacher activity fell into five groups, i.e. doing, experimentation, reflection, learning from others without interaction, learning from others in interaction. Outcomes for learning were based on combinations of acquisition, construction of knowledge and participation in terms of workplace activities. Their study found collaboration with others was a powerful learning environment especially when combined with experimentation rather than exchanging ideas and experiences. Honey and Mumford (1982) chose four learning styles to describe teachers' learning; these are discussed in 2.5.3. Meirink et al. (2009) noted that teachers who feel supported in their professional development were more inclined to look for professional development opportunities.

2.4 Teacher–related issues

Jones (2004) suggested that some barriers are more significant than others, such as teacher confidence and resistance to change, as these relate to the need for the teacher to 'change' in order to reduce the impact of the other barriers. Figure 2.4 illustrates how confidence is interlinked with other barriers and working to remove single barriers in isolation is not sufficient to overcome them.

Figure 2.4 The interconnectedness of barriers to using ICT (Jones, 2004, p.21)



2.4.1 Teachers are not convinced

Different reasons have been advanced as to whether teachers adopt ICT. The ImpaCT study (Watson, 1993) suggested that there are three main resource-related factors as to whether teachers use IT in lessons which are access to computers (chapter 5), the organisation of IT in the classroom, the teacher's skills and enthusiasm for using IT in the curriculum. Other studies, including those of Jackson et al. (1986); Hawkridge (1990); Drenoyianni and Selwood (1998); Forgaz (2002); Goldin (2016), have shown that beliefs are affected by a lack of understanding of the potential of ICT to support their work in the classroom, their personal technological skills, and their beliefs about how ICT can facilitate learning and how students learn. Drenoyianni and Selwood (1998) studied the use of computers in primary schools and found that teachers fall into two groups: firstly those who adopt 'a computer awareness' perspective perceiving that a main function of using computers was to improve computer literacy rather than subject knowledge and secondly those who believe that the computer should be used as a 'means to facilitate and enhance teaching and learning' believing that it helped the pupils in becoming better learners. This idea is also put forward by Jackson et al. (1986) and by Hawkridge (1990). In Victoria, Australia, Forgaz (2002) investigated how computers were used for teaching and learning of secondary mathematics finding a similar situation with key issues relating to the effective use of IT being teacher's beliefs about how students learn, the teachers' pedagogical approach and teachers' confidence with computers. The results of their study indicated that whilst most teachers thought that ICT had a positive effect on learning, a quarter were not sure. Drenoyianni and Selwood (1998) suggested that it is the teacher's lack of technology skills and knowledge of the psychology of learning that prevents them realising the potential of using ICT. In the teachers' view, more traditional tools have an established purpose and use over time and they question as whether using technology will improve on this. Cuban (2001) considered that no advances in efficiency of teaching and learning over the previous decade could be attributed to greater access to computers. Judgement about the efficacy of using ICT seems to have fallen under what was described by Orlando (2013) as 'wishful thinking of bureaucratic rhetoric and computer-company spin'. Rather than being seen as a tool to aid teachers in enabling understanding or in motivating learning marketing websites such as MyMaths (https://www.mymaths.co.uk/) and Mangahigh (https://www.mangahigh.com/en-gb/). suggest that using ICT would raise standards. This view was reflected in the OECD (2015) report, which did not find that levels of achievement are significantly raised by ICT, however the report was based on assessing the use of ICT as a deliverer of the curriculum and not as a learning tool.

2.4.2 Pedagogy and beliefs

Pedagogy, as defined by the Oxford English Dictionary, is the ‘science of teaching’ and is identified as teaching methods, student organisation, classroom management, content, ways of presenting subject knowledge, as well as teachers’ ideas and beliefs about subject matter. Teaching and learning values are included within this definition. Pedagogy is complex, influenced by the interaction of a range of ideas, for example, ideas and beliefs of teachers and policy makers with ‘conceptions of learning, knowledge and the purpose of education’ (Mortimore, 1999 cited in Loveless and Ellis, 2001). The concept of pedagogy is not universally agreed upon and authors have different foci in their description of pedagogy, for example, Shulman (1987) focuses on knowledge and beliefs and puts forward the notion of pedagogical content knowledge (PCK) that highlighted the importance of moving beyond teaching as ‘telling’ and learning as ‘listening’ so that learners can better understand the content. However, PCK like pedagogy itself, has been interpreted in different ways (Loughran, 2013). Alexander (1992) focuses on a definition that focuses on teaching methods and pupil organisation and suggests that in the UK there has been a greater focus on curriculum content though the national curriculum, instead of considering pedagogy and content together for improved teaching and learning. Loveless and Ellis, (2001) and Loughran (2013) illustrate the difference between the definition of pedagogy used in Australia, Canada, USA and the UK and that of continental European. Continental Europe approaches the definition from a broader definition with pedagogical institutes found within university departments (Watkins and Mortimer, 1999) and as a subject domain taught in universities. Their broader definition embraces health and bodily fitness, social and moral welfare, ethics and aesthetics. In contrast the USA and UK link pedagogy to the top-down control with teachers being prescribed ‘when, what, and how’ rather than developing their own pedagogy through curriculum documents which would be closer to the European notion of didactics. This represents a partial, mechanical, view of learning and according to Bruner (1996) is the view that children learn only from didactic exposure and should be presented with facts, principles and rules of action to be learned, remembered, applied and assessed.

2.4.2 How could ICT be expected to change pedagogy?

In the early days of computers in classrooms there was an expectation that teachers would change their pedagogy to a more constructivist approach as a consequence of using ICT (Shulman, 1987; Drenoyanni, 2006). Cornu (1995) suggested a more integrated pedagogy and that making IT inclusive would include a decrease in teacher direction and exposition. Students would be allowed more control over their learning whilst being supported by their learning by the teacher when and where needed. According to Duchâteau (1995), digital technologies provide opportunities for teachers to change their role and approaches to teaching. He suggested teaching would change with the use of ICT becoming more sharing and working in teams with a new relationship between teachers and learners, but teachers needed to accept that the introduction of computers into classrooms needed them to change at a personal level before the new relationship could be effective. Ruthven et al. (2004 p.2) commented that, 'Research on technology in education has given surprisingly little attention to teachers' pedagogical perspectives, given the central part that they play in classroom technology use.' This is particularly true of teachers who are not ICT specialists but are using ICT within their lessons. Within schools there has been focus on the technical aspects of using ICT rather than pedagogical practice (Alexander, 1992; Webb, 2002) so many teachers are not aware of alternative, effective, methods of facilitating lessons. According to Loveless and Ellis (2001 p.68) ICT impacts on:

> 'approaches to teaching, beliefs about subject matter, subject knowledge, pedagogical content knowledge, 'craft' skills in organisation and management, personal characteristics and perceptions of the current situation, teaching behaviours, context in which they are teaching.'

Changing from a non-technology environment to one that is technology-focussed requires a degree of change, even if it only entails moving to an interactive whiteboard from a blackboard or static whiteboard. Ridgeway and Passey (1995) list seven steps in the sequence for introducing change innovation, fire lighting, promotion, growth, coordination, integration and extension into everyday usage. Webb (2002) suggests that the sequence for delivering ICT within lessons can be broken down into steps. Firstly comprehension of the content to be taught, then transformation into a way that enables students to access and learn from ICT followed by instruction involving a variety of teaching and management skills and finally evaluation of the activities in order to make necessary or desired changes for the next cycle. Webb includes within these activities' preparation of ideas and materials to deliver the desired concepts and skills, ways to represent these, including any adaptations and tailoring, for the specified classes. For Ridgeway and Passey (1995) a key point concerned the instructional stage which includes teachers' comprehension, beliefs and values about the teaching itself and the receiving class. Knowing when to intervene is a skill that tends to be modified when using ICT, as whilst encouraging pupil autonomy, teachers still need to guide the pupils for them to benefit from the task (Loveless and Ellis, 2001). This guidance included knowing when to question, when to challenge, when to provide new skills. The shift in approach from teacher discourse passes greater control of the activity and learning to the pupil.

Rodd and Monaghan (2002) identified the time pressures teachers experience, especially with constant changing government-initiated initiatives, needing to be encouraged to adopt changes, such as using graphical calculators, and seeing the value of making these changes and the benefit to their learners and their teaching, while considering the time involved in finding or adapting resources. The time required to cover the set curriculum means that there is little left for trying different approaches, creating an element of risk in introducing a fresh style to the classroom rather than using 'tried and tested' models.

Ruthven et al. (2004) considered studies of the opposed paradigms of 'constructivist' and 'transmissionist' attempting to relate patterns of use of computers to these paradigms. They suggested that these studies 'may oversimplify the perspectives and practices of teachers' (p.4). Neiderhauser and Stoddart's (2001) study in the US found that teachers used skill based-transmission and open-ended constructivist software, choosing software according to the purpose, whether 'as a didactic teaching machine or as constructivist thinking and reflecting tools' (p.18). Neiderhauser and Stoddart intimated that there are three types of user relating to the types of software they chose to use (p.27):

> 'Teachers who only used open-ended software had a strong learner-centered orientation and a weak computer-directed orientation, while teachers who used only skill-based software had the strongest computer-directed and lowest learner-centered orientations as determined by factor scores. Teachers who used both types of software fell between the other two groups on both instructional orientation scales.'

Like Niederhauser and Stoddart (2001), Levin and Wadmany (2006) recognised that the teacher-centered (transmissionist view) and the student-centered (constructivist) classroom lie on a continuum, teachers adjusting their approach according to their experiences and the circumstances at the time of delivery. Where teachers predominantly use linear, authoritative, teacher-centred methods, they disregard computers, and resist efforts to move to a more student-centred classroom (Semple, 2000; Cuban et al., 2001) whilst teachers who readily integrate technology into their instruction are more likely to possess constructivist' teaching styles. Orlando (2013 p.232) also pointed out that practices are, 'not inherently constructivist or non-constructivist, what matters is how they are used and for what purposes'. She continues to say that the adoption of constructivist practices is used by research as an indicator as to whether teachers have adopted ICT. However, if teachers find they can use technology in accordance with their existing beliefs and practices they are more likely to adopt new technology (Veen, 1993). Levin and Wadmany (2006) suggest that educational beliefs are not static and that multiple conceptions co-exist as teachers move from teacher centred to pupil centred viewpoint and as such there is no necessity to abandon their original conceptual ideas, but to build on them.

The teachers view has been researched, for example, Rodd and Monaghan (2002) worked with 32 secondary schools in Leeds researching their use of graphics calculators. Rodd found that they were not used regularly, particularly with KS3 and lower groups in KS4. Her sample gave reasons for non-use as being time, cost, lack of training in how to use them, assessed curriculum, and the fact they are not necessary for examinations. Using them as a tool to check answers and drawing graphs with higher ability students were mentioned. In their research on how teachers perceived the use of computers in lessons, Ruthven and Hennessy (2003) interviewed teachers from several subjects including mathematics. They reported that teachers saw that it could provide for more effective working by enabling routine tasks, such as repetitive calculations and graph drawing, and being able to produce work to a higher standard more quickly. This last comment is particularly about students with special needs whose fine motor control and eyesight necessarily would inhibit their ability to produce neat and accurate work. In being able to check, correct and change work independently teachers also felt that all the students gained more ownership, consequently were able to develop trial and improvement methods and conjecturing skills more effectively. This helped raise self-esteem and motivation, especially in lower attaining classes where the computer liberated them from much hand-written work. The students were said to feel they were achieving more and this gave them the encouragement to work at a better pace.

Crisan (2004) also commented that there was evidence to support the view that teachers thought that the use of ICT enhanced enjoyment of mathematics by pupils and helped them develop understanding. Ruthven and Hennessy (2003) reported teachers valuing the use of calculators and spreadsheets for checking answers but also pointed out that they thought that 'hand methods' also needed to be developed. The teachers pointed out that using technology provided variety in lessons and a change to routine, although using it as a 'toy' was also mentioned suggesting that students were not always taking opportunities to work with computers in a serious fashion. Glover at al. (2007) commented that being able to work on the board while facing the class by using a computer was an asset and helped the students to pay attention. Using an IWB offers teachers the opportunity different presentation techniques or manipulations and the ability to revisit work and reflect saving time over starting again. Another advantage, especially where lesson planning was good was the ability to move quickly between 'animation, Internet linkage, video clips and annotation of board-based text' (Govier et al., 2007 p.16). Their study illustrated how students could become interactive by explaining their reasoning to other members of the class using the whiteboard. This they described as 'enhanced interactive' reflecting a development from 'supportive didactic' where the board was used as a display by the teacher, rather than using its interactive capabilities, with an interactive phase where teachers used interactive elements including software but not student input. However, the move from 'supported didactic' to 'enhanced interactive' needs to be accompanied by training to understand the nature of interactivity.

2.4.4 Confidence and competence

Rogers (2002) cited in Hennessy et al. (2005) found that teachers abandoning their existing pedagogy was a greater barrier to using ICT than access to technology. Hennessy et al. (2005) claim that contextual skills such as teacher confidence, experience, motivation and training along with personal attributes including cognitive and emotional styles can act as barriers to effective use of ICT. On the other-hand, Bingimlas (2009) considered that key barriers are lack of teacher competence and access to resources. Cox et al. (1999) suggested that the main priority for many teachers is maintaining order and controlling the learning environment. Research has shown that where teachers have pressure from above, such as an imposed curriculum, and are controlled by the expectation of high student performance it is likely that they will become more controlling of their students and less motivated in their own work (Pelletier et al., 2002; Fullan, 2008).

Hennessy et al. (2005) pointed out that developing staff confidence and competency in the use of ICT requires financial input. They also suggested that teacher's own teaching and learning experiences are able to enhance, or act as a constraint on ICT skills development. If teachers have been successful with traditional methods for many years, they would be less likely to change their methods for something for which they did not have evidence would lead to greater success, i.e. 'play-safe'/comfort zone option. They would view changing their teaching methods as 'risk-taking', especially as pupil influences and attitudes to receiving a different style of teaching would also have some effect. For these teachers experiences or stories of problems with using ICT would serve to reinforce this belief (Hennessy et al., 2005).

2.4.5 Perceptions and conceptions

Andrews (1999) mentioned that some teachers were using the rationale of 'inadequate time' for their lack of engagement with ICT. Using ICT requires consideration of a number of elements including:

- identifying resources that support the curriculum in terms of teaching and learning
- how to use the resources oneself
- how the resources can be used with pupils
- support materials for pupils if they are not familiar with the resources
- access.

Crisan (2004) found that there appeared to be two categories of conceptions about using ICT to teach mathematics, content and curricular. Within the first she included familiarity of features, how to access and use, as well as potential and limitations for different mathematical topics. Her second included perceptions regarding the national curriculum (and its recommendations), schemes of work, and the teacher's own position and experience regarding the use of ICT in teaching. Crisan also indicated that the teachers' conceptions about mathematics would affect how they used ICT resources, thus forming a personal constraint. Hennessy et al. (2005, p.159) commented that: 'The present subject curricular, assessment frameworks, and policies concerning ICT use seem to simultaneously encourage and constrain teachers in using technology in the classroom'. Cox et al. (1999) list some of the teacher's negative conceptions, including not enough time, restricting the content of lessons, making planning lessons more difficult and impairing pupils' learning.

Underestimation of the influence of pedagogy and belief was recorded by McCormick and Skrimshaw (2001, p.37) who commented that:

> ‘To cope with these developments in technology and effectively implement curriculum change, more attention must be given to the impact of ICT on the classroom. Traditional approaches to the use of computers in education have given insufficient attention to this impact, partly because of the lack of a clear enough model of pedagogy’.

Hennessy et al. (2005) found that teachers who experienced pressure to use ICT, had a desire to use ICT and to change pedagogy but that there were constraints to being able to achieve this. Using computer tools, according to Hennessy et al. (2005) helps to de-contextualise learning by offering new ways of thinking about mathematics, making the implicit explicit and accentuating that which is often un-noticed, for example using dynamic geometry gives opportunities to think about different ways of constructing 2D figures and 3D models, which would be very challenging to create on paper. Ruthven (2004) and Cogill (2008) also focussed on pedagogy, Cogill suggesting there are a number of factors that influence a teacher’s pedagogy which may also influence their approach to the use of ICT. These included:

- their belief in how learning takes place
- pedagogical knowledge
- content knowledge (including resources for supporting the curriculum)
- pedagogical content knowledge (delivery, effects on motivation and interactivity)
- the teaching context
- previous experiences
- their own learning dispositions.

2.5 Professional development issues

The difficulty for teachers in overcoming barriers and constraints without support was illustrated by Figure 2.4. Whilst they could acquire home and school computer access and self-train, they are still dependant on technical support and the ability to have skills and pedagogical training provided through the school, whether through external or internal means. Lack of adequate professional development is shown as a key barrier to raising teacher competence and developing confidence. The Laptops for Teachers Initiative of the early 2000's found that when teachers had their own personal computer this helped them to develop their skills (Becta, 2001; 2002; NFER, 2001; Institute of Employment Studies, 2002) so raising teacher's ICT confidence and competence.

2.5.1 Initial Teacher Training

The early core of enthusiastic teachers, who Hodgson (1995) described as 'multiplicative agents', were expected to pass on their knowledge to their colleagues. As not all teachers had experience of using IT in the early days Cornu (1995) suggested that integration of IT should form part of teacher training if teachers are to be able to break out from the models by which they were taught. He suggested that technology needed to be used in training so trainees experienced the opportunities and learning experiences technology could afford. 'Future teachers do not teach the way we tell them to; they reproduce the way they are taught' (Cornu, 1995 p.10). Recent reports (NCETM, 2009 and 2010, p.16) identified four issues in relation to professional development,

- access to, the nature and quality of professional development
- factors that influence the ICT skills of newly qualified teachers (NQTs)
- ICT professional development resources
- ICT resources.

Lee (1997 p.139) found that 'a great number of in-service teachers are not even equipped with basic computer operational skills' so their anxiety levels became raised when expected to use technology in the classroom. Wild (1996) further highlighted the under-use of IT by trainee and early career teachers and Townsend (1999) reported a significant number of secondary students with 'computer block' which suggests that some student teachers already had negative attitudes towards using ICT. Ofsted's (2012) Made to Measure report emphasises the currency of these issues, indicating a deficit in the use of digital technologies by mathematics teachers still exists with even competent users not realising the potential digital technology affords for teaching and learning. If there is to be an increase in the number of teachers using digital technologies for interactive teaching, as well as for explanation purposes in the future, then it is important that training is incorporated into the teacher training process. The Stevenson report (1997 p.7) stated:

> 'Both initial and in-service training need to take fully into account the need for confidence and competence in the application of ICT in schools. For example, the 20 to 30 hours typically spent on ICT during initial teacher training courses at the moment is less than half the amount of time that teachers actually need to become truly proficient.'

More recently NCETM (2010) highlighted issues in CPD provision in the interactive use of ICT and in supporting its use by learners. The centre introduced a microsite on their portal, included ICT in the self-evaluation tool, and provided four days of training to those responsible for training teachers (initial teacher training providers and local authority staff) in order to reach the largest numbers of people. A series of BESA reports (Rossi, 2015) also highlighted training for teachers as an issue, the lack of training has meant expensive equipment not always being used to its full potential. Although packages such as whiteboards originally included training, the introduction of approved supplier lists by Becta meant companies were required to sell goods to schools at lower prices, hence they reduced or removed the training element. The need for a teacher to want to take part in CPD, that is to be part of a self-actualised plan of career improvement (Kemmis, 1987), is particularly acute with ICT, because in order to ensure that expertise grows teachers will need to make a specific effort to use the ideas, even when they still feel unsure about some of the outcomes. In NCETM's RECME (2009) report there is an insistence that effective CPD should not be a one-off day out of school but a series of meetings building on the learning and in-class experimentation from one meeting to another.

The DfE changes in 2012 to initial teacher training meant that more training would be school rather than university-based (Universities UK, 2014). As the effective use of ICT to teach mathematics is still not widespread in schools (NCETM, 2010) it is possible that school trainers do not see the need to introduce ICT for mathematics as an element of their planned training, institutions considering their teaching methods are adequate. NCETM (2010 p.17) pointed out that ‘ITE institutions vary in what they offer to their trainees in ICT skills and pedagogy at both the generic and subject-specific levels’. Southampton University, as reported by Hyde et al. (2014), provided trainees with support in technology knowledge, technological content knowledge (how subject knowledge is changed by the application of technology) and technological pedagogical knowledge through having a digital technologies conference led by practicing teachers.

Since 2008, school-based mentoring by more senior members of the department has been playing a greater part in the development of people entering teaching (Hobson et al. 2009). Wu (1998) and Hammond et al. (2009a) showed that when NQTs join a school they are exposed to the values of the department and the institution, and this can be contrary to the beliefs they developed in training. There may be pressure to ‘fit in’ and ‘follow the line’ and may lead to the abandonment, at least in the beginning, of pedagogy and ideas about teaching that they formulated in order to avoid conflict with longer standing members of the department. Ellis (2010 p.109) suggests that it is,

> ‘… difficult for beginning teachers individually to criticise observed practice in their schools or, indeed, to challenge the views of their university tutor because of obvious concerns about ‘potential conflict with those who have power over their success on the course.’

Hobson et al. (2009) suggested that some mentors in schools wish to ’protect’ their pupils and so guide trainees into ‘low risk’ activities, while others will expect trainees to teach in the same style as themselves and follow the scheme of work. Where this is textbook-led they might be required to use teacher-led exposition followed by traditional practice exercises (transmissionist style) rather than using pupil-led (constructivist) enrichment tasks for deeper learning. These different styles are discussed in chapter 7. Webb and Cox, (2004), Scrimshaw (2004) and Condie et al. (2007) pointed out using ICT where there is little existing department use will present difficulties for an NQT (or a teacher following school-based training) (Hammond et al., 2009a). In their study of teachers in their first year Hammond et al. (2009a) report that some teachers commented that they had not seen good ICT being used in their schools as it was not there to see. These teachers did not have anyone to bounce ideas off nor the opportunity to observe good ICT use by other teachers. This lack of opportunity is not unique to new teachers; there will be impact on existing teachers and those who have moved into such a school. Chapter 8 shows that this situation has the potential to constrain further development.

The NCETM (2010, p.9) report showed that initial exposure in training courses has been a key issue in teacher use of ICT in their early careers for many years.

> ’General ICT skills are required by all Newly Qualified Teachers (NQTs). Recent evidence suggests that ‘key issues in developing very good use of ICT are access, support for and modelling of, ICT as well as the belief that ICT could make a positive difference to teaching and learning and a willingness to ‘learn by doing’. Use of ICT during the ITE period is a strong influence on use as a teacher. In particular past modelling of ICT use by mentors and tutors’.

Hammond et al. (2009a) stated that there were necessary conditions for developing very good use of ICT, including access to resources, and frequent use. Modelling of ICT use by tutors and mentors and encouragement from peers was also important. Hyde and Edwards (2011) developed knowledge in university sessions by integrating digital technologies into the course, on placement and using peer support as well as individual and group activities. They found that while their trainees had good personal ICT skills these ideas enabled the trainees to became more confident with using ICT both personally and in the classroom. Hammond et al. (2009a) noted that trainee teacher development in placement schools had been affected by levels of access, encouragement and technical support. They also suggested that the mentor’s own teaching style might be based towards the transmissionist end of the spectrum and portray very ‘old-school’ beliefs whereas using ICT does require a more social-constructivist pedagogy (Webb and Cox, 2004) and learner centred approach (Scrimshaw, 2004), additionally there might be problems of the age and condition of hardware, technical support, access to technology, under-development of ICT in the departmental planning (Condie et al., 2007) and having time to explore and learn to use the resources. Hammond et al. (2009a, p.104) suggested that pre-service training 'can be more influential than first thought' on the use of ICT by new teachers.

2.5.2 Teachers in-service

Hodkinson and Hodkinson (2005) reported that their data led them to make the following observations regarding courses:

- short courses or training events result in effective learning if and when matters raised are taken back and further developed
- short courses can be ineffective, if teachers attending do not personally value the experience
- courses outside school premises are valuable in enabling control and collaboration with teachers and others in related but different situations
- long courses, such as PGCE or masters' degree can have a deep and lasting influence on the ways in which teachers understand, see and approach their work.

They also identified approaches to CPD within schools as being either restrictive or expansive. Restrictive approaches are focussed on the needs of the school or on the teacher taking responsibility for their own CPD while expansive approaches are collaborative and teacher focussed. Table 2.1 illustrates the approach to CPD within schools adapted from Hodkinson and Hodkinson (2005).

Table 2.1 Restrictive and expansive approaches to CPD within schools

Restrictive	Expansive
Working by oneself	Working collaboratively within department and school
Prescribed and imposed ways of teaching and learning	Variations in teaching and learning methods supported
Teachers told which CPD sessions they have to attend (often not in school time)	All teachers may choose courses for their personal development
Unable to make use of what has been learnt soon after course	Able to incorporate learning from course into practice soon after event
No opportunity to feed-back or share experience with colleagues	Feed-back and sharing knowledge is built into ethos of department/school
Lack of support from department, and other colleagues, including management	Support from others relating to enhancing learning
Focus on crises e.g. behaviour, exam results	Focus on teachers learning
Training restricted to government initiatives and individual school agendas	Personal development allowed to include study not in school development
Few opportunities to partake in out of school meetings, training or courses, availability restricted to in-house	Opportunities to work with others in working groups both within and out of the establishment
Professional development linked to position in the school, e.g. post holders, who attend courses but don't share with colleagues	Open access for all, opportunities to develop via feed-back presentations

Only able to access long course due to position in school e.g. NPQH qualification for headship	Able to undertake long qualification courses with funding and time support offered

Teachers beyond their initial training do not necessarily feel they can exercise sufficient autonomy to take control of their personal development as teachers (Hammond et al., 2009a) while personal relationships and status within institutions can affect teacher’s confidence, self-esteem and professional growth (Pelletier et al., 2002). Hodkinson and Hodkinson (2004) described two participants in a study, who were both reported to be very good teachers but had different attitudes to professional development. One teacher felt undervalued, having suffered three career setbacks. His work and learning were individualised (learning on the job) and he was critical of imposed initiatives and courses, having to be convinced of their merits, especially when expected to undertake computer training. He developed knowledge though reading and was prepared to change his practice. He showed no enthusiasm to engage with new learning apart from that directly helpful to his teaching. Where he had chosen the course his approach became more positive. Hodkinson and Hodkinson (2004) suggested that his learning was isolated, unplanned and unacknowledged. In contrast they cited a head of department who felt valued and was more dynamic and ambitious and worked in a more co-operative way, developing his skills from other teachers, courses and books and setting himself learning goals. He believed in professional development for himself and other teachers, and would work to attain his goals. On imposed initiatives, he believed he should make the best of them to see how they worked out. As head of department he had power to make decisions.

There are clear lessons here, teachers must want to engage in the CPD on offer or at least understand the professional benefits in engaging. Studies, such as that of Underwood (1997), show that once teachers have completed their initial teacher training many do not take further courses. Of the courses that are available there are barriers and constraints regarding access, timing and quality. Within schools there has been focus on the content and technical aspects of using ICT rather than pedagogical practice (Webb, 2002) so many teachers are not aware of alternative, effective, methods of using ICT in lessons. This is particularly true of teachers who are not ICT specialists. Webb (2002) also suggested that whilst there is agreement about what there is to be taught, specifications give little guidance regarding the pedagogical skills needed to deliver the content, whether in ICT as a subject or ICT within other subjects (DfEE, 1999a). According to Loveless and Ellis (2001, p.68) and also highlighted by Cox and Marshall (2007) ICT impacts on:

> ’approaches to teaching, beliefs about subject matter, subject knowledge, pedagogical content knowledge, ‘craft’ skills in organisation and management, personal characteristics and perceptions of the current situation, teaching behaviours, context in which they are teaching.’

Bingimlas (2009, p.242) stated that: ‘Educational technological materials may be available in schools but teachers cannot use them because of a lack of pedagogical or skills-related (practical) training in how to use these ICT resources’. Although the under-use and lack of training are linked with problems of access, according to Jones (2004) the problem in the mathematics curriculum is that ICT is seen as an ‘add-on’ and presentational rather than an interactive resource.

The NCETM’s RECME (2009) report highlighted four main themes for effective CPD in mathematics education. These were different types of CPD (courses, within-school initiatives and networks) factors that contribute to effective CPD, evidence of effective CPD and the role of research in CPD, making five categories of recommendations:

- policy makers (recognise the need for CPD opportunities from CPD leaders to class-based teachers, and should include the impact of research)
- developers and providers of CPD (should consider the experience and expertise of the teachers and include time and opportunities for them to develop their own knowledge about mathematics and ways of teaching it)

- NCETM (support teachers who wished to engage in teacher research as well as further development of networks and their portal to encourage more engagement by teachers)
- schools and colleges (should set aside time within contractual hours and provide encouragement to engage with the different types of CPD which should be valued and give teachers encouragement to share their new knowledge and understanding with others)
- the research community (should undertake research into the engagement of teachers with CPD, including increase of uptake and accreditation, and the development of on-line networks)

In its conclusions the RECME report (NCETM, 2009) suggested that for effective CPD, teachers needed to be given time to engage and reflect on their practice, that CPD leaders should be well informed and knowledgeable and use relevant activities and ideas. In the report teachers reported that, on a course designed to help teachers develop skills in using Autograph, the presenter's enthusiasm made a difference. After the course they had access to the presenter via email and website support.

CPD is more effective if schools support teachers who want to try out new ideas. The NCETM's Mathematics and Digital Technology report also recommended that this could usefully take the form of the trained teachers becoming providers of professional development for fellow teachers (NCETM, 2010, p.3). At TSM conferences a session titled 'Training the Trainers' was included for those who wished to train others. The NCETM (2010) report recommends that a range of models of professional development should be supported and that all teachers should be given opportunities to experience a range of pedagogic opportunities.

2.5.3 Teachers as learners

Kemmis (1987) offered a reason for much of teachers' professional development with computers not being long-lasting or effective, this being organizers using a 'top-down' approach that assumed that experts knew what teachers wanted, as opposed to teachers being involved in the planning of their training. Holmes, et al.

(2007) suggested a more enlightened approach with teachers involved in planning the course, taking account of their needs and preferred learning styles, (Table 2.2) aspirations and school culture.

Table 2.2 Honey and Mumford's (1982) learning styles

Activists	'hands-on' learners, open minded learners, prefer to have a go and learn through trial and error. They are keen to try new things but do not have the patience for longer involvement. Activities include brainstorming, problem solving, group discussion, puzzles.
Pragmatists	'show me' learners and want to be able to put the learning into practice, but will also experiment to see if ideas work. They are keen to try out new things and put them into practice. Activities include thinking about application, problem solving.
Theorists	'convince me' learners and want reassurance that a project makes sense, need models, concepts and facts, and prefer to analyse and synthesise. Activities include background information, models, stories.
Reflectors	'tell me' learners who watch and think, often from the sidelines, and weigh up information from different perspectives before drawing a conclusion. Activities include observing, discussion.

Consulting with teachers prepares them for the training, gives some ownership and reduces the stress of the unknown (such as too hard, fear of being left behind, lack of relevance). Felder and Silverman (1988) suggested that an effective session should have four elements, presentation, learner participation, content and perspective with Knowles et al. (2015) adding learning motivation. Rogers (1983) built on Honey and Mumford's (1982) ideas, suggesting that adoption is related to risk taking and the need to see benefits before adopting new ideas. Robinson,

(2009) and Higgins et al. (2012) also identified these five categories of people (Table 2.3).

Table 2.3 Adoption of ICT in the workplace

<table>
<tr><td>Innovators</td><td>the first 2.5% to adopt a new idea and embrace technological developments seeing the risks as low because of their self-confidence and understanding of the innovations.</td></tr>
<tr><td>Early adopters</td><td>next 13.5% also categorised as early adopters who (according to Robinson, 2009), look for advantages and see the risks as low.</td></tr>
<tr><td colspan="2">These first two categories approach the use of ICT from a pedagogical perspective, looking at particular teaching and learning issues (Higgins et al., 2012).</td></tr>
<tr><td>Early majority</td><td>(34%) see a higher risk factor and so need to know of the genuine benefits before they adopt.</td></tr>
<tr><td>Late majority</td><td>(34%) see greater risk than the early majority</td></tr>
<tr><td colspan="2">According to Higgins et al. (2012) these two majority categories may have more focus on the technology rather than the pedagogy so are less efficient, using it as a replacement activity rather than in a supportive role.</td></tr>
<tr><td>Laggards</td><td>(16%) who see the innovations as high risk and something to be avoided (Robinson, 2009)</td></tr>
</table>

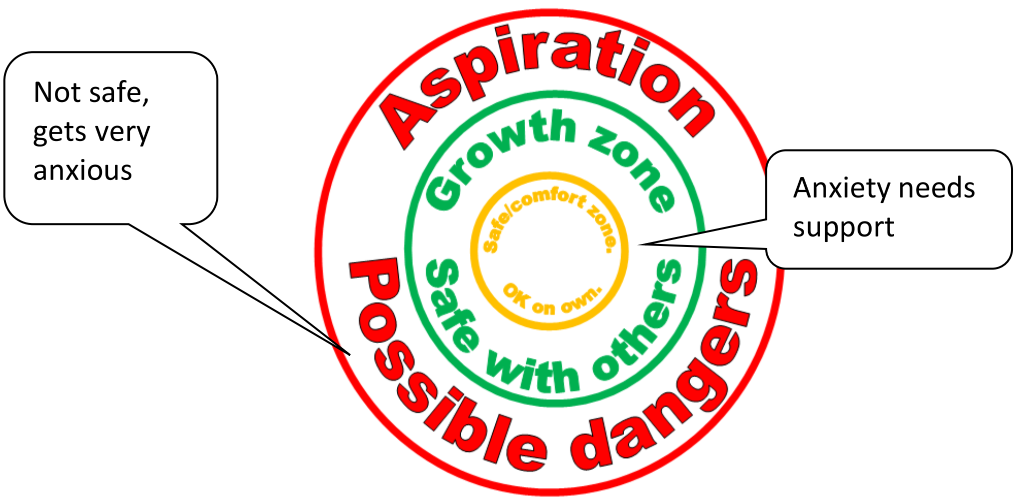
Higgins et al.'s (2012) report into the impact of digital technologies on learning made five recommendations identifying purpose for using digital technologies, the need for on-going professional development and support to evaluate learning (p.4-5):

- the rationale for the impact on teaching and learning needs to be clear

- the role of technology in learning should be identified
- technology should support collaboration and effective interaction for learning
- teachers and/or learners should be supported in developing their use of digital technology to ensure it improves learning
- identification of what learners and teachers should stop doing.

Vygotsky’s zone of proximal development (ZPD), (described as the gap between a learner’s present capabilities and a higher level of development that could be achieved with appropriate assistance), can be applied to adults (Hodkinson and Hodkinson, 2005; Tinsley and Leback, 2009), with the growth zone made comfortable with the support of others, such as a community of practice, and the aspirational zone representing feelings of being unsafe and very anxious, so needing much support (Figure 2.5). Risk is seen as increasing as one journeys outwards from the centre (Parish, 2013).

Figure 2.5 Zone of proximal development (after Vygotsky, Parish, 2013)



Gu and Day (2007, p.1302) suggested that, ‘A shift in focus from teacher stress and burnout to resilience provides a promising perspective to understand the ways that teachers manage and sustain their motivation and commitment in times of change’. Resilience (Lee and Johnston-Wilder, 2013; Lugalia et al. 2013) has to be built through having agency, belonging to a community of practice (Gu and Day 2013) or social group and feeling included in the learning process knowing that perseverance will yield success and to realising the effort is worthwhile in difficult times. Many digital technology training courses, especially short ones, leave delegates with a taste of the resources without the confidence, knowledge or skills needed to develop them for use with pupils. Holmes et al. (2007) pointed out that to help develop resilience, follow-up training is needed, including through media e.g. email and forums. Lack of CPD for building resilience was illustrated by Hodkinson and Hodkinson (2005) where courses are included in performance management they will be tied to department, school or national policies, rather than teachers' personal interests. School initiated courses deal with what is perceived by 'those with power' in a 'top-down' management system, (Fullan, 2008) as 'teacher deficit'. Table 2.1 summarised two approaches illustrating how restrictive school focused needs are in supporting an individual's developmental needs.

Hoekstra et al. (2009) outlined four categories, experimenting, reflecting on own practice, ideas from others and 'doing' which may or may not be done in collaboratively. Hodkinson et al. (2003) suggested informal and formal learning became inter-related when teachers discussed experiences amongst themselves with many informal attributes, although externally led courses played a small but significant part. Boud and Middleton (2003) highlighted different types of communities, including geographically bounded, closed with face-to-face contact (including workplace) and virtual, enabling participants to be widespread showing that participation within communities is a key to informal learning. Harland and Kinder (1997, p.73) pointed out that 'good practice' messages given on a course may not lead to change in classroom practice without a 'positive meaning or value of the changes advocated'. Their study illustrated the problem of the cascade model of CPD, as colleagues do not necessarily share the values of the course leaders, questioning of the effectiveness of different forms of CPD on practice.

Knowles (1975 p.18) described the self-directed learning route (SDL) as an alternative to formal courses and in-school training. This has the advantage that the teacher is able to take ownership of their training, its format, their goals, resources and outcomes. He said that it requires self-motivation and the ability to plan a learning trajectory, self-regulate and be able to work independently and on p.14:

> '…people who take the initiative in learning (pro-active learners) learn more things, and learn better, … than reactive learners. They enter into learning more purposely and with greater motivation.'

Hoekstra et al. (2009) stated that these activities could take place at an individual level or in company of others, and be planned or unplanned. Their research suggested that these activities are interlinked, for instance experimenting using something they had heard from others or read about, which was a positive experience the teachers would incorporate these activities into their practice. Saks and Leijen, (2014) stated that the term self-regulated learning (SRL) is often used interchangeably with SDL but differs in that it is a more recent term originating from educational psychology and cognitive psychology rather than SDL which has its origins in adult education. While SDL may be directed by another person e.g. teacher, SRL applies to the individual taking ownership and would take place outside of the school environment. With the expansion of internet resources and e-learning and communication via social media learners have unlimited access to resources to embark on SRL. Not all teachers practice SDL or SRL when learning to use ICT; so what determines whether teachers do? In their book Zimmerman and Schunk (2008) discussed SRL, they pointed out that someone who has a good self-perception with regard to learning, self-efficacy, and causality is more likely to participate in self-learning. Where a learner self-monitors and responds to 'feedback' on their self-learning in a positive manner, this serves to increase their motivation. Zimmerman and Schunk (2008) also suggested that seeking help or support can increase motivation rather than detract from it and, when confronted with challenges alongside focussing on mastery and enhanced understanding, results in greater interest, intrinsic motivation and persistence.

2.6 Conclusion

The literature in this chapter shows that the use of ICT has many advantages in terms of aiding the learning and conceptual understanding on many mathematical ideas. ICT provides an environment where teachers can explain ideas accurately and dynamically but perhaps more importantly it provides an environment where students can work collaboratively or independently, receive feedback immediately and build their understanding through playful but purposeful interactions. Despite this most mathematics teachers have been shown to use ICT only rarely if at all, other than using a white board as a presentation device. The literature has also shown that from the early days of computers being introduced, opportunities were missed for educational use and the needs of teachers were not the prime consideration. Lack of funding then and now has meant not all teachers have the skills and confidence needed to use digital technology as a teaching and learning tool, nor the technical support they need.

Successive government interventions and initiatives have led to a top-down accountable culture that has reduced teachers' autonomy in curriculum design and content and also the status given to digital technology use in teaching and learning. The lack of awareness of officials, schools and teachers of the potential for enhancing learning has led to a limited use of software resources and interactive teaching.

Hence from my exploration of the literature I have devised the following research questions:

> **Research question 1 -** How did teachers experience the introduction of ICT into teaching mathematics and what support did they receive in using it?
> **Research question 2** - What are the barriers and constraints teachers experience when using or contemplating the use of ICT?
> **Research question 3** - How do mathematics teachers' use ICT in their teaching?
> **Research question 4** - What training have teachers had in the use of digital technology?

Chapter 3 Theoretical Framework of the Reasons Behind Poor Uptake of ICT

The concepts that make up the theoretical framework behind this thesis are that ICT has advantages when teaching mathematics and what those advantages are, but also that most teachers choose not to use ICT and have reasons that make sense to them for making that choice. Since most teachers that I have experience of want to teach their students well there must be compelling reasons why teachers do not use ICT as extensively as it seems may be beneficial to their students learning. Hence key within my framework are:

- the use of ICT is inherently beneficial to the learning of mathematics. The ideas and concepts pertaining to these ideas are met in chapter 7;
- that there are extrinsic and intrinsic motivations that will affect the use of ICT.

In this section I will focus on the second part of my theoretical framework, the reasons teachers choose not to make use of ICT when teaching mathematics. These motivations are explicated in Figure 3.1 and also within the barriers and constraints as identified by NCETM (Figure 3.2), both explained and discussed in more detail below. The Technology Acceptance Model (TAM) provides a further framework that begins to explain the "barriers and constraints that are likely to be experienced by teachers in real schools and in real classrooms".

When trying to integrate ICT a range of problems may be encountered, which I variously describe as barriers and constraints. Within this study the two words, barrier and constraint, are used to mean factors that limit the use of ICT, but their meanings are not truly identical. While 'barrier' is defined in The New Oxford Dictionary of English (Pearsall, 1998) as "a fence or other obstacle that prevents movement … a circumstance or obstacle that keeps people or things apart or prevents communication or progress" (p.141), 'constraint' is defined as, "a limitation or restriction" (p.394), both terms are used by the literature cited in this chapter when discussing limiting factors. This section looks at two aspects, institutional and personal barriers and constraints teachers face, whether current users of ICT or not, and the impact of those limiting factors on using ICT in teaching and learning.

In his literature review concerning barriers to the successful integration of ICT in teaching and learning environments Bingimlas (2009) found several authors attempted to classify the types of barrier met by schools and teachers using the terms ‘extrinsic’ and ‘intrinsic’. He suggested that authors tend to use extrinsic to indicate issues that could be considered to be institutional barriers such as technology and time, and intrinsic to indicate more personal issues such as attitudes and beliefs. However, Bingimlas also found that there are instances of the terms ‘extrinsic’ and ‘intrinsic’ barriers being used with different meanings. An example is access and time, which are considered as extrinsic but with attitudes and beliefs about access and time seen as intrinsic. Barriers to using ICT in teaching mathematics are not unique to England, Bingimlas (2009) reported that barriers and constraints are found to differing degrees in many education systems.

Andrews (1999) also chose to place barriers and constraints into two categories, referring to them as institutional and personal, that were similar to Bingimlas’ (2009) extrinsic and intrinsic. Jones (2004) suggested that the terms ‘first-order’ (external) and ‘second-order’ (internal) might also be applied and, alternatively, school level (institutional) and teacher level (personal) barriers. Jones added a lack of time and lack of personal access to technology to the teacher level barriers, otherwise the two definitions (extrinsic and intrinsic, first-order and second-order) are compatible. Jones suggested that many barriers are inter-linked (Figure 2.4) and can only be overcome when attention is paid to both school and personal level improvement as increasing provision is unlikely to be successful if teacher level barriers are ignored. I find it useful to look at barriers and constraints using the concept of categories based on institutional barriers and personal barriers to the use of ICT whilst recognising the inter-related nature of the categories. I now look in more detail at these categories.

Figure 3.1 is compiled from a review of the literature (Andrews, 1999; Jones, 2004; Hennessy et al., 2005; Bingimlas, 2009) demonstrating potential areas in which constraints and barriers occur. Many of these are included in chapters 6 and 7.

Figure 3.1 Potential institutional and personal barriers

Institutional barriers

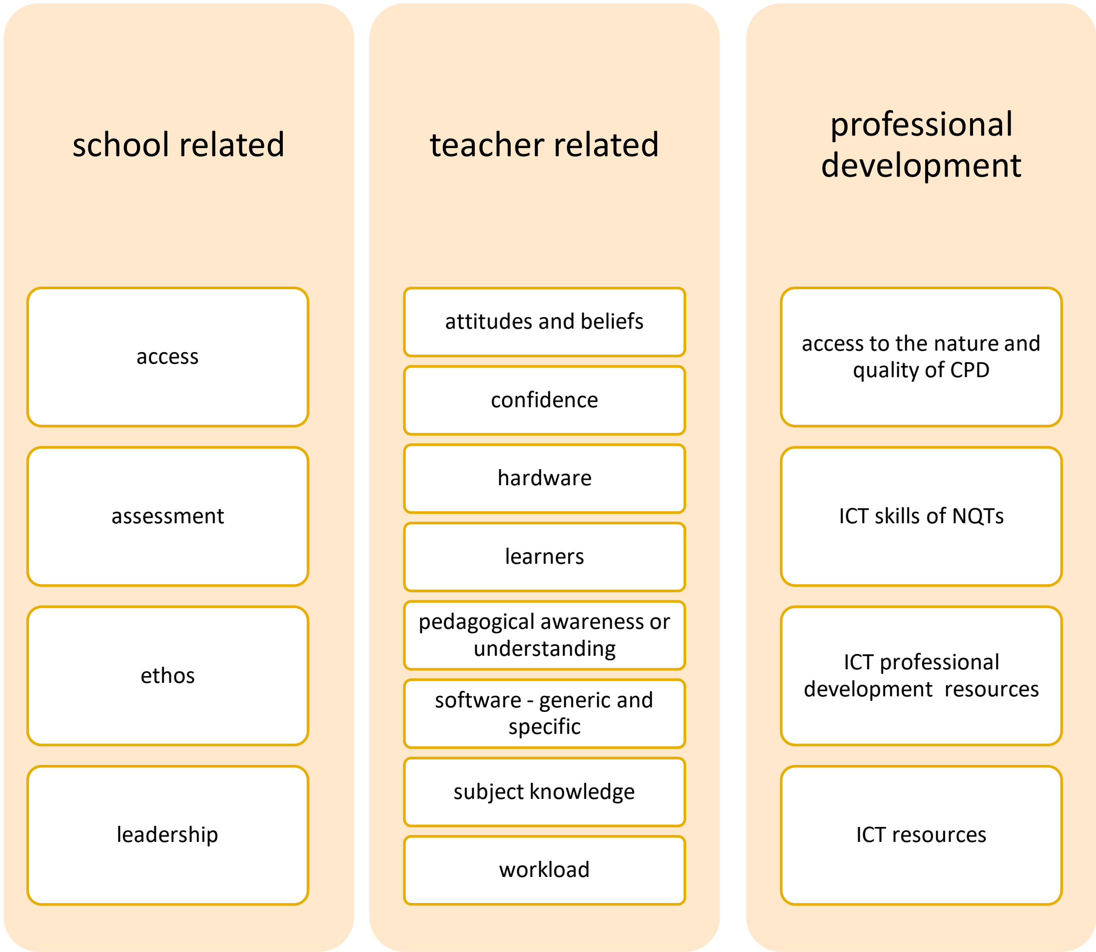
- school management
- finance
- organisation of resources
- access to resources
- quality of resources
- technical problems
- effective training
- time to develop new ways of learning and teaching
- time to develop resources

Personal barriers

- teacher confidence and anxiety
- teacher competence
- pedagogical belief
- resistance to change and attitudes
- perception of advantages
- gender differences

Unlike Jones (2004) where professional development was included within the external and/or school level barrier more recent work by NCETM (2010) identified three broad barriers, school-related, teacher-related, professional development issues (Figure 3.2) It is on these three that I base chapters 6 to 8.

Figure 3.2 Barriers and constraints as identified by NCETM



3.1 Technology Acceptance Model (TAM)

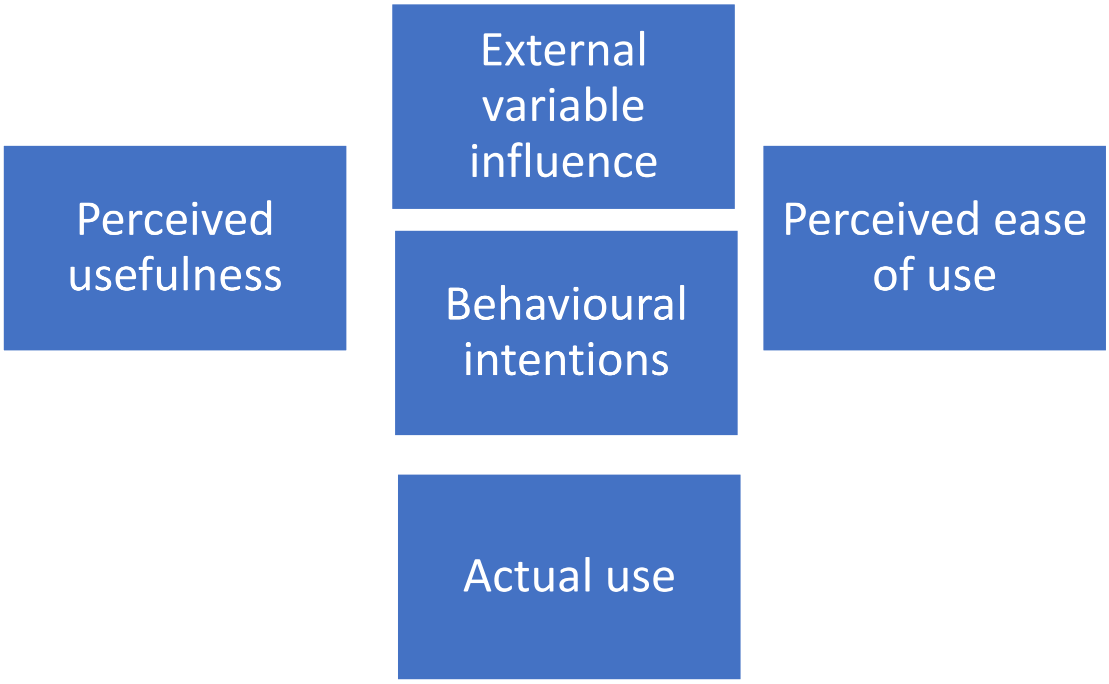
The Technology Acceptance Model (TAM) as suggested by Davis (1989) explains the influence of external variables on the use of technology, predicting user acceptance of technology as determined by three factors: (a) perceived usefulness, (b) perceived ease of use, and (c) behavioural intentions. It investigated perceived usefulness, perceived ease of use and behavioural intentions with a high degree of convergent and discriminant validity was found for perceived usefulness and perceived ease of use (Davis, 1989). TAM can be used in different situations as the stem wording can be revised, Smarkola (2007) used it in research with student and experienced teachers, others have used it in a business context (Venkatesh and Davis, 2000).

TAM built on the theory of reasoned action (TRA) proposed by Fishbein and Ajzen (1975) to explain and predict the behaviours of people in a specific situation by investigating subjective norm influence, describing the influence of others in the decision of whether technology is useful or not. By complying with social influences, a person's social standing within the group will be seen to rise. However their theory was based on the assumption that people were rational and used behavioural intentions rather than attitudes as behaviour predictors. This was modified to include attitudes, subjective norms and perceptions and known as theory of planned behaviour (TPB) (Marangunić and Granić, 2015).

According to Davis perceived usefulness is "the degree to which a person believes that using a particular system would enhance his or her job performance", that is a positive use-performance relationship. Ease of use refers to "the degree to which a person believes that using a particular system would be free of effort" and by inference more acceptable to the user. Behavioural intentions refers to whether a person chooses to use the technology or not. Davis (1989) found a significant correlation between perceived usefulness and usage and suggested that although difficulty can discourage use, something easy to use will not compensate for usefulness in encouraging take-up of technology. TAM has been extended, as Davis et al. (1989) found that both perceived usefulness and perceived ease of use directly mediated behavioural intentions (with perceived ease of use also having a direct effect on perceived usefulness) with behavioural intentions found to be a strong predictor of actual use (Davis et al., 1989).

As an extension of TAM, (Taylor & Todd, 1995) proposed the decomposed theory of planned behaviour model (DTPB), extending knowledge of the external variable influences and suggesting that a link with behavioural intentions would predict actual use. The decomposed theory of planned behaviour is more complex than TAM and considers attitudes, subjective norms (peer and superior's influences) and self-efficacy and facilitating conditions (resources and support) as behavioural control factors, producing a more detailed model with external variable influence mediating perceived usefulness and thereby perceived ease of use (Figure 3.3). TAM2 was proposed by Venkatesh and Davis (2000) and is an extended model to include not only external variables that influence perceived usefulness, but also voluntary and involuntary environments.

Figure 3.3 DTPB model



Venkatesh and Davis (2000) looked at how the external variables influenced perceived usefulness and added subjective norm, image, job relevance, output quality, result demonstrability and experience in both mandatory and voluntary systems. Within mandatory systems subjective norm was found to exert more influence than either perceived usefulness or ease of use whereas in voluntary systems voluntariness and experience were directly linked to intention to use (Davis et al. 1989, Mathieson 1991).

Much of the work on TAM and TAM2 has been carried out in a volitional environment (Venkatesh and Davis, 2000) while Brown et al. (2002) sought to analyse a mandatory use environment. They suggested that there might be other determinants such as need to keep a job and organisation loyalty that are not considered when participation is voluntary, over-riding positive or negative attitudes to using technology.

Smarkola, (2007) investigated student teachers' and experienced teachers' computer usage and intentional computer usage using self-reporting. She examined the TAM model with 160 student and 158 experienced teachers in the USA completing a computer usage intention survey. Smarkola, (2008) further developed this by using interviews based on the decomposed theory of planned behaviour (DTPB) framework. Smarkola found that the DTPB framework was the most important for predicting teachers' intentions and identified similarities and differences between student teachers and experienced teachers when looking at external forces. Student teachers focussed on the internet and not on subject software while experienced teachers were influenced by resources and support from administrators. For both groups computer training and support were an issue and critical for integration into classroom teaching. Smarkola (2007) found that there was a mismatch reported by student teachers in her study in that 'their self-confidence was at odds with their limited knowledge of using computers outside of the internet' while experienced teachers used a wider variety of tools to complement their teaching, identifying a need for opportunities for experienced teachers to mentor student teachers. Experienced teachers reported that personal perseverance was needed when using computers.

Drawing on the extensive review of the literature of TAM from 1986 60 2013 by Marangunić and Granić, (2015) my own literature exploration considered the factors within TAM, TAM2 and DTPB as:

a) Perceived usefulness, from my exploration of the literature, this factor is likely to encompass the ease of use of the actual equipment in school, the actual software available and how and whether teachers come to know about what is available and what it can do.

b) Perceived ease of use, according to the literature this encompasses the ease of using the technology in school and includes external factors. Perceived ease of use was shown to have a direct effect on perceived usefulness.

c) Behavioural intentions are suggested in the literature and were found to be a strong predictor of actual use (Davis et al., 1989; Taylor & Todd, 1995). They are determined especially by perceived usefulness but also moderated by external factors.

d) External factors, included in TAM2 and DTPB, give insight into belief systems that lead to actual use in a school environment and include the ethos of the workplace and colleagues, the training received and its accessibility and resource provision in terms of technical support, hardware and software (Figure 3.4).

Figure 3.4 External factors

These external factors are discussed in chapters 6 to 8.

Chapter 4 Methodology and Methods

"Social science is a terminological jungle where many labels compete, and no single label has been able to command the particular domain before us. Often ... researchers simply 'do it' without worrying about giving it a name."

Lofland and Lofland (1984) (cited in Verma and Mallick (1999)

4.1 The Research Questions

The framing of the research question was an evolutionary process as the possibilities for data collection were explored and the analysis of the data began. The initial question which sparked the research was 'How, when and why do English secondary school mathematics teachers use ICT when teaching mathematics?'. However this was found to be restricting for the data collection, as many teachers were not using ICT other than a data projector and computer, not necessarily connected to an interactive whiteboard. Thus the main question was changed to 'How might more English secondary school mathematics teachers be encouraged to use digital technologies in their teaching?' As the data and literature were analysed sub-questions were identified:

- How was ICT introduced into school mathematics, including the training and support given?
- What barriers and constraints did teachers face when contemplating the use of ICT?
- How was ICT actually used in teaching and learning mathematics in the classroom?
- How could the training of mathematics teachers be more effective in increasing the use of ICT for teaching?

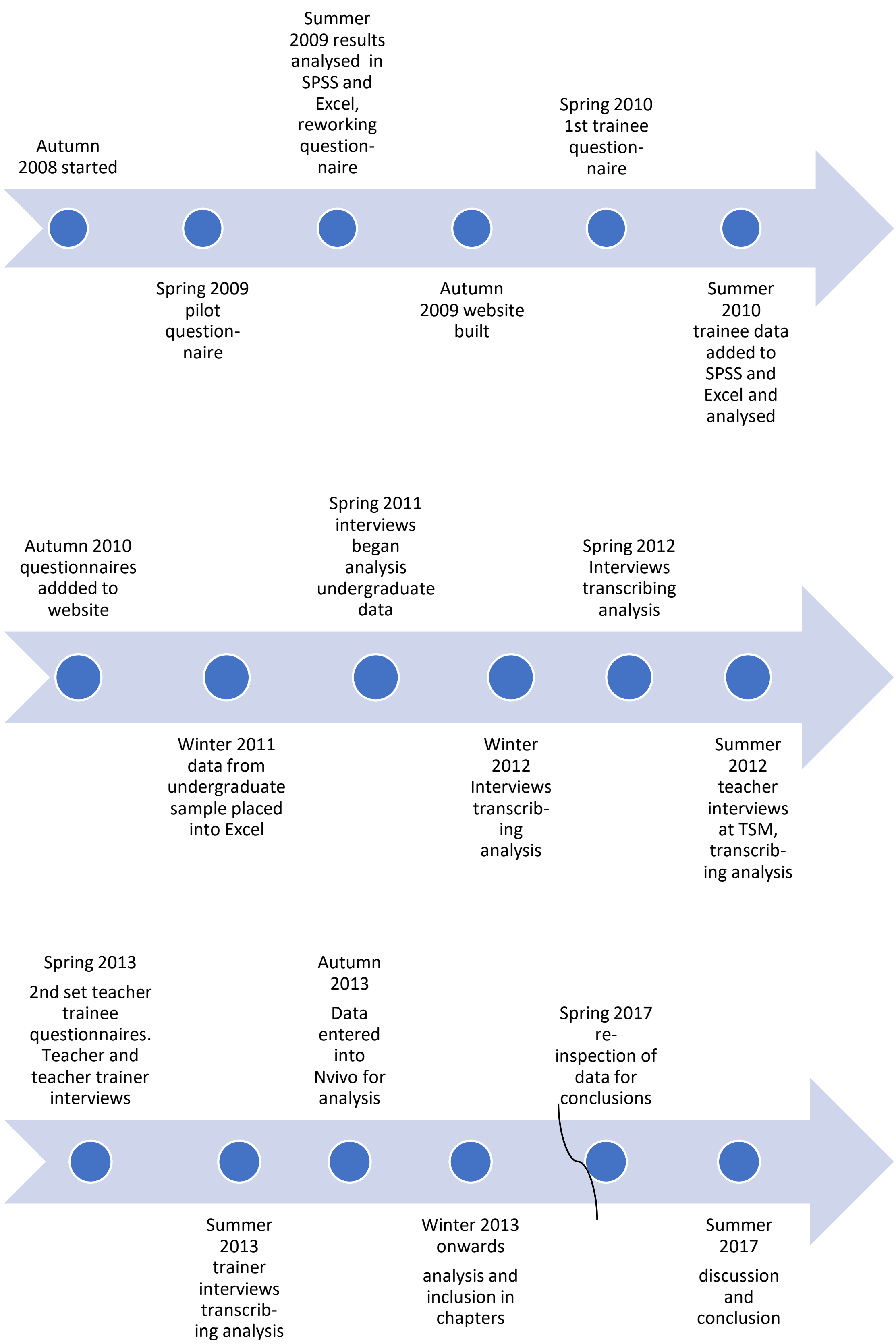
The initial proposal for this study was to establish the constraints teachers experienced and why some mathematics teachers use ICT while others either do not, or use very little. From the pilot and subsequent questionnaires, it became apparent that some teachers were overcoming difficulties and believed that using ICT was beneficial to teaching and learning. Thus, if using ICT was desirable, could other teachers be supported to use ICT? A final research question was added as the findings were explored and discussed, 'How could English secondary school mathematics teachers be better supported to integrate digital technologies into their teaching?

Reading around the subject and/or conducting a pilot survey helped to make the hypothesis and research question more focussed and specific. These pre-understandings formulated the framework for the investigation.

4.1.1 Research Stages

Figure 4.1 illustrates how the research progressed. Gaps on the timeline indicate time spent on other research activity such as literature review and writing chapters. The data collection periods were stage 1 spring 2009, stage 2 between spring 2010 and winter 2011 with an extra collection of trainee data to give a similar sample size to those of teachers and undergraduates in spring 2013. Stage 3 interview data was collected between spring 2010 and summer 2013 and analysed during the period winter 2013 to summer 2014 (Figure 4.2) Further work on analysis took place in autumn 2016 when the chapters were rewritten. The analysis method used at this point was thematic analysis although the initial research method was based in grounded theory in that pilot data was collected and analysed before a review of the literature. In hindsight, and with a knowledge of technology acceptance model, the questions would have been adapted to more directly reflect that research. Conducting the pilot study before detailed knowledge of the literature allowed me to explore ideas without pre-conceptions gained from other researchers.

Figure 4.1 Timeline of data collection and analysis.



4.1.2 Participants

Figure 4.2 Structure of the data collection

Stage 1

Pilot Questionnaire
- Teachers 25

Stage 2

Questionnaires
- Undergraduates 40
- Trainee teachers 47 (collected as two sets)
- Teachers 35
- Advisors 4 who were mathematics teachers
- ITT providers for mathematics trainees 5

Stage 3

Interviews
- Teachers 12 (including 2 who were also trainers)
- Local authority advisors 3 (2 retired) who were mathematics teachers

4.2 Methodology

Cronbach and Suppes (1969) (cited in Verma and Mallick, 1999) suggest that research, or systematic inquiry, is categorised according to purpose; there are different approaches available for research relating to decisions for policy makers (decision orientated) and that which follows the researcher's interests (conclusion orientated). The approach to this study falls into the conclusion-orientated category, focusing on English secondary school mathematics teachers and the use of ICT. I mainly use a qualitative approach that draws on approaches from a number of traditional methodologies. Tashakkori and Teddlie (2003) suggested that different research methods should be viewed as complimentary, especially as social science research does not fit into the qualitative-quantitative divide. Fuller (2002) suggested that knowledge cannot be about the world, unless it is situated in that world.

4.2.1 Ontological and epistemological stance

The ontological stance I take is within the perspective of constructivism, i.e. one that, according to Bryman (2001, p.16):

> '…asserts that social phenomena and their meanings are continually being accomplished by social actors, it implies that social phenomena are not only produced through social interaction but they are in a constant state of revision.'

In this study I take a realist position, recognising that people are part of networks and communities and as such form a social construction of the reality of the world. This is important as teachers may have established a 'truth' that using ICT to teach school mathematics is problematic so to explore this, I needed to talk to teachers and trainers. Teachers try to do the best for their students, so if using ICT is perceived as problematic when teaching, then I must question if there are constraints and barriers to using ICT as a teaching tool. I must also consider if, as part of an historic network, was there an existing tradition of conditions that led to the establishment of the 'truth' that using ICT to teach school mathematics was problematic. The lack of use in school mathematics appears to be 'out of step' with the use of ICT in a wider society where use of technology is widespread in business, industry and social situations. In subscribing to a social realism ontology, I acknowledge the importance of the subjective experience of individuals in the social world. This study involves an element of the interpretive perspective; I, as the researcher, use my experience of settings to 'read' the acquired information.

Taking a thematic analytical approach, as described by Braun and Clarke (2006), allows flexibility in analysis, drawing on aspects of other qualitative traditions rather than adhering to any one in particular. They suggest that there are two camps of qualitative analysis, firstly 'those that tied to, or stemming from, a particular theoretical of epistemological position' and secondly 'those independent of theory and epistemology' (p.78). According to Aronson (1995) and Roulston (2001) thematic analysis sits in the second camp, compatible with essentialist and constructionist paradigms (Braun and Clarke, 2006).

When undertaking social research from a constructionist standpoint awareness is required of how ‘reality’ is perceived. Pring (2015) commented that there are many realities that exist independently of the researcher and are to be discovered. My research is focussed on the perceptions of ‘realities’ of the participants, looking for similarities and differences within the groups’ to create a sense of ‘reality’. As those who are involved in the research are unique their responses cannot lead to generalisations for other situations but by looking at the similarities presented by the participants in their responses I can begin to establish what the inhibitions are to using ICT, and at which level in the social hierarchy the problem arises, whether governmental, institutional or personal.

At the heart of the epistemological debate is what constitutes truth, reality and verification. Pring (2004) stated that, ‘research is often focussed upon people’s ‘perceptions of reality’ where one lot of perceptions is as good as another’. The researcher’s position with regard to the situation has the potential to be influential on how the research is carried out and how findings are interpreted, as there is no one reality or truth as realism is ‘socially constructed’. Perhaps it is more accurate to say that the findings are ‘true in that situation’ rather than being absolute truth.

Objectivity considers ‘how the world is’ and steps must be taken to ensure that this is taken into consideration when drawing conclusions by following recognised procedures. However, whilst events may appear to be correlated, there are difficulties in making causal explanations. There may be other factors that have influence, such as social networks and interactions, background, and motivation making exceptions to the rule of which the researcher is unaware. Another difficulty is that it is possible to make different interpretations relating to the same actions. This arises through, amongst others, difference in experiences, motives, intentions, ability to understand situations and meanings on part of the researcher (to what degree are they able to display empathy) and participants. For example, ‘Are you good at using ICT?’ initiates a response relating to the participant’s conception of being ‘good at using ICT’ rather than a recognised scale. Unless the participant knows the criteria for ‘good’ and can measure themselves against it a statement such as ‘75% of the respondents are good at using ICT’ has little value.

The insertion of 'think they are' does qualify the statement but also gives it a different context, i.e. in their view and not that of the researcher.

No interpretation can be undeniably correct as this presupposes that there is one authentic interpretation, this applies to the questions posed and the interpretation of the answers offered. In dealing with people who bring their own understandings and interpretations, the researcher deals with interpretation so the process of interpretation is more cyclical or a spiral, not the linear model of positivist traditions. Through interactions with the subjects, the researcher may modify their own understandings as the work proceeds, leading to re-interpretation and different meanings being placed on them. This enables different and conflicting interpretations to be compared and contrasted leading to some consensus between the parties and with similar research. In using facets of both quantitative and qualitative methods an awareness of the benefits and drawbacks of both methodologies must be recognised.

4.3 Choosing the Data Collection Methods

The choices I made for my data collection was to use printed and on-line questionnaires plus face-to-face interviews apart from one conducted by telephone. Collecting data using questionnaires and interviews raises issues surrounding truth, reliability and verification. In my data collection and analysis I maintained an awareness that the responses were 'espoused' views as I was unable to observe the lived reality of these teachers.

I decided to follow an interpretive route committing myself as researcher to seek understanding of the truths espoused by the participants. I focused on interview data thus the methods reflect those of qualitative research rather than quantitative research. The data collection became opportunistic because of the circumstances such as closure and reorganisation of schools, staffing issues and workload associated with changes to the curriculum and examinations. Access to teachers and schools was constrained resulting in changes to the foci of the research. I decided that the criterion for participating was that the teacher should be interested in developing their personal mathematics knowledge and skills of ICT through attending, or delivering, courses.

A key issue in any research is the validity of the research, especially when the researcher ‘becomes immersed’ by participating or by expressing their stance and beliefs in the situation. Their personal or socially constructed ideas may have influence on both the investigation and the reporting. The recording of ‘what is’ rather than fiction or an interpretation of what has been recorded has to be firmly established from the outset. The researcher guarded against responses angled to what the ‘researcher wants to hear’ and sought to record situations without bias or interpretation. An attempt at verification of the credibility or replicability was made whilst conducting the research, by negotiating with the parties involved, ensuring the reported facts are, indeed, true as they see the truth.

4.3.1 The questionnaires

I decided to use questionnaires initially as I could administer them swiftly and thereby gain a great deal of data quite quickly. As I wanted at first to establish how, when and why teachers of mathematics used ICT in their teaching it made sense to ask these questions of as many such teachers as I could. As stated above the views expressed are espoused views, that is what the respondents chose to tell me, having a large quantity of data therefore seemed to be a good idea as I would be able to say with confidence, this is what teachers feel it is socially acceptable to say about the way ICT is used to teach mathematics.

The questionnaires included open and closed questions. The closed questions could be statistically analysed as responses were recorded using a point scale or by selecting a box with predetermined criteria. The open questions allowed participants to record their personal experiences and beliefs. In seeking to acquire the information I required, I determined that I needed to ask questions of teachers, those in training to be teachers and those with a responsibility for training teachers, and seek opinions from those who have recently been students in school studying mathematics. The recent students would have opinions about whether using ICT in mathematics lessons was beneficial or constrained their studies.

I wanted to investigate why digital technologies were not commonly used when teaching mathematics. Digital technologies were becoming commonplace within society, cheaper, faster and more portable. Barriers must exist. By asking questions of those who were developing their teaching skills or who did use ICT in their classrooms I wanted to establish their motivations to use ICT and whether there were ways that problems (perceived or real) could be overcome. In identifying possible participants I was able to be pragmatic and take opportunities to conduct questionnaires and interviews where and when possible.

4.3.2 The interviews

I chose to follow the pilot and main questionnaire sets by a series of interviews which Powney and Watts (1984) described as: 'a conversation between two or more people where one or more of the participants takes the responsibility for the reporting of the substance of what is said.' Interviewing meant that I could explore topics in depth and get to know and understand the respondent's point of view.

A key issue in any research is validity, especially when the researcher 'becomes immersed' in the situation; their personal or socially constructed ideas may influence both the situation and the reporting of the investigation. Where the researcher is interviewing, their own values, attitudes and perceptions are present to a greater or lesser extent. Steps should be taken to reduce the impact of the researcher's involvement to avoid the research being subjective rather than objective, for instance the wording of questions for neutrality, and the researchers' body language is important to reduce the risk of the participant telling the researcher what she wants to hear. Holloway and Todres (2003, p.345) commented on the 'considerable overlap in terms of procedures and techniques in different approaches to qualitative research'. They suggested a commonality in the approaches as researchers,

> '… often share a broad philosophy such as person-centeredness and a certain open-ended starting point. Researchers using these approaches generally adopt a critical stance towards positivist perspectives and search for meaning in the accounts and/or actions of participants.'

The questions in the interviews were semi-structured based on possible themes identified in the pilot questionnaire, they were designed to allow participants to elaborate and offer more information. Following completion of the second stage of questionnaires and the interviews this inductive approach provided the basis for the sub-themes. Interview coding took place after the questionnaire data was collected to avoid preconceptions (Braun and Clarke, 2006) and both were subjected to coding and re-coding and themes being adapted. The initial analysis of the questionnaire sets was at a semantic level and no interpretation was placed on it. After the more detailed interviews were analysed this was advanced to a latent level in which the underlying issues were highlighted.

4.3.3 Choices for Analysing the Data

Boundaries of specific qualitative approaches are often blurred. An initial thought for my study was to use grounded theory with the literature review following the initial data collection as I was looking for theory to emerge from the data (Strauss and Corbin, 1994; Cohen et al., 2007). Additionally, Glaser and Strauss's (1997) idea that the world does not occur in a vacuum and that actions are interconnected fits with the search for reasons that teachers were, or were not, using ICT. However following grounded theory through iterative sampling (Cohen et al., 2007) proved impractical and the focus for data collection was changed to conducting semi-structured interviews. The interviews also contained elements of narrative inquiry using retrospective and contemporary life histories relating to participant's experiences with technology. The diverse group of participants, lack of documentary evidence and the focus of the research did not lend itself to a full use of narrative inquiry.

A promising option for analysing my data was to use thematic analysis which is a commonly-used qualitative method to identify, report, and analyse data for the meanings produced in and by people, situations, and events (Aronson, 1995; Braun and Clark, 2006; Floresch et al., 2010). O'Leary (2004) commented that thematic analysis, 'Includes content, discourse, narrative and conversation analysis; semiotics, hermeneutics; and grounded theory techniques' (p.11) while, according to Braun and Clarke (2006), thematic analysis, 'offers an accessible and theoretically-flexible approach to analysing qualitative data' without the constraints of traditional paradigms (p.77), describing thematic analysis as the 'foundational method for qualitative analysis' (p.78). The use of different approaches within qualitative methods was also noted by Pring (2004, p.48) who commented, '… and within any one piece of research there is frequently the employment of different approaches as different questions are asked'. The data from two sources, i.e. questionnaires and interviews also enabled comparisons to be made and using participants from a wider geographical area gave a more generalised picture.

4.4 Considerations for the research

4.4.1 Ethics

In conducting research involving questionnaires and interviews several ethical issues are raised, namely confidentiality, access, informed consent and negotiation. In dealing with data analysis, processes and transcribing materials into a more formal academic form there are issues of relationships and accountability. Doucet and Mauthner, (2003) pointed out that maintaining relationships is important and certain safeguards need to be put in place with a need to include those on the periphery who are associated with the group and research but do not appear to fit into the researchers' frameworks and analytical concepts. The second point they make is one of accountability. They suggested that reflexivity is concerned with holding the ontology, epistemology and methodology together and that the researcher must decide how much they should let the participants know. When data is analysed there needs to be an awareness of possible different agendas regarding the outcome where there are stakeholders as it could be exposing power and privilege. In the case of this research, the participants selected for interview are from different establishments across England to include those who do not appear to fit into the researchers' frameworks and analytical concepts. Through negotiation with participants there is a reduction in the risk that the interpretation is of 'what is' rather than 'what is thought to be'.

Where data was gathered on courses permission was sought to collect data before approaching potential participants. Participants were given a copy of the purpose of the research in a letter (Appendix A4) as well as having the research explained to them verbally, by completing the questionnaire they gave their consent. It was pointed out that participation was entirely voluntary and that questions could be left unanswered. Questionnaire participants were coded to preserve anonymity and no person or establishment was identified. All interviewees were asked to sign a participation form, they were sent copies of their interview transcriptions and requested to comment on its accuracy hence providing a check on the validity of the research.

4.4.2 Trustworthiness

Thematic analysis falls into the realm of qualitative research so the trustworthiness of the data (rather than validity and reliability of quantitative research) needs to be addressed. Thematic analysis (Holloway & Todres, 2003) provides a useful method of looking at similarities and differences through examining the perspectives of the research participants (Braun & Clarke, 2006). According to Lincoln and Guba (1985) trustworthiness has four criteria, credibility, transferability, dependability and confirmability.

4.4.2.1 Credibility

Credibility addresses whether the research is true and accurate and if others are confronted with the experience, they can recognise it. Lincoln and Guba (1985) suggested using triangulation and in this study the use of questionnaires and interviews with common core of questions support triangulation. Credibility was also checked through the participants being sent transcripts of their interviews to check for accuracy and an opportunity to comment. As suggested by Cutcliffe and McKenna (1999) at this point there are four options:

- interviewee agreeing with the authenticity of the data and the interpretation so can be accepted
- interviewee agreeing with the authenticity of the data and the interpretation but adds information to clarify or assist better understanding

- interviewee disagrees with the authenticity and interpretation so redirects the researcher
- interviewee completely disagrees, with researcher needing to rethink line of enquiry.

In this study none of the interviewees disagreed and few clarifications were needed. In coding for questionnaire and interview responses the same labels were appearing in the data sets thereby supporting the credibility of the study.

4.4.2.2 Transferability

Although the focus of this study was English secondary school mathematics education and digital technology the questions are able to be modified to be transferable to other subjects, school environments and different groups of participants in other managed environments, for instance nursing (Oxtoby, 2018; Royal College of Nursing, 2018), who also experience government-led hierarchal institutions and the need to access professional development.

4.4.2.3 Confirmability

The initial stimululi for this study were the Ofsted reports (2002, 2004, 2006, 2008) that highlighted the lack of digital technology use in schools and my personal interest was to investigate this situation by giving voice to those involved. By use of open-ended, semi-structured questions participants were freely able to express their thoughts and ideas and interviewees were given transcripts to check for credibility.

4.4.2.4 Dependability

This research could be duplicated with other samples, using the same criteria for selection in that they are interested in participating in professional development. A study using a sample such as people not engaged in professional development, or working in a different phase of education would enable a comparison to be made.

4.5 Methods

For this study I considered a number of approaches, both qualitative and quantitative and familiarised myself with NVivo and SPSS computer programs for analysing my data. I found I needed to be flexible in my approach at the time of my data collection so elected to take a pragmatic and opportunistic stance to minimise the effect on the data. The flexibility offered by thematic analysis was deemed to be appropriate as it would allow techniques from different paradigms to be used, with themes drawn up and adapted throughout the process as circumstances changed. The data collection fell into three stages, stage 1 a pilot questionnaire, stage 2 the main set of questionnaires and stage 3 the interviews.

4.5.1 Sampling

Having obtained ethical approval (Appendix A1), I was able to commence data collection. The pilot questionnaire was designed to enable me to follow qualitative, and quantitative analysis so I began collecting data that could be statistically and/or thematically analysed to explore appropriate methods open to me. In my study, I initially used an empirical approach by using the first set of questionnaires to identify influential factors through random sampling, but with a limiting factor or potentiality for bias being that all participants were interested in updating their own teaching skills at a NCETM residential conference.

I decided to limit my samples to those interested in developing their skills by voluntarily attending courses. My experience with the pilot survey showed me that there was more to be learnt from personal contact than from participants filling in questionnaires in isolation, whether postal or via an internet survey. My pilot highlighted a problem of question interpretation. The problems arose when people tried to gauge their actions against unknown others, they found it difficult to quantify their use of ICT as they had no idea if their use was greater or less than others. Internet (or postal) questionnaires do not appeal to everyone, and have a poor response rate (Denscombe, 2003 quotes less than 20%) and present a problem of bias as only those who knew me or had a particular interest in the subject would complete them.

A face-to-face request to complete a questionnaire can yield richer data as the questions are discussed and the interviewer can get a sense of validity of the answers by deeper questioning. Whilst balancing participants by selecting criteria such as age and gender (Denscombe, 2003) is a good idea when attempting to limit bias, as, for example, gender is often felt to be a factor in ICT use, I was interested in gaining data on as many people's experiences as possible.

My pragmatic approach to including as many people as possible is illustrated by one teacher interview which was conducted by telephone. I first sent the questions by email to which the teacher responded by emailing me short responses. I then telephoned them and was able to ask for elaboration on their short answers. Thomas and Purdon (1995) maintained that regarding reliability there is no suggestion that these methods, (post, on-line or telephone) are less valid than other methods.

I decided to use purposeful sampling of mathematics teachers who I knew, or had been recommended to me (which may be termed snowballing) as ICT users. Snowballing, where references are passed from participants to the researcher enables the sample to grow purposefully. This gave a control element to the data i.e. this sample consisted of mathematics teachers who did use ICT and were interested in gaining skills and knowledge through voluntary attendance on courses run by local education authorities or national organisations such as ATM and NCETM. Non-probability sampling is appropriate when it is not feasible to include a sufficiently large number of examples or it is difficult to contact a probability-selected sample while purposeful sampling implies that the sample is 'hand-picked' as they would provide the most valuable data (Denscombe, 2003). This method also gave a contact point with prospective participants who were nominated against certain criteria, giving a purposeful sample.

In the end there were three distinct samples (Figure 3.2). Firstly, the purposeful sample of mathematics teachers who were all interested in using ICT in their classrooms who completed a pilot of the questionnaire to ensure the data collected and the wording of the questions produced information I could analyse. The second was another purposeful sample consisting of similar questionnaires given to different groups interested in secondary phase mathematics education including undergraduate mathematics students, trainee teachers, teachers and those in an advisory or training role. The third sample was collected by semi-structured interviews of people known to use ICT in their classrooms or promoting it in an advisory or training capacity having formerly taught secondary mathematics. When completing questionnaires, the majority of the teacher, trainee trainer and advisors completed them in my presence, whilst the undergraduate mathematics students' responses were all completed on-line. Fitting in with the interpretative style of methodology the sample sizes of the questionnaires and interviews are small and will not lead to generalisations for applications to larger groups.

4.5.2 Data collection

Where data was collected on courses in stages 1 and 2 I was given permission to collect this by the course organisers with the participants volunteering to complete questionnaires, omitting any questions they did not wished to answer. The pilot set of teachers was attending a course where I was one of the presenters; we were unknown to each other. This stage 1 data collection was a questionnaire which served to find out which digital technology resources a small sample of teachers were using, how they used them and when, as well as to 'test' the questions. As I was present when the participants completed the questionnaire they were able to give feedback and/or ask for clarity on the wording of questions. The original concept was that early fieldwork should be carried out before the review of literature to minimise the risk of me influencing the outcomes as the researcher.

As a result of the pilot the wording of some questions was changed for greater clarity for instance in the original version I only listed six pieces of software whereas in the later version this was nine plus internet use and gave space for other programs to be added. When asking about training I elaborated on the headings to give guidance on determining whether it was excellent, good, poor or ineffective. Other questions were deleted, such as preferred learning style, or added to giving the opportunity to further investigate points of interest whilst dismissing those of no interest. In the revised version there was space to write about advantages and disadvantages of using ICT which then formed part of chapter 6 Barriers and Constraints. I also included a question about the timing of training and how much they thought they needed. This revised questionnaire was adapted for use with other groups (Appendix A2) which were planned to include groups other than classroom teachers who had an interest in English secondary school mathematics, including 40 first year mathematics undergraduate students who had been taught in English schools. This latter questionnaire was designed to determine whether ICT was used in a random (unidentified) sample of schools and to give a school student perspective. Data was also collected from trainee teachers, trainers and advisors, the trainee teacher data was collected from two groups of students of mixed ages (early twenties to fifty plus) and gender from two different universities who had completed at least one placement in schools as part of their post graduate teacher education course. The teacher participants came from my visits to schools, on a MA level course and at a mathematics conference. They were of mixed ages, gender and teaching experience. Questionnaires were also given to mathematics initial teacher Training (ITT) providers to see how much ICT was included in their courses, if at all.

The data collection in the second stage was cumulative in that it built on that of the pilot, and during analysis became more focussed with fewer categories being explored such as use of whiteboards and how hardware is used. Some of the information from the questions was combined such as what put them off using ICT and disadvantages as the responses overlapped. Following the introduction of the second stage teacher questionnaire, and after reviewing the data collected in the pilot, I carried out an extensive literature search using Google Scholar and used references from works of authors known to be researching the use of ICT in schools, including Sarah Hennessy, Kenneth Ruthven, Margaret Cox, Adrian Oldknow and John Monaghan. Using their references I was also able to locate other literature relevant to this field of study. This cycle of reviewing new literature and that used in other research continued throughout as the study developed.

Initial analysis of the questionnaires made it clear that some questions gave insight into teachers' beliefs and experiences and needed probing in more detail. I moved from the initial stage 1 and 2 data gathering through questionnaires into the 'third stage' interviews. The aim was to find out more about teachers who regularly use ICT in their lessons and whether there were any similarities in personal experiences or as teachers that contributed towards this. The stage 3 semi-structured interview questions (Appendix A3) based on the questionnaire questions were also developed on the same lines for teachers, advisors and trainers in order to seek deeper answers to the issues raised and to find out about the background of these interviewees who were, or had been, users of ICT for teaching mathematics (Figure 4.2). The interviewees were randomly picked from people who I knew used ICT, but, not having seen their work in the classroom, I was unaware of the depth of use and what they actually used, so the data consists of explanations and reflections on their practice. The interviews were recorded where possible with notes being taken to assist transcription. All the interviewees were given written information about the project (Appendix A4) and permission was given to use their information.

Using semi-structured interviews in stage 3 was particularly relevant in this study as the age range included those were involved in placing computers into schools and are now retired or retiring from the teaching profession and without their stories the context and events of that time will be lost. When the interviewer, such as myself, has knowledge of the situation, the interviewer and the participants are able to share experiences, with the reflections of the interviewer jogging the memory of the participant to enlarge on their experiences or to add extra information. As the majority of the interviewees were well known to me, we were able to share past experiences of using ICT. This enabled me to build a rapport with the participants, and provided opportunities for me to reflect on their 'story' and its position in a wider social or cultural context.

I consider a strength of the investigation to be that I was an "insider" researcher, having experienced the context that I was researching, able to ask about or prompt for clarification of ideas and experiences that I knew the interviewee was likely to have views on. However I remained aware that my position also had the potential to introduce bias. I worked to avoid bias, asking carefully worded questions that asked for their opinion without adding in mine, and prompting the interviewee to “say a little more about …” without agreeing or disagreeing with their point. Notwithstanding, my position within the whole research, my prejudices and attitudes have to be considered part of the research, as in any other qualitative study, and thus I have attempted to be transparent about these throughout, rather than pretending otherwise.

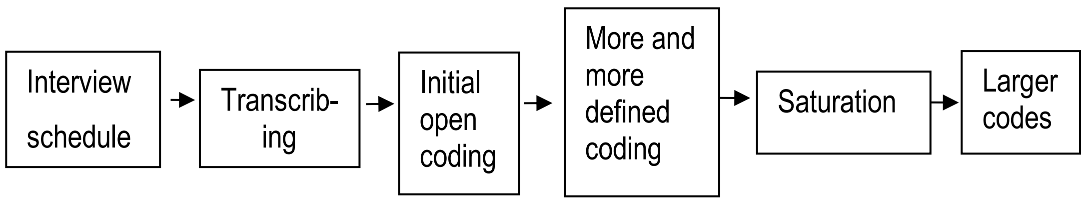
The semi-structured interviews about the historical background with a former advisor (L) and an advisory teacher (R) (both now retired) were based on the questions I wished to explore about early experiences of computers in education and around their personal background with computers in education during the period prior to 1980 when ‘computers in schools’ were in their infancy and before my personal involvement. Additional information of the early days was provided by teachers who participated in interviews and questionnaires providing me with a background to their early experiences of using ICT at home and at school. All interviewees were enthusiastic about sharing their stories, knowledge and reflections on their experiences. The interviewees’ information provides a backdrop for their comments in later chapters and a snapshot of the early days of using ICT in mathematics education.

This study was to a large part designed to tell the story of how and why ICT is positioned as it is today in the teaching of mathematics. It is likely that the story could have been completely different. One of the advantages of collecting people’s stories is that it enables accommodation of stories being told and retold with different emphases, building the narrative. When collecting these stories the researcher is able to engage with the participant through open-ended questions (Strauss and Corbin, 1998; Webster and Mertova, 2007) which enhances the developing narrative as lines of thought are able to be discussed and elaborated within the interview session as well as allowing space for reflection and recall by the participant. I have used the semi-structured interviews using a pre-determined guide so approaching the same questions with each participant enabling comparisons to find ‘like events’, whilst allowing interviewees to answer questions or discuss topics in their own way. The order in which the questions were presented was not fixed so participants could develop thoughts along their own lines. As the interviews neared the end questions were checked to make sure that none had been omitted. My own role was more of an active conversant rather than passive observer, with the intention of creating an atmosphere akin to a discussion. Connelly and Clandinin (1990) suggested that the researcher's own story should also be told, with some merging with that of those interviewed to form a collaborative story. My own story, outlined in the introductory chapter, is not included in the data per se except where important to ensure transparency, but within the discussions there will have been memory prompts as experiences were shared with those being interviewed.

4.5.3 Analysis

I used the six phases described by Braun and Clarke (2006) as a framework for my analysis and the same terminology for the data, i.e. data corpus being all the data, a data set to the data being used at that time, a data item is individual data within the set or corpus and data extract is the coded data from within a data item. A stepped approach was used on each data set within the corpus, including analysis of longer answers from the questionnaires. For interviews this is demonstrated in Figure 4.3.

Figure 4.3 Analysis process for interviews



4.5.3.1 Phase 1 Familiarisation with the data

The examination of the pilot data highlighted issues worthy of closer investigation, such as time and support to learn, how to use the technology including software, the reliability of equipment and access. As the questionnaire data was collected from different sources each was, initially, treated as a distinct set, giving three teacher sets (one was the pilot data and two from individual teachers), two trainee teacher sets, one undergraduate set, and one trainer. Collecting together the responses to questions in each set would also enable comparisons within and across sets to look for trends.

The data from the undergraduate group and the teacher online questionnaire was collected through Warwick University's site-builder questionnaire facility which enabled transference into a .csv (comma separated value) extension file and export into Excel and SPSS. The data from the other questionnaires was also entered into Excel to enable flexibility in analysis. Initially some of the data was interrogated with SPSS but problems in transfer from Excel meant I used Excel only rather than re-checking and re-typing data. The questions that required a text input were sorted across the data sets typed into an Excel sheet.

Early interviews were recorded with an mp3 recorder alongside written notes. After the recorder failed to record one interview it was replaced with a Livescribe pen with conversations being recorded and notes made simultaneously. The audio data were transcribed verbatim with time markers and compared with the written notes. Livescribe soundtracks were transcribed into an audio portable document format (.pdf) to show the handwritten notes and sound position in the interview as a sound-line. Thus I was able to return to key points in the recordings when analysing. After transcribing the interviews a copy was sent to each interviewee for checking and comment.

4.5.3.2 Phase 2 Initial codes

Woods (1993) suggested using critical events as a unit of analysis, and two other categories, 'like events' (these being where more than one participant gives a very similar story) and 'other events' (informal exchanges). I initially used an open form of coding suggested by Strauss and Corbin (1998) then continued to saturation, looking for critical, like and other events as suggested by Woods (1993). Transcripts and questionnaire sets were initially hand coded to identify potential themes via key words such as those referring to the software they used (Word, Excel) and how they used ICT (demonstration, worksheet). When analysing the data items (Braun and Clarke, 2006) I found that similar stories were being told by participants so I formed main categories and applied tags to the various events, by use of colour codes to collate similar statements within the set and the wider corpus so enabling the responses from different participants to be compared in increasing detail.

The initial codes highlighted that there were problems with using ICT caused by others such as external policies, support, attitudes and training. As the themes were to be 'data-driven' (Braun and Clarke, 2006) not 'theory-driven', i.e. coding to be across the corpus rather than identifying for specific questions, data extracts from individual questionnaires were collated.

Initial ideas for themes from this stage of coding included:

- early experiences of computers
- contribution of ICT a) to teaching, b) teaching and learning
- use in school including the software used and support
- the teacher themselves including personal qualities and attitudes
- problems

Some comments were coded under more than one heading.

4.5.3.3 Phase 3 Searching for themes

Following the initial coding of the corpus the data was checked and collated within the collection sets. This resulted in a long list of codes, some of which were similar. The task was to merge these into broader potential codes before being collated, first manually then into NVivo using the theme structure of Historical, Modern and Teaching and Learning. Some provisional headings were sub-divided as shown in Table 4.1.

Table 4.1 Initial themes as entered into NVivo for analysis

Historical						
hardware						
software						
programming experience						

personal experience						
training received						
Modern						
hardware	calculator	IWB	recording			
software	uses	internet	types	games		
training opportunities						
ideal world						
VLE						
Teaching and Learning						
teaching	benefits	problems	teaching style	text book	support	record -ings
learning	benefits	problems	student view			
savvy pupil						
ideal world						
view of mathematics						
advice						
teacher's attributes	beliefs					

Using NVivo subdivision enabled exploration of areas within these initial themes, while looking at possible similarities and differences between the participants. I split the data into three separate files, as shown in Table 4.1 which increased manageability but reduced my ability to cross reference within the program, however using this format did focus the data into themes. The category "Training received" was re-analysed as it reflected the current usage of software by the participants and fitted more closely with training opportunities.

4.5.3.4 Phase 4 Reviewing themes

Manual coding sub-divided these themes again to give four chapters, historical background, barriers and constraints, teaching and learning and teachers as learners, the last three being regarded as themes. The sub-division "historical background" placed the themes in the context of what had happened in the past, enabling me to identify progress and change in approach over time as shown in Table 4.2 I decided not to pursue all analysis lines shown at the open coding stage as, while they were appropriate in the original line of inquiry, they ceased to be relevant when my focus moved into experiences and greater teacher involvement. This later coding also identified other factors such as government control through initiatives, curricula and examinations.

Table 4.2 Themes and sub-themes: showing development from the initial data input

Historical	programming experience	personal experience	training received
Barriers and Constraints			
external	curriculum	examinations	accountability
institutional	access and reliability	support with technology	ethos and leadership
personal	confidence and competence	teacher conceptions	professional development
Teaching with ICT	beliefs and pedagogy	curriculum	integrating ICT
teaching	benefits	support	
learning	student view	benefits	problems
Teachers as learners	ITT	teachers in service	learners

4.5.3.5 Phase 5 Defining and naming themes

As the study progressed the top-down influences became more apparent so the historical data was re-visited and edited to emphasise earlier interventions within the system, particularly with regard to opportunities in developing use of digital technologies by teachers. As some of the data statements could have been used in more than one heading, the boundaries of each theme needed to be established but as the themes were 'telling a story' an order for the themes needed to be fixed. Once this was drafted the data was organised to give a coherent account and a narrative written to accompany it.

4.5.3.6 Phase 6 The report

Chapters were formed for each distinct theme although cross-referencing remained important as the themes could not be treated in isolation. An analysis of each theme entailed reading and re-reading of the data extracts comparing and contrasting the findings between and across the different data sets, drawing out key points and forming an argument that would be an integral part of the chapters and final discussion. During this process some of the findings were stronger and of greater interest to the study as a whole, whilst other findings offered a supporting role. The findings were linked with the literature review and comments were made to link them.

4.6 Summary

Drawing on elements of different methodologies and developing a thematic analysis of the data and literature I sought to investigate where the origins of the lack of use of digital technologies lay as this is not a recent phenomenon.

The order of the chapters is deliberate, the historical background 'setting the scene' of where schools and teachers were starting from and who the 'players' are. Within the English education system the government has much power as outlined in chapter 6 and this has impacted on schools, teachers and pupils additionally schools have policies and agendas leading to other barriers and constraints for classroom teachers and finally, teachers will create barriers and constraints themselves. Chapter 7 considers why, if there are barriers and constraints, teachers might use technology for teaching mathematics and includes some reflections on school experiences from mathematics undergraduates which leads into chapter 8 and professional development experiences of mathematics teachers and people responsible for training. The chapters address the sub-questions before being drawn together to respond to the research question itself of 'How could English secondary school mathematics teachers be better supported to integrate digital technologies into their teaching?'

Chapter 5 Recollection of early experiences with digital technologies

Research question 1 - How did teachers experience the introduction of ICT into teaching mathematics and what support did they receive in using it?

This short chapter gives a background to the introduction of digital technologies and associated training as reported by teachers and students. The history of digital technologies in schools from early 1980s to the present day is discussed through curriculum change, impact on teaching, provision of resources and training, drawing on the voices of those involved in the early days. The chapter includes recollections of school use and of home experiences. I particularly include two former mathematics teachers involved in introducing IT into schools, firstly R whose enthusiasm kindled my interest in using IT for teaching primary mathematics and L who was an advisor in the early days of IT in schools. Decisions made in these early days have influenced the present situation in schools including beliefs and attitudes of teachers and management.

5.1 Looking back, personal reflections

I investigated some participants' recollections of their experiences as students and whether ICT had contributed to their learning of mathematics. Two groups were chosen, twenty-nine trainee teachers (26 responders) who represented were of a wide age range (Table 5.1) and interviewees who gave a more in-depth picture. It is recognised that (as with any recall) some memories will have faded while others may have been enhanced or distorted with time.

Table 5.1 Age range of trainee teachers

Postgraduate teacher trainee sample		
Age (2010)	Age in 2000 (1980)	Number (n=26)
21-30 years	11-20 years (0)	11
31-40 years	21-30 years (1-10)	7
41-50 years	31-40 years (11-20)	7
51-60 years	41-50 years (21-30)	1

These recollections of early experiences demonstrate the enthusiasm, motivation and resilience needed, initial success was not guaranteed. They worked with few resources and received little pedagogical or software training. Although only limited software was freely available, including content-free Logo, there appeared to be more opportunities for experimentation and exploration with, and by, pupils; in both primary and secondary schools. Rogers (1983) suggested that an 'Innovative Diffusion Model (IDM)' could be used to explain the process by which innovation is taken up by a population. The model relies on communication between members of a social group. These early enthusiasts would fall into Rogers' (1983) categories of innovators and early adopters.

5.1.1 Trainee voices

To investigate how time has affected hardware and software resources the trainees were asked what was available in their schools as students and who used them. The participants aged 51 to 60 at the time of the data collection would have left school by 1980 so would have been unable to contribute information about experiences as a school pupil. The results for the trainees are shown in Table 5.2 and Table 5.3 (T represents teacher use and S student use).

Table 5.2 PGCE trainee's school experiences of hardware

Trainee age	used by	class computer	projector & static WB	projector & IWB	calculator: basic or scientific	calculator: graphics / hand-held	laptop	computer suite
21-30	T	6	8	5	10	6	2	7
21-30	S	0	2	1	9	5	2	8
31-40	T	0	0	0	5	0	0	1
31-40	S	0	0	0	5	0	0	1
41-50	T	0	0	0	0	0	0	0
41-50	S	0	0	0	0	0	0	0
Teacher		**6**	**8**	**5**	**15**	**6**	**2**	**8**
Student		**0**	**2**	**1**	**14**	**5**	**2**	**9**

Table 5.3 PGCE trainee's school experiences of software

Trainee age	used by	spread-sheet	graphing	dynamic geometry	integrated learning system	IWB soft-ware	380z/480z/ BBC software	none of these
21-30	T	8	4	3	1	4	0	3
21-30	S	7	1	0	1	1	0	4
31-40	T	1	0	0	0	0	0	6
31-40	S	2	0	0	0	0	0	5
41-50	T	1	0	0	0	0	2	5
41-50	S	1	0	0	0	0	3	5
Teacher		**10**	**4**	**3**	**1**	**4**	**2**	**14**
Student		**10**	**1**	**0**	**1**	**1**	**3**	**14**

Fifteen participants responded with longer comments seven of which mentioned calculator use including:

> *'Big advance on logs/slide rule, saved time to concentrate on the maths' (TT26), 'Calculators used to check answers' (TT17), 'Scientific calculators allowed time to understand concepts without having to spend time on manual calculations' (TT5) and 'Students had the opportunity to use calculators (sci) in order for them to complete their work' (TT30).*

The age 21 to 30 age group discussed the advent of the internet and more mathematical software, although not all had hands-on experience.

> *'We had internet-based learning' (TT1), 'Programs to show transformation of graphs' (TT2), 'Occasional teacher demonstration. Use of Microsoft Office packages in the ICT suit. Use of Logo. Wasn't used much in classroom. Tetris shape and space' (TT10), 'Shape and trigonometry' (TT27) and 'Much of the lesson content was transmitted/conveyed through PowerPoint. No apparent use of dynamic geometry or graphing packages were used. Used various computer games from BBC bitesize (sic), and other websites. Too much Power Point but missed out from using other more relevant packages such as GeoGebra' (TT30).*

5.1.1 Interviewee voices

The interviewees were aged from mid-twenties to late sixties, the majority being in their late thirties/early forties. All interviewees below the age of 50, apart from C, had home computers when children, including BBC machines, Sinclair Spectrum and ZX81. This was a time when software for purchase was limited and people learnt to program in BASIC. They reported:

> *'I was a young child in the early 80's when home computers became a big thing and we had, as a family, a couple of different sorts of little home computers Acorn Electron, I think, was one of them, which we got when I was quite young, about five or six years old, initially used as a games machine, as I'm sure most things were then used for. The way the machines of that time*

were sort of built, you almost had to start programming them to do anything with them. You know, so you had to, um, build on them and get games loaded, you had to know how to type things onto a machine and get it loaded and press play on the tape, and things like that, so, and then wait for about ten minutes while it loaded, so there was much less instant gratification than, I think, than there is these days.' (J)

'My father was a secondary school ICT teacher and had a Commodore PET. He was a deputy head, having been a head of maths who was into computers. Early education experience was one of role play which was text based. We had a ZX81, ZX Spectrum and BBC B and I learnt to write in BASIC.' (D)

W mentioned his mother's influence while K stated her father had encouraged her to study mathematics at A level at school:

'Yeah. I mean growing up my mother was very keen. We bought a BBC computer and she taught me to program in BASIC. .... So I knew the basics and that kind of thing, a dot matrix printer and basic word processing'. (W)

'My dad gave me a Sinclair scientific calculator when I was 16, I was the only person at school who owned a calculator at all … I sat and watched the cricket all summer, working out batting averages, and everybody thought whoo! How do you do that? Brilliant!' (K)

At that time there was little ready-made software, but magazines provided games, some of which were more successful than others:

'...we had a ZX spectrum when I was young, so I guess from about 10 or 11 I was playing some of the very early computer games. ... There was one of those part-work magazines … it built up a computer program for, an adventure game, so we sort of tried to follow that through, but we couldn't get it all to work; … it was quite interesting, but we struggled with (it), we must have got something slightly wrong in the code and then obviously it didn't work, ... it was enjoyable to do, obviously a very different experience from what you'd have if you put a computer on nowadays.' (A)

'...which as a BBC Acorn Electron user, … I'd sort of bought a couple of magazines that had listings in them of programs that you typed in, and if you typed in everything perfectly then you got something appearing on the computer, and sort of that extended it.' (J)

Computer were used in schools prior to 1980 for programming by using punch cards to input data (Millwood, 2009):

'… in school there was this big blob of a box that read punch cards. We did have programming lessons, except programming lessons were typing in sums onto, one line calculation-y things that you typed into these punch cards and the machine did the answers.' (K)

R mentioned that for larger projects the cards were sent away for processing, so there was no immediate feedback, unlike today:

'...we had an arrangement the Technical College where we took our punch cards with one hole cut at a time with a little stylus, they ran them through their computer and sent a printout back to us. I mean, it was an incredibly tedious process, just a series of columns with holes that you could punch out with a little stylus … children were writing programs in BASIC, and every character had a line on there, so every character would have several presses of the stylus to get the thing in. … they couldn't try anything out, they wrote something and then it went … and we got it back again several days later they (had) probably punched one hole too many or something, so they didn't work. It was very tedious.' (R)

BBC, Research Machines and Spectrum computers were introduced into schools in the early 1980s. Interviewees commented:

'My school had 3 Spectrum computers on trolleys … and they used to be wheeled around from classroom to classroom. … Those were the days when you had things on tape, audiotapes, and you'd play and it didn't quite hear and you rewind and you'd do it again.' (F)

'We had one, two computers across a class of 30, and I didn't have a computer at home so we got dragged out of the main class lesson, sat with a teacher and did something on Logo that I didn't really understand because I'd never used a computer before in my life.' (C*)*

F also remembers how using Logo in secondary school gave him a freedom to explore mathematics. He recalls using Logo on IBM machines in the school computer suite:

'... they weren't like any computers I've seen before or since, and they did Logo, which was fantastic. We had this teacher … and she used to take a small group out of the top set and we'd go and do exciting things, and one of those was, um, regular time in that room, using Logo, and a lot of it was really free exploration. It was just trying to draw something and show the teacher when you'd drawn something you were pleased with. So there was a very exploratory feel to that … .' (F)

Other experiences were limited, even after 2000. C mentioned using PowerPoint. Excel, word processing and website coding and taking IT GCSE. W took a GCSE in information systems while J took IBACC computer science. It was at university or college where several interviewees became more involved with computing, taking optional courses as part of their mathematics degree or Higher National Diploma. For some this was on programming using languages such as Pascal, Fortran and C++:

'We had to do a bit of programming in Fortran, … the project was to do a matrix inverter for an n dimension, n-dimensional matrix, square matrix … it might have been Gaussian elimination or something to produce a method for producing an inverse.' (P)

'… we did a bit of Fortran 77 programming which was pretty old hat. … so I had to do, a computer project, I think part of the physics course was a bit of programming, but very, very minor. And then later on in my degree when I did more Chemistry there was a bit of computer modelling, so the silicon graphics

machines came in and used to use that for some of the courses write short programs for doing mathematical calculations on the structure of chemical molecules, that kind of thing, working out the geometry of, a nice stable geometry structure. you'd send off your code and then you'd wait overnight while it ran and then you'd log in the next day and you'd get your results of all the bond angles and lengths and there were, it was just a trial and error thing, you'd try all these different combinations and find which had the lowest energy and that was your answer.' (F)

'I seem to remember feeling that the computer project was a distinct thing from the rest of the course, … it wasn't so much a part of the other things I was doing. It was integrated, we'd done the maths as part of our lecture courses, and the task at that part of the course, if we chose to do the computer project model, it was to, to implement some of the things that we'd learned, but it was an option as well, it wasn't a compulsory part of the course.' (A)

For those who took teacher training courses such as PGCE some inspirational lecturers developed in their students a confidence to use IT while other courses offered little guidance:

I did my PGCE in '95 Sue Johnston-Wilder led a session on Logo. That was the only ICT I did. I did program a clock in Logo – it would draw a face and the numbers. (D)

'… the PGCE course I was doing was very encouraging of the use of ICT – they insisted you learnt the basic programs but they were also very encouraging of why ICT could help you. A couple of lecturers I had were actually very keen in why pupils should be entitled to use IT in maths.' (W)

'I think in my PGCE course, we didn't refer to software except that you could type worksheets and they'd look nice, but I don't remember any sessions on IT to teach with.' (H)

At this time interested teachers cooperated to develop resources. There was a lack of hardware and software for use in schools and little training was available. All the interviewees said that they were, to a large extent, self-taught:

> *'I enjoyed working on computers, practically self-taught. I left before the ICT training was commonplace in schools but was online from 1998/99 at home – well in advance of most people.'* (G)

5.2 Discussion

From the earliest days, participation in using digital technologies was adopted by a number of enthusiasts who were risks takers, creative and who shared their ideas with others. The introduction of the national curriculum meant that teachers were expected to include ICT in their teaching. Prior to the internet being widely available many participants developed their expertise at home rather than through training or in education establishments. Unreliable hardware, and lack of hardware and software meant that schools did not encourage learning in the workplace. Comments showed that early adopters were self-taught, learnt from magazines or more knowledgeable others with little formal training. As teachers were not incorporating ICT into their teaching, their students would not have been able to gauge whether it benefitted or hindered their learning.

The older trainees, (41 years plus) would have been in secondary school when early computers were introduced. Their experience would have been very limited unless they chose specifically to study computers. The 31-40 age group would have attended both primary and secondary school in this period but again their access would be limited and their teachers untrained. In the late 1990s money was given for IT installations and more software became available, although internet access remained difficult. When the 21-30 age group were at secondary school using computers remained fraught with difficulty. There were insufficient machines for a whole class to use them and loading programs, originally via tapes or a tape recorder took a long time. The introduction of floppy discs improved uploading but they were easily damaged. Education focused software remained very limited encouraging some enthusiasts to write programs themselves and to share them with others. Training remained focused on how to set up and run the system. There was no internet or intranet until around the year 2000. NOF training (chapter 2) was implemented in 1998 for teachers-in-post as it was assumed that trainees were already informed.

5.3 Summary

In response to the research question 1 **'How did teachers experience the introduction of ICT into teaching mathematics and what support did they receive in using it?**' my data suggests that experience was poor and depended on where and when you were educated. As computers were expensive there were a limited number in schools. In the early days the computer would be stored on moveable trolleys to enable sharing between classrooms. As the earliest ones had no operating system, programs had to be loaded from tapes or floppy disks causing logistical problems for teachers. Initially the lack of commercial resources appropriate for education left enthusiasts to develop their own projects, such as SMILE, (Pimm and Johnston-Wilder, 2005) and Newman College (Govier, 1997). Enthusiasm amongst teachers remained limited to those who were especially keen on technology. The data suggests trainees' and interviewees' experiences of ICT in their school mathematics lessons were limited and teacher use appears to be dominant, for all the participants.

It was chiefly those who were interested in ICT either as a personal interest or by opting to take an ICT course who would have gained the confidence, knowledge and skills required to use ICT in teaching mathematics. Widespread continuous training of mathematics teachers in ICT was limited from the time computers were first in schools. This has implications as without personal worthwhile early experiences and support to use resources teachers continue to lack the skills to identify and effectively use available resources.

Chapter 6 Barriers, Constraints and Disadvantages

Research question 2 - What are the barriers and constraints teachers experience when using or contemplating the use of ICT?

In this chapter, I consider the constraints and barriers that prevent teachers using ICT. The evidence is gathered from issues raised by teachers in the data from the questionnaires and interviews as well as my reflections on my own experience as a practicing teacher and teacher educator. Some of the disadvantages of using ICT mentioned in the questionnaires will be included as they also they form constraints and barriers for some teachers at a personal level. In chapter 8, when considering teachers as adult learners and their experiences of professional development, there are some suggestions as to how some of these constraints and barriers might be overcome with manageable input on behalf of the teacher.

6.1 Literature Links

The definitions of barriers and constraints were given in chapter 3 in discussion of the TAM. I have used the three terms (school-related, teacher-related and professional development) described by NCETM (2010 p. 12) to categorise the limitations expressed by the teachers and trainee teachers, as these resonated with the data from the questionnaires. In this chapter I deal with school-related issues of reliability, software, the internet, access and cost as well as the limitations of the teachers own expertise. This chapter also includes many of the factors shown in Figure 3.1 (chapter 3) based on work by Andrews (1999); Jones (2004); Hennessy et al. (2005) and Bingimlas (2009).

Key issues mentioned by the participants were identified and detailed in the literature in chapter 2, especially section 2.3. Here I summarise the pertinent literature for the data analysed in this chapter. Many of the issues raised are, as will be seen, under the control of management, often government initiated, rather than controlled by mathematics teachers. Decisions made by school management affect the provision of resources through financial control and attitudes towards using technology for teaching. Fullan (2008) mentions support of management in motivating staff, the effect of school ethos and attitudes of management are discussed by Andrews (1999) Cox et al. (1999); Glover and Miller (2001b) and Teeman et al. (2009). Other authors highlighted the role of funding for technical support and maintaining equipment including Preston (2000); Jones (2004) and PwC (2004). Smith et al. (2008a) found a link between using ICT and technical support (ibid). Teachers found access coupled with reliability, were major barriers and constraints and this was also identified by Hodgson (1995); Preston et al. (1999); Andrews (1999); Mutmaz (2000); Jones (2004) and Hennessy and Deaney (2004). Reliability of equipment was raised by Ofsted (2008); Becta (2008); NCETM (2010). Davis (1969) and Cuban (2001) suggested reliability problems impacted on ease of use and teachers' confidence.

Training shown to be a barrier in reports such as those by PwC (2004) and BESA (Rossi, 2015). Miller et al. (2008) identified this barrier in their work on interactive whiteboards. Some schools rely on extant knowledge of their staff for in-house training (Smith, et al., 2008a) or use the cascade model (Hayes, 2000). Morris (2012) maintains that this lack of funding and time inhibits professional development.

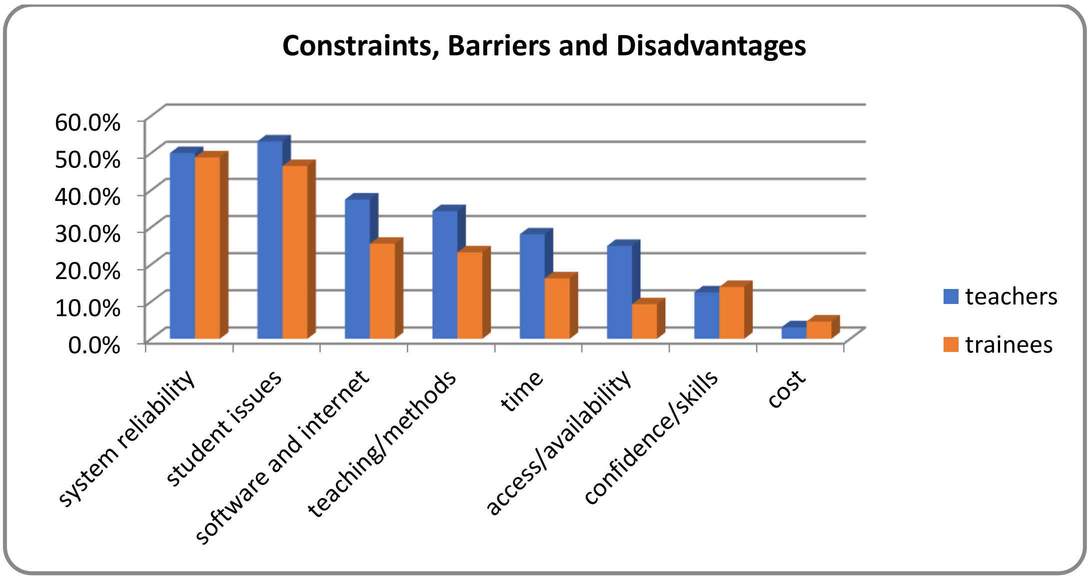
The previous examples of barriers and constraints are generated by decisions made within schools. Schools, including the teachers within them, are subjected to government initiatives and examination criteria which impact what is taught. A statutory National Curriculum (DfE 2014 p 42) began in 1989 and has had many revisions over time. Particularly influential was the 2001 amplification of intent provided by the National Numeracy Strategies (NNS). Kryacou and Goulding, 2004 investigated the NNS effect on pedagogy and Barnes et al., 2003 the effect on teachers' workload. Teachers trying to work with the National Curriculum and NNS were constrained (Tanner et al., 2005) as they were not synchronised and gave different expectations of content and teaching. While public examination boards have similar subject matter (Webb, 2002) there is little guidance on pedagogy. Teachers were expected to interpret the official orders, conform to external regulations and examination syllabi creating conflict and undermining pedagogy (Drenoyanni and Selwood, 1998 and Selwyn, 1999). Ruthven (2004) noted that some schools interpreted the guidance loosely while others were more literal. Hennessey et al., (2005) suggested that there was an expectation on teachers to adapt their use of ICT to fit expositional pedagogy and that the centralisation of the curriculum resulted in the reduction in autonomy of teachers to develop ICT in their own subject. Flores, 2005 and Hammond et al., 2009a commented on the expectation of strategic compliance by teachers.

6.2 Data

The breakdown of participants in the study is detailed in 4.1.2 and shown in Figure 4.2. In the pilot survey of 25 teachers attending an ICT-related session, the questionnaire included the question, ‘In your view, are there any changes that could be made to IT training to encourage you to use more IT in your classroom?’ Twenty-one of the participants took the opportunity to include in their responses the barriers and constraints they were meeting. The two barriers mentioned most were time, mentioned by ten, and resources by seven. This pilot question led to changes in the later questionnaires. ‘Is there anything that puts you off using more ICT in lessons?’ and ‘What do you consider are the disadvantages of using ICT for teaching and learning?’ were added to the teachers (T) survey. Trainee teachers (TT) were asked what they saw were the advantages and disadvantages of using ICT. Some responses included items that are discussed in chapters 7 and 8.

The questionnaire responses by the teachers and trainees fell into eight categories, with hardware issues (such as slow processing speed or failure) and the effect on the students being the most common. Several respondents commented on student and teacher behaviours, students being off task or showing poor concentration and teachers’ over-use of PowerPoint. Other issues, such as time and access, were also considered important, but little mention was made of training, or costs. Figure 6.1 illustrates the percentage of participants mentioning different constraints in the combined groups of teachers and trainees. The interviews provided an opportunity to probe these issues further.

Figure 6.1 Results from questionnaires



Trainee teacher (TT20) illustrates the time-effectiveness constraint with the observation that, '*We can get 'lost in Technology where too long is spent finding/making the right resources that not enough is spent helping the pupils to learn'*.

6.2.1 School–related issues

School-related issues included non-functioning of hardware, age of hardware and its functioning speed. Lack of technical support and access to computer suites for class use were raised in the responses to the questionnaires and were further verified in the interviews. Interviewee J commented on how teachers are not always party to the purchase of resources:

> *'I was amazed actually how, going back a few years, how quickly these interactive whiteboards got distributed around the country, even in subjects which don't really use them all that much, you know. I, I can't believe that every single subject out there is a, you know, is a big user of interactive whiteboards. Projectors seem to be quite a useful thing, but the actual interactive whiteboard side of it, certainly in sort of lessons I've observed, often isn't really used much at all. It is promulgated in schools more for a, a*

sort of, a top-down approach, more of a political way of doing things rather than teachers actually saying 'I really wish I had a way of doing this' and they say 'oh, I know,' It's, someone goes to a, a head goes to a conference and they get sold on the idea that they can get fifty whiteboards at fifty percent discount. And so they tell all their teachers that 'you are going to have an interactive whiteboard in your classroom'. I remember when I was doing teacher training, one of the rooms I was training in was being upgraded to have an interactive whiteboard. But to do this, they took the normal whiteboard away and then they didn't actually install the interactive whiteboard for another week, so we had a week there with no, nothing to write on, and then when they put the interactive whiteboard in they didn't put a computer in, next to it, so, there was an interactive whiteboard there, but it couldn't actually be used and you weren't allowed to write on it, which is ridiculous, isn't it. And these sort of things occur in schools all the time. Where you get your sort of top-down things but the bottom up planning hasn't been put in place with them, you know. As you get more IT in schools, the big thing I think of, I think, is that you need the infrastructure, the IT support to be there, which in most schools I don't believe is adequately thought about. You know, the poor IT technicians in schools are almost always harassed and overloaded with work because there, there's one or two of them to support what really should take a, a department of ten people to. Things like, once you start getting wireless things all the way round the school and, for a school like this it's not really designed for wireless, you know, stone, wi-fi doesn't work through stone very well or anything properly solidly built anything before the second world war, basically.' (J)

Introducing interactive whiteboards did not always mean that teachers used them intuitively, as interviewee H pointed out,

'when we got whiteboards we became a specialist Maths and Computing College and that I think partly funded having the whiteboards, I suspect we (maths) were the first and I guess to a varying degree of success, that some

people struggled to do anything more than they would have used an old fashioned whiteboard.' (H)

Decisions made at school level also included the introduction of Virtual Learning Environment/Platforms (VLE/VLPs), which as some interviewees explain have caused some problems. J states that:

> *'… actually one of the issues we've been having with the school with VLEs is the fact that a lot of them are very techy … they're designed, they're very good for people who want to spend an hour creating something but not for people who've got a few spare minutes.'* (J)

In an interview conducted at the end of the summer term, S commented on the fact that schools change their VLEs to different formats:

> *' … and they've just changed the format at school again, so we had a program called Frog and they are dismantling it over the summer and we are going to have another one, which we don't actually know what it is yet.' (S)*

K had a similar experience as the school abandoned a second system for a return to their original Moodle saying,

> *'The first one was absolutely rubbish, 'cause we spent two and a half years getting them there, learning platforms don't work unless you're going to have an IT, you know a department that runs them. … we had a couple of guys from a school with ASTs (advanced skills teachers) who came to show us how to use Frog and all the wonderful things we could do. … They showed the maths department and geography department stuff and there were lovely resources … and the school had a maths AST and a geography AST and they use d all their AST time and money on developing the VLE. When you actually looked at it … there's no content anywhere else in the school.' (K)*

One of the reasons given for a VLE was to allow teachers to set work for pupils remotely. K notes that there is a problem when a school has, *'… a significant proportion of kids who don't have access to IT at home'*.

Laptop use was also said to raise barriers such as speed of wireless access and the amount of charge in the battery. From the questionnaires, laptops were reported as not having sufficient charge to last the whole lesson, if they had been used by other classes previously. Graphics calculators (and handhelds) also presented battery problems resulting in a reduced number being available for class use at any one time. Slow wireless or internet connection, was discussed in terms of frustrating the smart use of the technology. This was an important issue as this presents 'dead-time' in which pupils can become restless and meant the teacher needed to be prepared with another task 'just-in-case. Teaching time was lost while problems were sorted out. Several teachers reported that IT lessons had to be adapted or even abandoned at short notice. Another problem reported was loading software onto the computers, especially if the school system demands loading onto each computer individually. Teachers felt at the 'mercy' of technical staff and their availability to attend to requests.

The data from the trainee teacher and the teacher questionnaires supported unreliability of computers and software as a concern, 50% of the teachers (n=32) and 49% of the trainees (n=43) commented on this aspect with comments such as:

> *'System failures - school internet down on world maths day! It was dreadful':* (T1)
>
> *'When it is not maintained properly. When it is not up to date. When it is slow because needs upgrading. When security/firewalls are not adequate'* (T11)
>
> *'Wretched thing throwing a wobbler and corrupting'* (T16*)*
>
> *'Reliability of workplace ICT! This is an issue as a resource that is unreliable is worse than no resource'* (T22*)*
>
> *'Computer crashing – virus. It did actually happen during placement'* (TT27),
>
> *'Computers not working can cause a lot of disruption'* (TT34*)*
>
> *'Potential for IT infrastructure to fail when you need it to work in the classroom – or inadequate performance'* (TT44).

Some of the comments related to the speed of log in, others to age and reliability, alongside software and internet access problems, such as,

> *'Having outdated hardware and software. Systems breaking down at key times! Observations!!'* (T5)
>
> *'Network can be unreliable – internet is down!!'* (T27)
>
> *'Slow to upload, not always reliable to connect to internet – always have to have a plan B'* (TT29).

Teachers who regularly use ICT were not immune to problems with hardware and software. Interviewee J has a set of voting pods that have a texting-style keypad, which includes symbols, linked to his computer so that pupil's written responses can be seen.

> *'The good thing about the voting pods is you get a record of what different people have said. Aside from that, 80 per cent of the benefit is getting everyone to answer a question*.' (J)

However, he continued:

> *'You can actually say, 'what's the, what's the answer?' and then everyone types in the answer and then you can see on the whiteboard who's answered and what everyone's answered, you can see the different answers, have a nice conversation about the wrong answers and things like that, and the idea behind that was really good. But what often happens with IT is that there's a real bit that gets dominated by practicalities, and the big practicalities with something like that is actually the difficulty with registering the machines. These things are all wireless, they have to communicate with a little um, dongle that's sitting on the computer over there. You quite often get the issue that the signals they're sending don't seem to go through human bodies very well. So if you're, if the computer's trying to get a signal from the person on the opposite diagonal corner, it can't see it, and so you just sit there for ages not being able to type something in. And even at the start, you know, the*

registering process, when people come in the room they have to register the voting pod to themselves and sometimes it just doesn't work, so you've got out of 24 people, 20 people it's registered and then there's 4 people where it's just sitting there, saying 'registering'. And while it's doing that, you can't get on with the lesson. So this, the IT, this thing which is supposed to be a transparent thing that helps you, ends up dominating the entire start of the lesson and transitions of lessons, particularly the start of lessons are probably the most important, or one of the most important phases of the lesson, because you want people to get in and get into a, the right atmosphere. And if they come in and they're just staring and waiting around, not doing anything, it destroys the atmosphere for the whole rest of the lesson.' (J)

J also added, 'I've been trialling the voting pods this year, had enough of them and gone back to the mini white-boards.'

Access is a problem, and is the second highest issue raised by both teachers and the trainees. Where computer suites are available, there are often problems in the number of (working) machines, one teacher (T10), commented about a computer suite '*Problems with access to suites of computers. Teaching a class of 35 in a suite with less than 30 machines is difficult to help individuals'* while T20 found that unreliability of internet connectivity and lack of resources was a problem. This theme was also present in the interviews. F commented,

'I mean there's a big shortage of computers … so booking a computer room has to be done weeks in advance and sometimes it is cancelled at the last minute because somebody else has a more pressing need, i.e. English coursework, so they need the room continuously for weeks and weeks. It's very annoying when you see teachers go in there and they don't seem to be using the machines and they've booked it to try and preserve that slot and so they've got it each week. … I used to be quite anxious going to the computer room that you'd never get all the computers working at once and if you have a big class there's only one spare computer you worry that what do I do if there are only 29 computers and 30 kids? If you put two kids on a computer how will

they manage the mouse and keyboard and will somebody be sort of sitting by and watching. I find this quite problematic.' (F)

Some schools provide teachers with laptops for their own use, as interviewee K mentions: *'Every teacher has a laptop'* however T7 comments in the questionnaire response *'My laptop is outdated and very slow'*. School owned laptops will, of course, be maintained at the same level of the other equipment in the school.

School-related barriers and constraints included schemes of work, whether schemes were supported by text books and how students were prepared for public examinations. Heggarty and Pepin (2002 p.584) reported that all the teachers in their study used textbooks. They found that, 'Heavy users of the textbook in class relied on the textbook to provide them with most of the materials and ideas they would use in their lessons'. Teachers in their study also mentioned that time constraints inhibited planning so there was an increasing reliance on textbooks. Decisions about which books to adopt are normally taken at departmental level. A change in department lead was recollected by interviewee S who was a user of ICT for teaching and had worked without prescribed texts recollected,

'Somebody else came in, which is the way it happens very often and then suddenly we were all supposed to use textbooks all the time, which was horrendous, and a number of us sort of rebelled against that and said, look we'll follow the scope and sequence of the books but we will teach it how we want to teach it. I think that was successful'.

In these circumstances the approach to ICT within these texts will have considerable influence. S added that she used textbooks as a framework and for examples. Interviewee W explains the text in his school incorporates ICT alongside textbooks, his thoughts about the influence of text on use of ICT and what might be the effect of it not being examined.

'I don't follow a set text, I follow a scheme of work because I have to but ...Some texts I know are making moves towards it, and I have seen, I've got one particular book series in mind, where they try and encourage ICT

> *throughout, but then they actually have a double page spread at the end of the last chapter saying "Use ICT to explore the properties of triangles and quadrilaterals". So, in a sense, they are trying to force the teacher's hand there. But then I think it might be counter-productive because I could imagine nine out of ten teachers who don't feel comfortable using ICT would just skip that double page spread. … So do texts encourage it or not? At the end of the day, I think it is down to the individual teacher. I think teachers' guides that accompany set texts area a bit ... need to be much more savvy about how ICT can be used to expand things and text book series are now sold with an accompanying disc with little games. However a teacher could use a textbook as an excuse not to use ICT, or they could use the wider textbook series to use ICT, but I don't think it is really down to the text. Don't think that texts will change teachers' perceptions. So practice is, you know, alright. The other thing that came up, quite a lot in looking at GCSEs was it's not examined therefore people will not do it… So exam boards are sort of sitting there and thinking how we could be examining it to help teachers actually put it in. Simply because of that statement, "That's not examined therefore will not ..." I'm finding in my work there is a heck of a lot of inertia, and that is not just inertia to do with ICT. That it is an inertia to do with everything, curriculum, pedagogy (um) and I think that is more of a salient issue necessarily. The exam is quite a convenient excuse, but it is a bigger picture'. (W)*

Interviewee H, reflecting on the influence of examinations, also felt that they had an influence on the use of ICT and added, '*We could do much better exams if we were allowed more ICT' and* commenting on topics taught at A level, said, *'computers seem to make some topics horribly redundant, I guess we shrug and tolerate them. It would be a lot better if we didn't have to'*. With regards to use of graphical calculators he pointed out that the International Baccalaureate,

> *'… leans a lot more on graphical calculators' than A levels, 'so things like solving equations, you can draw it in the calculator and solve it that way'… 'I've got a graphical calculator that will solve problems algebraically, and the kids wouldn't be allowed to use it in an (A level) exam.'* (H)

6.2.2 Teacher–related issues

6.2.2.1 Learning

Some comments related to students' learning. As computer room design frequently does not allow for groups of students sharing computers, the space is not conducive to a collaborative learning environment. Five participants commented on situations where pupil boredom would set in, such as student concentration on a screen only lasting thirty minutes when lessons are one hour long. Accessing a computer suite for only one lesson does not allow skill development over a series of sessions, which is necessary for learning, for example, dynamic software and spreadsheets. Both teachers and trainees mentioned pupil disruption and off-task behaviour (25% and 23% respectively), including comments such as:

> '*When pupils treat lessons as IT lessons and just follow instructions without thinking about them. The risk of distraction by the internet, other pupils etc.'* (T3)

> '*Some students might keep playing around or distracted by thinking "how is this work" (in the terms of the mechanical view of technology)'* (T15)

> '*Students viewing lesson as an easy lesson where they don't have to do anything'* (TT36).

Working in a computer suite can tax pupils' concentration, '*Opportunities to digress from what the focus of the lesson is. Doesn't work and need interesting alternative lesson as back-up. Could mean double preparation for lesson'* (T11). For a full mathematics lesson in a computer suite, a teacher needs to prepare a back-up or extension lesson in case of problems including dis-engagement of pupils or the task being completed more quickly than anticipated.

Although the focus of the interviews was on why some teachers use ICT, barriers and constraints were also evident in the interviews. W commented about how he worked with a colleague to demonstrate that using ICT does not mean turning ones back on the class:

> *'I remember one school I was helping out and they refused to use Autograph for teaching transformations of graphs. And I said, "Why?" and they said, "Well, to fit in an equation I need to turn around, get the mouse, go to the equation, go to enter an equation and then to do a parabola type in y, type in equals, type in a little square button and press 'Enter'. And by the time I've done all that, because it is not second nature to me, well, I turn my back and suddenly I've lost ten kids attention." (um) and it's fantastic because, again, just to keep praising Autograph, Autograph is very much written with secondary school teachers in mind, and when I showed her you could pick up a keyboard and press 'Enter' to enter an equation, put 'y=x' without even turning round, you know the parabola was there. She was more inclined to use it after that because, I don't think, she thought it would impact on her classroom management.'* (W)

6.2.2.2 Programs

However, as with any resource, there were associated problems or inappropriate use mentioned by the questionnaire respondents. '*When it is used as a back-up for proper teaching (e.g. overuse of mymaths)' (sic)* (T1). For some subscription sites such as MyMaths might be seen as a substitute that would satisfy the 'use of ICT' curriculum requirement. '*Problem with sites like MyMaths, some detailed pages, some not very useful. Avoid becoming a gimmick e.g. PowerPoint'* (TT27). Interviewee C thought that '*exams encourage people to use things like MyMaths and pupils loved it because they liked the success when practicing questions, some choosing easy options to get the little ticks on the screen'.*

Schools considering whether pupils should use their own devices in the classroom were highlighted by B.

> *'Now, bring-your-own-device … it's coming, and the number of schools on their web sites say very exciting plans for BYOD. Now you try running a maths lesson where they just brought anything. They might bring the odd Samsung phone, or an iPad, or a Galaxy tablet or a Nexus. Now from a software developer's point of view this is mayhem, because they're all different*

operating systems. So it was bad enough when we had Windows and Mac, and we had to rewrite everything for the Macintosh. Now Apple … they've produced the iPad out of thin air, it's basically just a large phone, and as such it does what the phone did and precious little more, it ran none, absolutely none, of the existing software base. Nothing, so it's all new stuff, it doesn't run any of the Flash, Java, - all gone. So every Tom, Dick and Harry round the world reckons they can write apps for the Apple, and they are doing so and so there's an awful lot of rubbish being produced, and it's going to be quite a while for people who've been at this for twenty years to get their stuff on it as it is a different environment. I feel so sorry for people like the Freudental Institute in Belgium, they've invested hugely in all these Java apps, and none of them work. So they've had to write them all again. Which means they've got to stop, down tools and spend all that time. Gapminder is another one, brilliant piece of software but he's had to stop and write it all again so that it'll work on the pads. It's such a waste of time, and creatively it's a nightmare. Now there is another way round this, which is to write everything in HTML, If you want something to run on all these different operating systems, bearing in mind we're talking about Apple, PC, iOS which is on iPad, Android, and then Windows RT is another one, so that's five different systems, if you want to run natively in all these different systems, … because maths software in particular needs to be composed so that it's snappy and fast, … we can't do that anymore, it's just not a viable option. And I think GeoGebra are having exactly the same problem, they have to do it in the HTML. Then you've got Apple being their usual silly self, they won't let WebGL work on the iPad. Now WebGL is the HTML version of OpenGL, which is enabling GeoGebra to go 3D. Autograph been using 3D for years, but we use a different system, but that won't run on the iPad as it stands. But even as and when all these downloadable software developers get their act together and get an HTML version, a) it won't be as snappy as we are used to, and b) the 3D won't work on Apple, as Apple don't want 3D working in on HTML, because the games manufacturers will just bypass iTunes. … As I say, I'm afraid we're going backwards'. (B)

Some schools barred groups of people accessing certain programs such as YouTube. Interviewee C described the YouTube situation in her school as teachers being able to access it while pupils are not allowed to. Although it is possible to download the YouTube files she said it was *'a real pain to do so*.*'*

6.2.2.3 Time

Using resources such as interactive whiteboards and virtual learning environments (VLE) has the potential to be time consuming. TT20 suggested that teachers need to seriously consider time spent against the contribution that ICT makes to the teaching and learning. T13 commented about the lack of evidence of pupil's work or notes for the pupil's to recap on later, and T19 added, *'..thinking it is time consuming but less effective'.* Other respondents, T2, T22 and T23 also offered time (pressures), as being one of their constraints.

J pointed out that the interactive whiteboard has advantages and disadvantages when a teacher wanted to save files for future use.

> *'The disadvantages would be actually having to make sure that you save all the stuff. If it's easy, that's fine, if it's something, if I have to spend 10 minutes after every lesson going through some annoying upload dialogue and having to create a page and then doing this, that and the other, I can see it not happening. If it's just a matter of I save the file and the com, you know, it automatically picks up the folder and then does it for me, then I can see that that would be a, a very useful thing.* (J)

It was not only the whiteboard, the VLE was also time consuming and J said VLEs needed an hour or so rather than minutes to create pages,

> *'… as a teacher, that's often what you have. You don't have, you know, two hours to do something. You very rarely get something perfect, it's all about sort of iterating. Get some, getting something there and then moving on. I get the sense that a lot of IT that's aimed at schools isn't actually really trialled by full-time working teachers. It may be, it may be that there is …. someone who is particularly interested in one particular aspect of technology and they,*

because they really like that aspect of technology, they are going to think it's perfect and they are going to use it all the time. But what you need to do is try and convince people who, it, it's not the main part of their lives. They just want to know 'how is this actually going to help me teach' their subject, whatever it is.' (J)

Interviewee K commented lesson preparation takes longer with an IWB as there was an expectation that information such as,

'… titles, WALTS and WILFS and dates and links and diagrams and putting in links into other pieces of software takes forever and it is done outside of lesson times whereas writing the date and title on the board with a pen used to be done in lesson time and it didn't take … you know'. (K)

6.2.2.4 Confidence

A very real barrier is teachers having the confidence to use ICT with a class, even if they are confident with using it for their own purposes. Some teachers began teaching prior to the widespread introduction of computers in school, younger teachers and pupils may have been exposed to them as part of their school learning environment. Respondent T2 commented, '*Most teachers lack confidence so don't use it and don't understand it'* while T22 mentioned that they, *'would need to feel comfortable with software before using it, because you need to be able to swiftly rectify and sort out problems when in class'.* On the issue of confidence and teaching with ICT and the perception of the need to be flexible W suggests that as with teaching other aspects of mathematics, familiarity enables teachers to become more flexible as they grow in confidence.

'I think flexibility is key when you are teaching. This is true whether or not you are using ICT. But you can teach in an inflexible way and you can use ICT in an inflexible way and I think it is the same with anything. Say it's the first time you are teaching A Level, and you are a bit unsure. You might teach it in a definite way and have a very definite plan, but after teaching A Level for five years you'd be a lot more flexible, right let's make links between these chapters or if you don't understand this let's do it in a different way, or let's do

this rich task. (Um) And, it's the same with ICT. I think flexibility is really important, but you can use ICT in a really rigid way and I would suggest that, in some cases, that it might be better than not using it at all, especially if that is the first step of moving towards using it in a flexible way.' (W)

6.2.3 Professional development issues

One of the problems that has been identified historically (chapter 5) is the introduction of new ICT resources without the accompanying training. Interviewee J commented,

'…in terms of some specific training for, for programs to use in teaching, we haven't really had all that much. There was, you know, you, you get a little bit of internal staff training at this school, for example there've been a couple of sessions, not run by external people necessarily but run by other teachers in the school on things like using interactive whiteboards, …someone in a department meeting might say 'here's a nice computer program I use', or someone at a maths conference might try and convince you that the program they use, or the programs their stand are selling is the best thing ever.' (J)

J added that schools will give staff a piece of software and expect them to learn how to use it:

'I know, for example, there are some quite nice animations and interactive things in Boardworks, we've got a copy of Boardworks on the intranet, but I haven't really used Boardworks for years … no one's ever sat down and said 'here's Boardworks, here's all the different things'. It's just, we've got a copy of this, I, I think it, I first saw it when I was doing teacher training, I was doing my PGCE, and the first school I was in said, basically told me 'here's, here's lots of useful stuff for you, go away and have a look at it … the standard teaching, the standard way of getting things as a teacher just tends to be that you get given a pen drive with loads and loads and loads of different things on it.' (J)

J also offered insight into how do teachers might learn about using resources.

'How do I learn to use new resources? It is mainly through you playing with them yourself but I'm, I'm aware that even with the stuff I currently use, there is a, they have a lot of capabilities that I just don't have time to properly get to grips with. Interactive whiteboards and interactive whiteboard software, for example, do a lot of quite interesting things. The issue is, not just that sometimes they're not very discoverable, they're not very easy to learn, but that to use them properly you have to put quite a lot of time into preparing things before you use them. And the amount of time you have to spend preparing them is often out of all proportion to the amount of time you spend using them. Yeah, if, if you have five hours of time, you know, to plan a weeks' worth of stuff, and you can either think up some interesting questions to ask students or I can learn how to use a particular, you know, I, I'd much rather get the basic teaching right rather than have a flashy animation between one page and another of a presentation.' (J)

It appeared that there was little school time set aside for training teachers in the use of different IT resources. Interviewee M commented that his skills to use Autograph and Derive were 'self-taught'. This was the case with P who had managed, to his surprise, to secure finance to attend a TSM course. P revealed that,

'I think the previous staff development manager had been very frugal with the staff development budget, so I just got lucky really. We've had sometimes people come in like to do Autograph training … but 95% of the IT I've taught myself really.' (P)

A similar picture of self-teaching is presented by F who says 'everything I've learned, I've learned myself or have been shown by somebody'. Another interviewee K mentioned her experience with the school changing VLE and while the training they received was supposed to be a full day, they were only given an hour or two.

6.3 Discussion

This chapter addresses research question 2 - 'What are the barriers and constraints teachers experience when using or contemplating the use of ICT?' The literature and data were examined under three headings, school, teacher and professional development although these are intertwined, for example government policy and initiatives through the Department for Education have a great impact on what teachers do in the classroom as implemented by school leaders.

Changes to school structures, the curriculum and examinations commonly follow a change in government or ministers. The 2010 election had a marked effect on the focus of this research. All schools have a performance target to reach in examinations which is then made public via league tables, which may be seen as a 'top-down' and punitive strategy. Such a system does not show the characteristics of a motivational strategy that leads to an enthusiastic, productive workforce (Fullan, 2008). Some of the interviewee comments in sections 6.2.2.1 and 6.2.2.2 reflected the influence of examinations both the syllabi which do not include or examine digital technology (W), or allow the use of graphical calculators in A level examinations (H) and that examination preparation encouraged the use of testing software such as MyMaths.

As mentioned in chapter 2 there is little reference in the national curriculum concerning the use of digital technologies in areas of mathematics e.g. geometry where interactive teaching and learning opportunities may be considered appropriate (chapter 7 section 7.2.3) although the complexity of the subject matter to be studied at Key Stage 4 implies the use of some form of digital technologies to handle elements such as large data sets and trigonometry. Hennessy et al. (2005) suggested teachers felt an external pressure to use ICT when part of the national curriculum and also pressure by managers to assist pupils to achieve high grades in examinations encouraging schools to purchase revision programs such as Mangahigh.

Schools were given financial incentives to install interactive whiteboards and virtual environments that were originally developed for business and industry (reported by H and J, section 6.2.1). Rossi, (2015) reported that businesses were encouraged to discount hardware for schools by reducing the amount of training included. This point was raised by teacher J who suggests that discounts persuaded head teachers to take up offers without first discussing with teachers how the products might benefit teaching and learning. Teacher J commented VLEs, which schools were encouraged to use, were 'very techy' and not designed for people who have little time to spend developing them. Fullan (2008 p.46) suggests that success is more assured when leaders engage in purposeful interaction, once people realise something is good they are more inclined to be positive about the decision. However he also states that one of the greatest failures of leaders is the, 'dead certainty that they are right in times of complexity' (p.6). In July 2012 interviewee S remarked that they were having a different VLE installed over the summer holiday for use in September 2012. However, the staff did not know which one it was going to be. Similarly K commented that after two and a half years they were about to return to their original VLE. In K's comments she mentioned that little had been uploaded onto the VLE (section 6.2.1), which suggests that either staff did not have the time or the knowledge to do this. Cuban (2001) found a similar situation in the USA. Lack of consultation with teachers has meant that not all purchases have been successful. An example was the voting pods mentioned by interviewee J where the wireless connection was inadequate for the whole class of pupils to connect simultaneously. The benefits of the pods were not realised and the teacher resorted to using mini whiteboards so that pupils had the ability to display their answers.

Schools and therefore teachers are limited by the resources available to them. A school decision about whether to use machines which are on the Windows, Apple, Android, or Linux platforms will restrict choice. Interviewee B, who was also a developer of Autograph software, spoke about how he, and other, software developers may not convert their tried and tested programs to work on other systems or revert back to a previous language such as HTML (which is less functional in terms of speed and graphics) and thus some teachers may not be able to use them.

It is not only management's strategies that affect the teachers' ability to access resources. Being able to search for information on the internet and word process may be adequate for some subjects, however teaching mathematics has specific needs such as graphing tools. Computers arriving in schools have generic software such as an office suite commonly used in other environments, such as business, loaded onto them. Some respondents stated that permission had to be obtained to purchase subject specific software, such as Autograph, and then they had to get the IT technician to install it, as teachers did not always have the administration rights to do this themselves (section 6.2.1). As interviewee J said, you also had to rely on the IT department cloning laptops with the appropriate software in order for laptops to provide identical learning environments.

System security is sometimes used as an argument for not allowing teachers having administration rights which allow them to upload their own resources. The IT department may also impose further restrictions on teachers, as well as pupils, as to access on the internet, such as YouTube (section 6.2.2.2). This can be very limiting especially if the IT technician or others who hold permissions, do not understand the relevance and usefulness of for example, mathematics videos on YouTube. Other issues affecting teachers are the lack of urgency with which requests to repair equipment or connections are dealt with. This was highlighted in the questionnaires and by interviewee J (section 6.2.1).

At departmental level 'them and us' situations may exist where the whole department is not involved in drawing up the scheme of work and identifying appropriate resources for the department. The extent of such a situation depends on the personnel involved and the amount of co-operation that exists. A scenario when the lead person has fixed ideas and expectations can lead to teachers feeling compelled to work in certain ways, which can stifle creativity. This behaviour does not bring about sustained improvement, or an environment which enables 'all employees find meaning, increased skill development and personal satisfaction in making contributions that *simultaneously* fulfil their own goals and the goals of the organisation' (Fullan, 2008 p.25). Interviewee W (who was an experienced teacher) mentioned that he followed a scheme of work, 'because I have to …' and also states that texts have a tendency to put the ICT element on one double page spread rather than including it throughout the chapters.

Technical problems have also been mentioned in the responses in the questionnaires (section 6.2.1), T1 mentioned the failure on a World Maths Day and TT27 recalled a virus attacking the system causing a crash during their school placement. None of these are new; one reason for breakdowns is overuse, demand for computer access has increased and aging computers are used throughout the school day (Ofsted, 2008). At the same time the number of technicians has fallen (Smith, 2008). Teachers are not technicians so are not normally able to sort problems. Even if they might have the skills to fix the problem, they also have a class of pupils to whom they have a responsibility. This leads to frustration for both teachers and pupils. Another problem was reported by Interviewee W who described a colleague's reason for not using ICT was the risk posed when turning one's back on the class to manipulate the software (section 6.2.2.1). W described how he overcame the problem.

Where there is a risk of unreliability or insufficient machines for the number of pupils, teachers may choose to have a 'plan B' lesson just in case, but the room with computers is not necessarily appropriate for this lesson, so time will be wasted. When pupils are engaged in a series of lessons on the computer, teachers cannot rely on pupils being able to access their files the following lesson due to the booking system and prioritising of certain subject's examination requirements that necessitate ICT use, disrupting what should be a continuous activityso reducing the impact of their study. Where teachers used individualised programs, such as MyMaths and Mangahigh that requiring a machine for each pupil, a reduction in the number of machines available presents a dilemma, as the programmes' structures do not cater for shared use. Access problems can also be caused when another class takes booked computer time, as interviewee D mentioned. Other subjects may have controlled assessments to complete for examinations which take priority.

If ICT is to be integrated into lessons, and used throughout the cohort, sufficient computers need to be available all the time, not as an optional bolt-on. As attention spans diminish over time having access for periods appropriate to the work set is a good model. This is a point highlighted in the questionnaire data. In England secondary schools have between three and six lessons a day, so individual lessons can be over 60 minutes. It is questionable whether pupils need to have a machine each unless using a 'testing' program such as MyMath or Mangahigh, although interviewee F and T10 assumed this as necessary.

Pedagogy is highlighted as a barrier or constraint in both literature and data and is explored further in chapter 7 as is becoming aware of new software and developing the skill to use it effectively. All the teachers, tutors and advisors who were interviewed said that they were largely self-taught and this is discussed in chapter 8 considering teachers as learners. One teacher (J) said that they became familiar with resources '*mainly through you playing with them yourself*' but also went onto say that even with resources they use quite often pieces of software '*have a lot of capabilities that I just don't have time to properly get to grips with'.*

6.4 Summary

Chapter 6 sought to address the research question **'What are the barriers and constraints teachers experience when using or contemplating the use of ICT'**.

In chapter 2 external factors were shown to influence the perceived usefulness, behavioural intention and actual use of technology (Taylor and Todd, 1995). Chapter 6 has demonstrated that barriers and constraints experienced by teachers seem to have arisen from external and internal sources but one theme that permeated all barriers was how education in England is governed from the top down, leading to a 'them and us' culture, starting at government level with initiatives, funding, curriculum and examination syllabi. Schools and classroom teachers are increasingly subjected to external impulsion such as the government using assessment for accountability purposes and a hierarchical governing structure that includes Ofsted, local authority or academy provider, school management, governors, parents and pupils.

Past government ICT initiatives have included assisting schools to buy computers (from approved suppliers) and interactive whiteboards and virtual learning environments for their use, and NOF compulsory training for teachers. New technologies were sold to schools as a result of smart marketing and schools persuaded to purchase without consulting teachers. The original learning platforms and interactive whiteboards were not specifically developed for educational use by schools, rather they were targeted at business and higher education, hence their features are not necessarily intuitive or inherently useful to teachers in schools. The discounting was at the expense of proper training to enable teachers to fully benefit from the IT's features in an educational setting (Rossi, 2015). Funding for replacement resources and employment of technical support is controlled by the school management team or academy chain and not in the hands of the classroom teacher, but has great impact on the way teachers can integrate technology into their teaching of mathematics.

A top-down culture was also evident at school management level where the data showed that classroom teachers were not consulted about change, for instance introduction of a different learning platforms, (K and S) and voting pods (J). Where school management is tempted by new products it does not necessarily follow that there will be a commitment to providing appropriate training for staff (Cox et al., 1999) or that staff will use it. This was described in chapter 3 about the technology acceptance model. Where management, including heads of department, are not keen on use of ICT in teaching there will be a resistance (Cox et al., 1999). Interviewee F made the point that schools spend money on textbooks each time the curriculum changed, but they do not buy new manipulative software. Teacher voices tended to not be included in decisions that impact on their work in the classroom. This affects teacher's ability to develop their pedagogy, knowledge and skills for working with ICT in mathematics lessons and the provision of suitable resources (Glover and Miller, 2001a). Thus a 'them and us' situation develops and the lack of consultation about provision leads to non-engagement of staff and a lack of motivation to spend time developing resources.

The inclusion, or otherwise, of ICT in the scheme of work and the priority given to resourcing and training by the department will also affect the ability to use ICT in lessons, a forward-looking department as described by Andrews (1999) and Glover and Miller (2001a) supports staff and ensures appropriate resources will be available. Where this is not the case, new members of staff, particularly NQTs will be expected to be ‘strategically compliant’ and follow the departmental line in their manner of teaching (Hammond et al., 2009a).

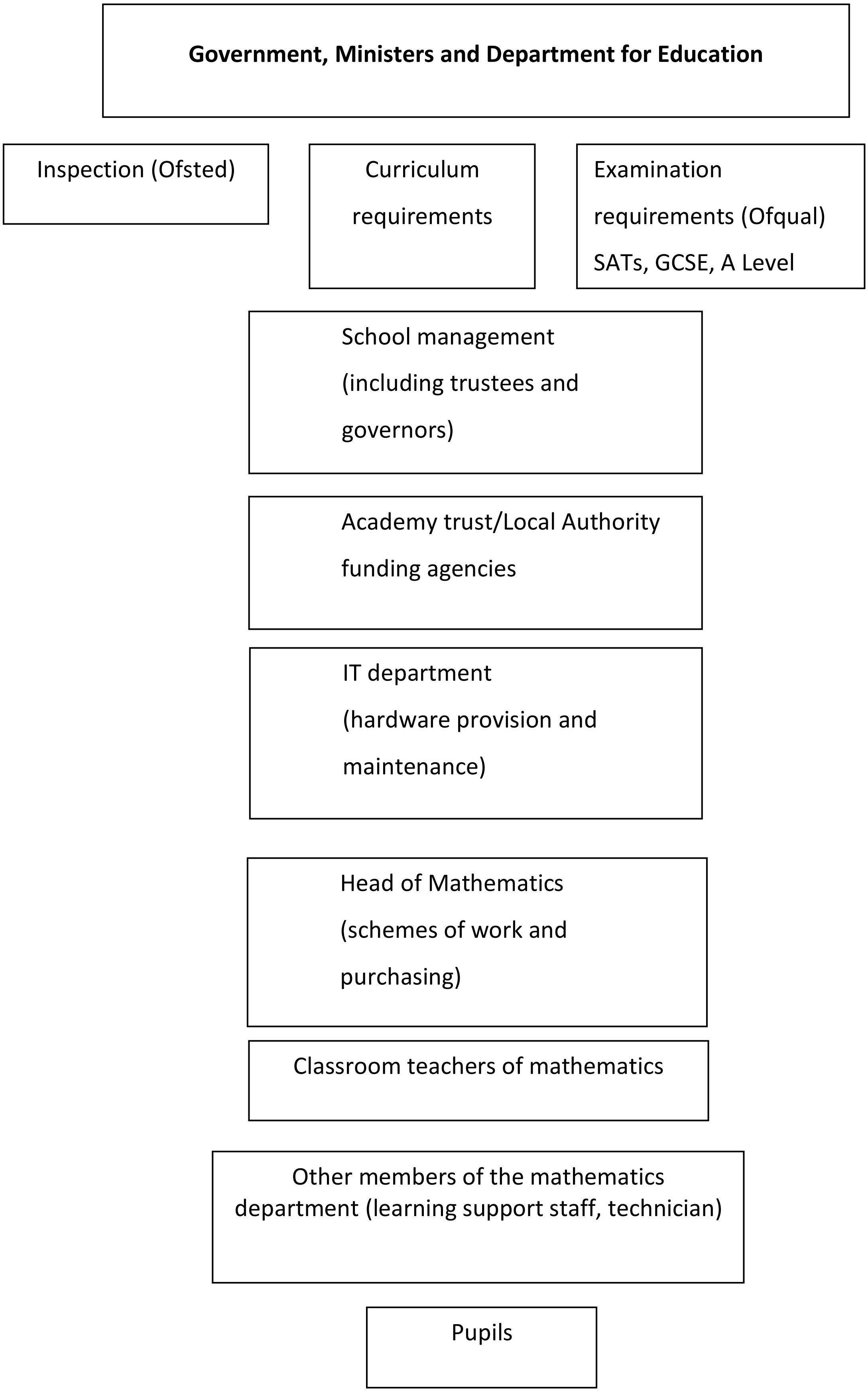
IT personnel can control what resources teachers use and teachers are often ‘at the mercy’ of the technical support staff and their schedule. Apart from the impact of personal beliefs and expectations of those who have positions of authority, reliability of the hardware and supporting services has been cited as a major de-incentivising issue for teachers (Preston et al. 1999; Hennessy and Deaney, 2004), whether it is hardware refusing to work, glitches in software, internet problems or lack of maintenance and technical support (Andrews, 1999; Jones, 2004; Smith et al., 2004).

This suggests that in practice the hierarchy of control in the English education system is a top-down management system with those towards the bottom having little self-autonomy regarding their classroom practice (Figure 6.2).

Reliability and access were shown to be serious issues, in these cases teachers had to plan a ‘back-up’ lesson just in case of failure so increasing workload. Insufficient working computers for a class activity created dilemmas, especially when programs are aimed at individual assessed activities. Access issues also arise when classes compete for computers with some subjects requiring a high level of access.

Teachers are required to maintain order and be in control of their class (Cox et al., 1999) however when the equipment is unreliable or there are not enough machines working the lesson may be disrupted and pupils disengaged. This situation creates a tension on the part of the teacher that may be described as ‘I need to be in control of the lesson, I need to do it right and the IT is preventing me from achieving this’. Using IT then becomes too risky, particularly when the class might be formally or informally observed by senior management or academy observers. The observers do not see the situation in context and may make snap judgments regarding the teacher’s competence and ability to control the class. In the existing performance management climate there is a risk that the situation will affect the teacher’s future status (and pay) (Ball, 2003)

Figure 6.2 Hierarchy of control



The data in this study clearly supports the idea from literature that becoming familiar with a technological environment takes time, enthusiasm, knowledgeable support and a willingness to adapt pedagogy (Andrews, 1999; Hennessy et al., 2005). Familiarity is therefore unlikely to develop in an ad hoc fashion. Where departments have begun to use such software as Autograph they may well have done so as a whole department, for example, one teacher said *"We've had sometimes people come in like to do Autograph training"* however the same teacher followed up with *" … but 95% of the IT I've taught myself really".* The kind of support that really allows a depth of knowledge to be built (Bingimlas, 2009) was not evident in the data.

The teachers interviewed discussed software issues in terms of how long it might take them to familiarise themselves with and use the piece of software. They were clear that if the software took too long either to learn, to prepare work for lessons or save work for re-use later then they would not use it. The teachers discussed the use of MyMaths and Mangahigh particularly as they do not require teachers to learn how to use them. Both digital applications are promoted commercially as examples of software with the potential to enable pupils to develop concepts in mathematics while 'teacher developed' Autograph (Kayali and Biza, 2017) and Grid Algebra (Lugalia, 2013) that are more open to developing pupil thinking do not have large commercial resources behind them. Chapter 8 develops these ideas further.

Chapter 7 will take these ideas further by investigating how teachers' beliefs and the opportunities to use digital technology enable them to use ICT in their teaching.

Chapter 7 Beliefs and Opportunities

Research question 3 - How do mathematics teachers' use ICT in their teaching?

'Teaching and learning may best be seen as two sides of the same piece of paper. We can choose to focus exclusively on one side only, but you cut one and you cut the other.'

Merttens (2001, p.12)

This chapter seeks to answer research question 3 'How do mathematics teachers' use ICT in their teaching?' I investigate what ICT is used, if there is one teaching style that dominates the teaching context and whether pedagogy is a key issue in the view of the study participants. I consider the use of digital technology in a wider sense to include calculators and interactive whiteboards (IWBs) and virtual learning platforms (VLPs) for which the government provided purchasing schemes.

Pupil learning is, of necessity, related to how they are taught (Merttens, 2001). Hence this chapter also includes data from two sets of former school pupils giving opinions on the use of technology as a learning tool in secondary mathematics lessons. The first set was a sample of 40 first year mathematics undergraduates under 25 years of age educated in English schools who completed an on-line questionnaire. The second set was a sample drawn from students completing a PGCE course (TT1 sample) whose age ranged from early twenties to fifties. School experiences are relevant as these affect the beliefs of new teachers regarding the use of ICT to teach secondary mathematics.

7.1 Literature links

As in chapter 6, here I link the literature which has been discussed in detail in chapter 2 to the specific ideas in this chapter, teachers' beliefs and opportunities. In the early days of computers in schools there was an expectation expressed in the literature that teacher's pedagogy would become more constructivist (Shulman, 1987; Duchâteau, 1995; Semple, 2000; Cuban et al., 2001; Drenoyanni, 2006). An integrated pedagogy was suggested by Cornu (1985) and Niederhauser and Stoddart (2001). However a lack of training (chapter 6) has left teachers without knowledge of alternative ways of teaching (Ridgeway and Passey, 1995; Loveless and Ellis, 2001; Webb, 2002), making changes in practice unlikely. Veen (1993) and Levin and Wadmany (2006) indicated that building on existing practices was an option.

Ruthven et al. (2004) suggested there has been little research into teacher's pedagogical perspectives in the use of ICT although views of teachers on the impact of using ICT have been researched (Rodd and Monaghan, 2002; Ruthven and Hennessy, 2003 and Crisan, 2004). Glover et al., (2007) looked at interactivity with an IWB. Crisan (2004) and Hennessy et al. (2005) comment on the influence of teacher's past experiences and attitude to risk-taking.

7.2 Data

This section describes and exemplifies the evidence about teachers' beliefs and their opportunities to use ICT. The discussion of what these findings mean will be presented in section 7.3.

7.2.1 Teacher Beliefs and Pedagogy

How a teacher views the benefits of using ICT gives an insight into their beliefs about using ICT. The questionnaires asked teachers specifically about their beliefs. The data from the interviews were analysed to intimate such beliefs from the longer dialogue. In order to be consistent across the questionnaires and interview data the questionnaires responses were briefly analysed before the interviews took place. Key words were identified as well as themes based around use of ICT, teaching approaches, influence of textbooks and examinations and the digital technologies used. As I wanted the interviewees to be free to offer their thoughts without being led through the themes, they were not used to form specific questions in the interviews, enabling other issues to be mentioned in addition to those raised by the questionnaire respondents.

7.2.1.1 Beliefs

Responses to teachers' questionnaire about the benefits of using ICT (n=35, including two nil responses to this line of questioning) from the questionnaires were, on analysis, found to fall into 12 categories as shown in Table 7.1, Table 7.2 and Figure 7.1. Two of these related to time issues, immediacy (which included feedback to students), and pace in carrying out tasks. Teachers commented on how ICT can help to make explanations easier (Ease of explanation) when demonstrating concepts, particularly graphs and geometry. Teachers also thought that the ability to repeat tasks, saving work for another day was another benefit (Reproducible), and that being able to draw graphs and geometric figures accurately was a further advantage (Accuracy). They felt that the ability to present ideas in an interactive way allows for changes (such as variables) to be seen rather than imagined (Visualisation). Teachers also commented on pupil engagement, application to real life situations and being able to access different and more complex mathematical ideas using ICT. There was also a mention of using ICT for helping consolidate work for examinations. The same headings were used to categorise the first-year university students' (S) comments and those of the trainee teachers (TT).

Table 7.1 Teacher questionnaire sample comments

Benefits of ICT (n=35)	Example of comments given
Immediacy (6)	Instant feedback (T1) Some instant marking helps with individual feedback (T20). Speed of students trying things out, checking ideas. (T24)
Pace (6)	Pupils able to generate large numbers of examples than would be possible with paper, thus providing a greater source to generalise from (T2). Fast, (T12). Labour saving (T16). Lots of examples quickly (T17).
Ease of explanation (5)	Ease of description, (T6) Shows concepts in a way chalk and talk can't. (T13), Easy demonstration of ideas (T35).
Reproducible (2)	Reproducible, (T12) replicable when taken to logical conclusions (T16)

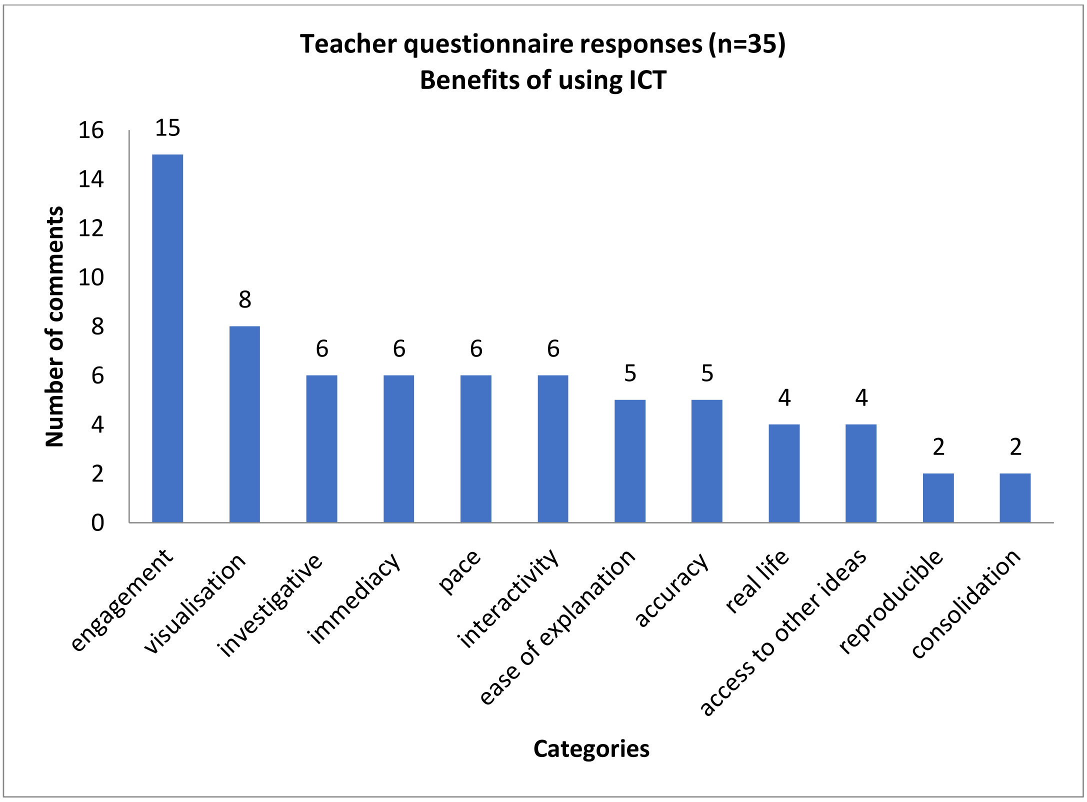
Benefits of ICT (n=35)	Example of comments given
Accuracy (5)	More accurate drawings/diagrams. (T17) They can 'see' geometrical ideas are correct (e.g. Circle theorems) without having to do the proofs first. (T23) Shows something I can't draw (T34)
Investigative (6)	Discovery for themselves e.g. Finding relationships using Autograph. (T6) Students have their own 'handle/control' of the activity. (T22) Exploring mathematics and being unable to 'undo' mistakes. (T25)
Visualisation (8)	Visual image (T6) helps visual and kinaesthetic learners. (T13) able to visualise graphs/geometry in different dimensions. Easy to understand if able to visualise rather than imagine it in head (T15). For pupils’ ability to 'see' the effect of changing variables quickly (T21). Highly visual and saves need for some physical resources. Easy for everyone to see modelling. (T28)
Pupil engagement (15)	Pupils enjoy it (T1). Lessons are more alive, engaging, interesting. Children enjoy learning (T4). It engages disaffected learner, it produces general interest, it prepares pupils with essential skills (T5). Provides a more engaging, dynamic view of maths (T9). Students like the variety of media (T10). Individual learning. Pupils can work at their own rate. Can keep them focussed (T27).
‘Real’ life (4)	Builds upon the learner's own experience of a more technological world (T9). (T17) ICT is what students will use in real-life!
Ability to access more complex ideas (4)	Being able to access mathematical ideas in ways that can't easily be done otherwise. For example, using logo, or dynamic geometry (T3).

Benefits of ICT (n=35)	Example of comments given
Consolidation (2)	Consolidation of topics. Revision (T8). Reinforce from another source (T34).
Interactivity (6)	Movement seems to capture students' attention (T23). Ability to work dynamically. (T25).

Table 7.2 Teacher questionnaire benefits of ICT as a percentage of respondents

Category	No. (n=35)	%
Engagement	15	45.5%
Visualisation	8	24.2%
Investigative	6	18.2%
Immediacy	6	18.2%
Pace	6	18.2%
Interactivity	6	18.2%
Ease of explanation	5	15.2%
Accuracy	5	15.2%
Real Life	4	12.1%
Access to other ideas	4	12.1%
Reproducible	2	6.1%
Consolidation	2	6.1%

Figure 7.1 Benefits of using ICT (questionnaire teachers)

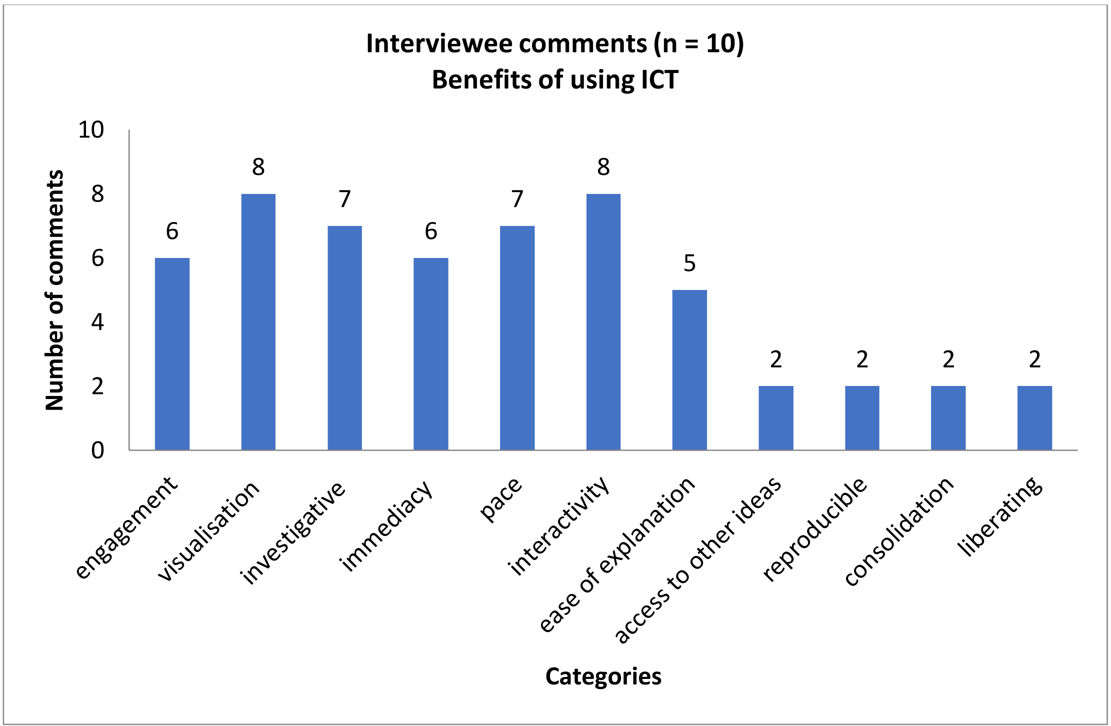


Following the analysis of the questionnaire responses, the transcripts of the interviewed teachers were analysed using the same categories but with the addition of 'liberating' which had not been identified in the questionnaire responses as shown in Table 7.3 and Figure 7.2. The interviewees highlighted similar benefits to using ICT as those given by the questionnaire sample although visualisation and interactivity were seen as the greatest benefits with engagement coming in equal fifth place. Accuracy and real-life were not mentioned. Their results were (presented in the same order as questionnaire responses): (n=10)

Table 7.3 Interviewee comments

Interviewee comments n = 10	No.	%
Engagement	6	60.0%
Visualisation	8	80.0%
Investigative	7	70.0%
Immediacy	6	60.0%
Pace	7	70.0%
Interactivity	8	80.0%
Ease of explanation	5	50.0%
Accuracy	0	0%
Real Life	0	0%
Access to other ideas	2	20.0%
Reproducible	2	20.0%
Consolidation	2	20.0%
Liberating	2	20.0%

Figure 7.2 Benefits of using ICT (interviewed teachers)



H commented:

> *'I think we had better maths use out of Autograph and out of Geometers Sketchpad … you could draw many more triangles, or explore graphs more efficiently by getting the computer to do it...'*

He continued by talking about making resources and projecting them:

> *' …electronic ones are usually easier to edit and skip bits, and it is not like a worksheet you give out and then realise you did not like half the questions, at least on a screen it is much easier to gloss over a page if you don't want to use it so much.'* (H)

C commented about interactivity,

> *'I think I quite like the interactive side of sort of dynamic geometry. So if you are demonstrating circle theorems it's a lot better to demonstrate it and move it and help them visualize. If you can get them to investigate transformations, then that is quite nice because you can move it and you can see a lot more*

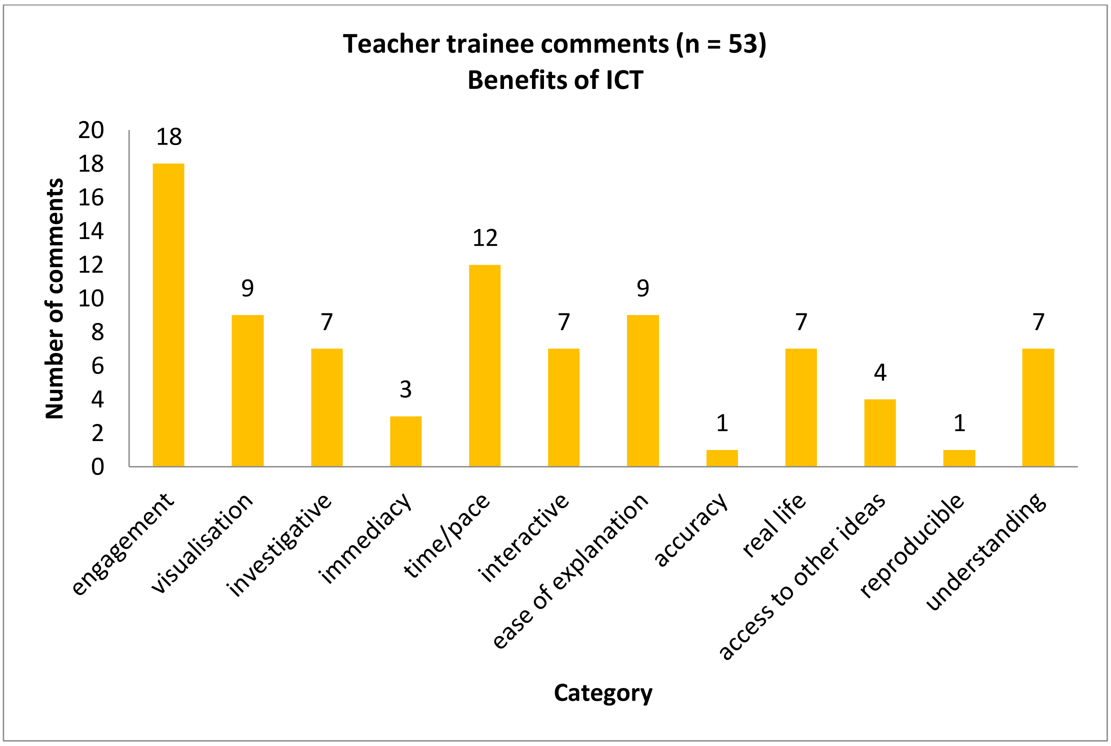
different things at once, rather than having to draw them out separately, which is quite good.' (C)

Inspection of the trainee teacher (n= 53) and undergraduate (n = 46) responses revealed that they had different priorities. Responses of trainee teachers (Table 7.4 and Figure 7.5) included greater understanding by the pupils, while consolidation was not mentioned. Pupils' self-learning was also included. The category order is the same as that for the teacher questionnaire.

Table 7.4 Trainee teacher comments

Teacher trainee comment area	n = 53	%
Engagement	18	34.0%
Visualisation	9	17.0%
Investigative	7	13.2%
Immediacy	3	5.7%
Time/pace	12	22.6%
Interactivity	7	13.2%
Ease of explanation	9	17.0%
Accuracy	1	1.9%
Real life	7	13.2%
Access to other ideas	4	7.5%
Reproducible	1	1.9%
Understanding	7	13.2%

Figure 7.3 Trainee teacher comments



34 out of 46 of the undergraduates mentioned positive outcomes of ICT use. They recounted their impressions of ICT use in recent school experiences, shown in Table 7.5 and Figure 7.4. Ease of explanation (by the teacher) and visualization were regarded as key benefits of using ICT for learning:

> *'It allowed a teacher to modify a function much more effectively than trying to constantly redraw it. This made it great for teaching the effect of scalars on functions.' (S33)*

> *'It made it easier for the teacher to interpret the geometrical meaning behind certain operations.' (S34)*

> *'Projectors can be useful for demonstrating graphs and the like, especially videos / graphs that change over time etc.'* (S38)

> *'The most effective was the interactive whiteboard and how the graphics calculator that the teacher was using would be projected on the board and the students could follow what was happening.'* (S42)

'For example, giving visual representations or animations of transformations and such to aid understanding.' (S18)

'Provides useful visual aids especially in terms of graph-sketching.' (S36)

*'I am a visual person so using the graph drawing packages that were available online was very helpful.' (*S32)

The undergraduates saw the benefits of ICT in a similar manner to the teachers and trainee teachers. One person mentioned that ICT use felt more intuitive and another mentioned ICT's role in problem-solving (Table 7.6).

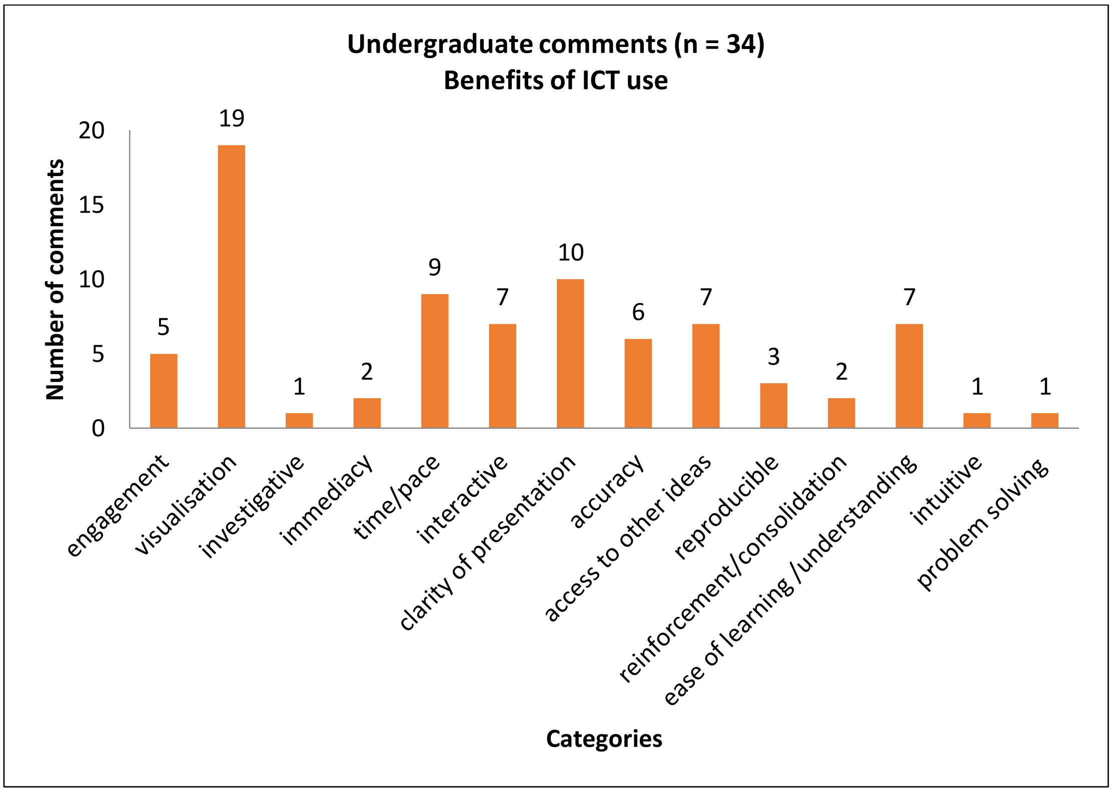
As 6 out of 40 did not respond to this question the percentage has also been calculated using n = 34 as well as n = 40. The order of categories reflects those of the teacher, and trainee teacher questionnaires and interviews. Extra categories were ease of learning/understanding, intuitive and problem solving.

Table 7.5 Student comments

Student comment area (n = 40)	No.	% when n=40	% when n=34
Engagement	5	12.5%	14.7%
Visualisation	19	47.5%	55.9%
Investigative	1	2.5%	2.9%
Immediacy	2	5.0%	5.9%
Time/Pace	9	22.5%	26.5%
Interactivity	7	17.5%	20.6%
Clarity of presentation	10	25.0%	29.4%
Accuracy	6	15.0%	17.6%
Real life	0	0%	0%
Access to other ideas	7	17.5%	20.6%

Student comment area (n = 40)	No.	% when n=40	% when n=34
Reproducible	3	7.5%	8.8%
Reinforcement/consolidation	2	5.0%	5.9%
Ease of learning/understanding	7	17.5%	20.6%
Intuitive	1	2.5%	2.9%
Problem solving	1	2.5%	2.9%

Figure 7.4 Student comments



S2 commented:

> *'The use of ICT could be useful in cases such as drawing trig graphs and seeing how the plot can be created by a point moving around a circle. It was useful to be able to visualise what was going on in the maths without the need for long calculations. It also meant we could do lots of calculations quickly (i.e. in Excel) to find the mean of a set of data for example.'* (S2)

mentioned A specific graphing package (Autograph), was mentioned by 7 of the 26 students:

> *'Software such as Autograph can very quickly and easily give visualisations of functions that at first glance may seem very complex, which can often be helpful. Also, the processing power of software like Excel was often useful.'* (S7)

Some thought that taking out some of the tedious tasks helped make mathematics more interactive.

> *'Absolutely, because I think that a lot of school students are put off maths by imagining it as only consisting of tedious calculations and hand-drawn graph plotting. ICT allows teachers to almost gloss over those time-consuming parts by having it all automated, allowing them to spend more time talking about interesting examples and applications, helping to engage more with the students, and making the lessons more interactive and fun.'* (S44)

Table 7.6 Comparison of comments

Comparison of comment areas as percentages of participants				
	Teacher comment area n = 35 as %	Interviewee comment area n = 10 as %	Teacher trainee comment area n = 53 as %	Student comment area n = 34 as %
Engagement	45.5%	60.0%	34.0%	14.7%
Visualisation	24.2%	80.0%	17.0%	55.9%
Investigative	18.2%	70.0%	13.2%	2.9%
Immediacy	18.2%	60.0%	5.7%	5.9%
Pace	18.2%	70.0%	22.6%	26.5%
Interactive	18.2%	80.0%	13.2%	20.6%

Comparison of comment areas as percentages of participants				
	Teacher comment area n = 35 as %	Interviewee comment area n = 10 as %	Teacher trainee comment area n = 53 as %	Student comment area n = 34 as %
Ease of explanation	15.2%	50.0%	17.0%	
Accuracy	15.2%	20.0%	1.9%	17.6%
Real life	12.1%	20.0%	13.2%	
Access to other ideas	12.1%	20.0%	7.5%	20.6%
Reproducible	6.1%	20.0%	1.9%	8.8%
Consolidation	6.1%	20.0%		5.9%
Liberating		20.0%		
Understanding			13.2%	
Clarity of presentation				29.4%
Ease of learning/ understanding				20.6%
Intuitive				2.9%
Problem solving				2.9%

7.2.1.2 Pedagogy

When technology was first introduced into classrooms there was a sense that this was an opportunity for teachers to change their pedagogy (Shulman 1987; Drenoyanni 2006). The interviewees were asked how they would describe their teaching style. All of them said that they would not keep to one style, but used one which was appropriate to the context, which is as Neiderhauser and Stoddart (2001) suggested. The students were asked about teachers using ICT with their class, S11 commented, *'If it changes the way I am taught, it is unhelpful'*, suggesting that teachers may change the way they taught if they were using ICT. Another student commented that teachers using ICT in lessons did not necessarily affect the way they were taught:

> *'I think this because we had two maths teachers, one that used the interactive whiteboard for all classes and one that did not. Their methods were almost identical and any differences were not related to the use of ICT.'* (S26)

Another student said that:

> *'it changed the way we were taught in that teachers were able to draw much more accurate (and understandable) graphs or produce effective and clear diagrams etc. Though whether we learnt better from this technology than from a good teacher is a different matter.'* (S9)

This student went on to say that using programs like Autograph were useful in checking work.

The students made references to the quality of teaching experienced with ICT such as:

> *'… teachers usually took a preference to show slides so they didn't have to write anything on the board, which in my opinion hampers learning'* (S29)

> *'Usually I don't learn much from the use of ICT, particularly if you have to input answers into a website, it makes maths unnecessarily frustrating. I find it particularly difficult to learn from PowerPoint slides'* (S11).

A number of the students also commented on constraints such as wasting time getting the technology to work and that using ICT was distracting to the learning process. S8 said, '*because IT was not used correctly and was more of a hindrance and often wasted most of the lesson messing about trying to get it to work'.* S39 reported that IT changed the way they were taught and made teaching less effective as teachers were forced into using ICT when they were hopelessly incompetent at it. S39 continued by reporting that this caused students to have substantially less respect for the teacher and that loss of control was more likely. Student S43 recognised that access to technology could benefit learning but that there can be misuse or over reliance, further mentioning that one teacher had used a maths package to teach the class so making his role redundant and some people had looked up the answers online before attempting the questions.

Changing the teacher's role or class expectations raises other problems. W took on a class that had been taught in a transmissionist way:

> *'If I'm being perfectly frank, I'm quite pragmatic in the sense that I like to be connectionist, but if the class is not used to that then they will get incredibly frustrated. So, for example, I have a perfectly lovely Y9 class. They are not top set, but not far off it. We were doing linear graphs and I wanted them to draw lots of linear graphs and I said, "You need to work out what 'm' and 'c' are". Maybe three or four of them rose to the challenge. The others didn't have the confidence to do that and as soon as we said what it is, everyone said, "Is that it?" then they got it. But then, they were not prepared to take that risk for themselves (pause) yet. So there is a kind of, like a median, going on at the moment, as I have just joined that new school where they are thinking like that. So, although I refuse to spoon feed, then I am aware that I cannot just set open challenges every single lesson.'* (W)

When asked about his view on whether he lent towards a constructivist or transmissionist end of the spectrum H replied,

> *'Watching other people and reading influences me. I'm not convinced by the "everything can be explored and discovered by yourself" end of the spectrum –*

but I am also a good way from the didactic end. I find weaker classes need more explanation before they will work on things for themselves – stronger classes are usually more willing to try things.' (H)

C was asked whether she tended to tell her pupils what to do or allow them to explore. She replied,

'I'd like to say explore it but most of the time it's probably telling them and then sometimes exploring, I sort of think. So we do exploring things and problem solving sometimes, but I probably teach from the front a reasonable amount as well.' (C)

A was asked if using ICT in a lesson is different to not using ICT in terms of his approach.

'I think, teaching with ICT is a particular kind of teaching so I would say that when I'm using ICT in a lesson, I've chosen that as what I think to be the appropriate way of teaching what I want to teach. And I think it is a different thing, because to be honest I wouldn't really want to bother with setting it all up if it was the same as not using it. I think it, for the things I do it's the fact that you can make things dynamic that's the biggest thing, so seeing how things are changing.' (A)

In response to the question 'Have you changed your beliefs and way of teaching to include ICT' A replied:

'I don't think so, I think I've always sort of, I've always seen it as something that you have to do with a purpose. I might have made very slight changes in some of what those purposes are as I've learned to use different pieces of software, but I think broadly speaking I probably have very similar views.' (A)

J discussed his teaching style, commenting,

'It's very easy to say that I have a particular view of teaching maths. It may not actually be the way I actually teach maths. If you see what I mean. I would certainly see myself, no I see, you can see by the way my room is laid out that

it is not a particularly individualist way of teaching. The default way I have is that I have all the desks, you know, all facing the front. That doesn't mean that every single lesson I have is me lecturing at them for 40 minutes, they write down their notes and then they go away. I think my default style of teaching would probably be more whole-class based than individual group based. Where you will work on a problem for a while but then I will try and lead the group, sorry lead the class through it. I certainly see, you know, my role is there to guide them through something, rather than they come up with every single thing. That is a, ultimately my role.' (J)

The interviewed teachers did not see ICT as an everyday approach but used it when they considered it would make a difference, by illustrating a concept or encouraging pupils to develop their thinking. They recognised that using ICT requires a change in teaching style, particularly when they want the pupils to challenge themselves, although this might necessitate giving weaker pupils more support. They also say that they have flexible teaching styles including 'teaching from the front'.

7.2.2 Curriculum influences

As mentioned in chapter 6 many schools follow textbook schemes aligned to the national curriculum and examination syllabi. Most interviewees had texts available to them.

> *'…it depends on the class. Some, well I've got one class in particular and they're very happy with textbooks so we do textbooks and then we do something fun, and then we do some more textbooks and something fun so we do something fun at least every week but actually if they're happy and you can do extension tasks through a textbook quite easily and I'm kind of happy to do that if they're happy.'* (C)

> *'textbooks, well we have textbooks but I don't use them very much. And they do have little suggestions about ICT in them but I haven't really read the suggestions so I can't really comment how good they are.'* (F)

Other participants expressed similar views. J mentioned that text book publishers are not always knowledgeable about prior learning when writing texts for older pupils and tend to repackage what has gone before.

> *'When you do long division of polynomials at A-level, it sort of always assumes that you know how to do long division of numbers and people don't, these days so you're actually introducing them how, this, I, and big thick books need to catch up to the fact, long division is gone, effectively, from the school syllabus.'* (J)

J and H commented on the value of studying mathematics and its relevance to the digital age and syllabi not being 'up to date'.

> *'… it is much more than what you, the, the actual syllabus that you actually learn and I, I think there's a bit of obsession in National Curricula of listing the 500 things that you need to know. When I was training to become a teacher I had to re-teach myself all these circle theorems because they had not been part of my life for a very long time, they're not very hard to learn But the thing is, they were, I can understand why people think you have to teach them in school, but they're there as a, as a representative of the history of mathematics, they're there as a signifier of, you know, the lineage of mathematics all the way back to the Ancient Greeks.'* (J)

> *'I suppose it depends what you're trying to use the ICT for. Doesn't it? I mean, I tend to use, I tend to use Autograph to introduce 'e', to year 12. Not because I think they'll use it, they'll want to be able to look at it that way in the exam, but because it's a good, it's a good illustration. I mean, there are some dreadful topics at A-level, which computers seem to make horribly redundant. I guess we shrug and tolerate them. It would be a lot better if we didn't have to. It seems odd to have a, for a tool to exist that we ignore, but the complexities of using it properly in an exam do seem quite difficult. The grammar school when I left were just adopting, well, letting some students choose to do the IB in the sixth form, and the IB leans a lot more heavily on graphical calculators.'* (H)

My Maths and Mangahigh are seen by some teachers as useful as they include assessment tools which, as interviewee H mentioned are used at his school to help students know what they needed to do to improve. Interviewee K believed some of her pupils had developed their understanding of concepts by using the games whilenterviewee H could also see benefits in using MyMaths and Mangahigh because of the culture in his school, as it allowed students to move to the next level by trying out something new.

> *'I think that as a whole my school is quite keen on target setting and students knowing what they need to do to get to the next level and that sort of thing, so My Maths, or more recently, Mangahigh have been fitted into that quite well … But I think we probably end up using the kind of MyMaths a lot … I guess that is driven a lot by the school being quite obsessive about students knowing what they're up to themselves a bit more'.* (H)

The influence of examinations plays a major part in focusing schools and teachers and F commented that he used MyMaths saying,

> *'… well I think they encourage people to use things like MyMaths and so our school did get MyMaths for kids to practice questions on, which a lot of the kids loved, unfortunately, you know I, I didn't like it very much but they would ask can we use MyMaths. They like the success, I think. Some kids would like to go onto MyMaths and do something quite easy and get them all right, and the little ticks go on the screen, they get a lot of satisfaction from that. And so I was torn between sometimes thinking, well let's get that out of their system then, let's just do a lot of that and, and thinking that this just isn't a good use of time so I think exams have encouraged that sort of software to be more and more widely used.'* (F)

H commented on calculators and public examinations such as GCSE, GCE A-level in the International Baccalaureate (IB) and wonders what would happen if the more advanced calculators were to be allowed.

'… I've got a graphical calculator that will solve problems algebraically, and the kids wouldn't be allowed to use it in an exam. We had it as a sort of experiment to see how good they were, and whether it was worth the students having … It's quite interesting to try A-level problems when you've got a computer algebra system in your hands. It does make it sort of quite different, sort of feeling you're doing it with a CAS calculator … at the end of C4 where you've a huge amount of integration to do. you look at a problem and kind of figure out what tool should I be using to make this function and how do I get this to work, and ok, what sort of integration is it? The calculator doesn't care, it just works it out. So it would be interesting to know if we let them use them are we really losing a skill and, how much do we need them to be able to integrate by hand?' (H)

S made comment on examination influences on ICT use:

'I think unfortunately yes. I mean you know, whichever way you look at it, you try very hard not to teach to the test, but you also know that you're going to be judged by students' exam results, and particularly at our school we are very much, you know, they've pushed the target levels up from what they used to be and so the students are supposed to be making so many, so much more progress and the bottom line is, that's not always possible, with students… yes I think exams filter down actually, way too much.' (S)

The interviewees suggested that examinations and the material presented in textbooks is not a reflection of current society because of the lack of inclusion of technological resources. However with pressure to help students 'pass the test' software such as MyMaths is seen as a way to do 'drill and practice' at an individual's own level. S46 commented that the way they were taught was, *' … more targeted for the exam, websites and course-specific material on the internet narrowed potential mathematical experience'*.

7.2.3 Integrating ICT within mathematics teaching

In this section the findings from teacher questionnaire and interviews are supplemented by the findings from questionnaires given to first year mathematics undergraduates. The software teachers and students use has been included in this section to ascertain range and purpose.

7.2.3.1 Software

Reasons given in both the questionnaires and the interviews for using ICT, or not, fell into several categories which were both teacher and student focussed. Out of 35 teachers who responded to question 8 (benefits) fourteen mentioned engagement or interest by the pupils, making comments such as *‘Lessons are more alive, engaging, interesting. Children enjoy learning’* (T4), *‘It engages disaffected learners, it produces general interest, it prepares pupils with essential skills’*. (T5*),* *‘children more engaged, can adapt their learning and make progress relevant to individual needs’* (T11) added *‘Individual learning. Pupils can work at their own rate. Can keep them focussed’* (T27). Twelve mentioned pupil independence as being a factor, one teacher (T1) writing, *‘Investigative - pupils can discover things for themselves by playing around with software*’. Eleven identified that it encouraged or enabled an investigative approach with the same number mentioning the dynamic possibilities, *‘Provides students with opportunity to discover more for themselves’* (T20) and *‘Exploring mathematics and being unable to 'undo' mistakes. Ability to work dynamically’* (T25). Some mentioned that it provided better access to the curriculum, with seven mentioning visualisation, including *‘able to visualise graphs/geometry in different dimensions. Easy to understand if able to visualise rather than imagine it in head’* (T15) and *‘helps visual and kinaesthetic learners. Engages students. Shows concepts in a way chalk and talk can't’* (T13).

6 out of 10 interviewees commented on the increased engagement of pupils by offering them variety and a chance to be active learners. Five of this group mentioned that they used YouTube demonstrations of concepts and revision support.

S was asked if she ever used anything off the internet. She replied,

> *‘Oh, yeah, absolutely. All the time. And it’s quite often sort of the YouTube sort of things get the kids’ interest in, so we’ll use it, because we have hundred-minute lessons, it’s quite useful to use it as a sort of snap-back, where you put*

something up, snaps the kids back into what you're doing, and then you can pick up again with what you're doing. Yes.' (S)

J put the case for integrating ICT to help pupils who need to practice/see numerous examples reach a higher standard by exposing them to higher order skills and concepts.

> *'I like having the IT there, if it helps people to focus on the higher order stuff, the issue is, of course, they're then ultimately examined on the lower order stuff as well. So they have to be able to do both. It, it's very easy to get students who are very good at thinking these things, but because they can't churn through five hundred different procedures, they don't end up getting as good marks as the ones who can.'*

The interviewees gave more explanation to the manner in which they used software:

> *'a lot of the things I want to do are to do with being able to show relationships and show how things depend on other things, so lots of dynamic geometry and things, showing, just things like moving, moving tangents round curves and things like that, which I like doing with Autograph and then I may, when we're doing the Further Pure Maths, get them to work out the general tangents of an equation and then putting it in and showing the calculations so that they can either have a bit of a laugh when it goes off the curve and does something weird or just see that that's what they're doing. That it's not, it's not a fixed thing.'* (A)

He had also been working with colleagues in Economics:

> *'I'm actually working with someone in our Economics department on creating some dynamic graphs using Geometer's sketchpad, so that they've got the, the economic principle is about certain lines moving on the graph, and different areas represent profit and loss, so I've constructed it as a geometric construction, to illustrate the points so that they can move it around and now we're looking at using the ipads with sketchpad explorer so the students can*

move them around and then show the graphs they want, so I'm quite excited about that, I'm quite, I don't know it's a bit silly really, I'm quite excited about talking to other people about what they can do in their lesson.' (A)

I asked participants and interviewees about the programs they commonly used (Table 7.7 and 7.8). In examining this data I became aware of the limited variety of mathematically specific software being mentioned by teachers, trainee teachers and students in-spite of there being much free and paid-for software available (Appendix A7). Some generic programs such as Excel and Word are used by teachers for administration and for projecting tasks rather than being used in a learning activity.

Table 7.7 Mathematics use of software given by questionnaire respondents

		Questionnaires (n=32) as %	
Type	**Example**	**Use by teacher**	**Use by pupil**
Generic:			
Spreadsheet	Excel	59.38	53.13
Word processing	Word	68.75	46.88
Presentation	PowerPoint	75.00	43.75
Database	Access	28.13	15.63
Internet:			
Internet resources	BBC	78.13	71.88
Subscription sites	MyMaths/Mathsnet	62.50	65.63
Games/Puzzles	Cool Maths	59.38	50.00
Mathematical Tools:			
Dynamic Geometry	Cabri II, GeoGebra	50.00	50.00
Graphing Software	Autograph	43.75	31.25
Grid Algebra		12.50	15.63
Logo			
Integrated Learning System	Successmaker, Sam Learning	12.50	15.63

The teacher interviewees tended to use only a limited range of software with six out of ten mentioning that they used websites or the internet for information regularly in their teaching. Amongst this group there is greater reported use of software that is more open ended than in the questionnaire group.

Table 7.8 Summary of software usage by teacher interviewees

Type	Example	Mathematics use given by interviewees	Number (n=10) as %
Generic:			
Spreadsheet	Excel	Algebra, statistics, variables	100
Presentation	PowerPoint		70
Internet:			
Subscription sites	MyMaths Mangahigh	Drill and practice	50 30
Resources	YouTube video		40
Mathematical Tools:			
Dynamic geometry	GeoGebra Cabri Geometers Sketchpad	Geometry	70 30 40
Graphing package	Autograph	Statistics, variables	100

Both Table 7.7 and Table 7.8 show that there are only a limited number of programs in regular use by teachers. Many of those were used outside the classroom, including administrative tasks. In the interview sample there is a wider range of software being used, including a greater percentage of exploratory programs. Subscription sites are mentioned less frequently by the interviewees. Use of the internet covers many activities from revision sites to videos to small apps. Subscription sites such as MyMaths present activities that are personal to the pupils and are used in some schools for homework or 'cover' lessons. Other software that was used included Logo (2) and Derive (1). Graphics calculators were mentioned as being used by 3 people. This limited range is also evident from the student responses with 26 out of 40 mentioning graphing (Autograph (7) or GeoGebra (1)) and Excel (7). The student group were also asked about their school experience of using mathematics software and whether pupils as well as teachers were using it in class (percentages have been calculated to allow comparison with teacher data in Table 7.9).

Table 7.9 Teacher and student use of mathematics software

N=40	Teacher only	Student only	Both	Not used
Spreadsheet	4 (10.0%)	2 (5.0%)	34 (85.0%)	0
Dynamic geometry	2 (5.0%)	0	4 (10.0%)	34 (85.0%)
Graphing	11 (27.5%)	0	22 (55.0%)	7 (17.5%)
Logo	1 (2.5%)	1 (2.5%)	12 (30.0%)	26 (65.0%)
MyMath	1 (2.5%)	0	12 (30.0%)	27 (67.5%)
Integrated Learning	1 (2.5%)	0	8 (20.0%)	31 (77.5%)

This group were only asked about these specific programs, but it illustrates the narrow range of software used and that more of these post-A Level students had access to spreadsheets and graphing tools than would have been suggested by the teachers' responses.

7.2.3.2 Interactive Whiteboards and Virtual Learning Platforms

As mentioned in chapter 2 (literature) interactive whiteboards are to be found in many classrooms although not all teachers have access to them. Interviewee K commented that when her teaching area was created there was insufficient money for interactive whiteboards but she does have ten computers and projectors in the room which enables pupils to share their work simultaneously with others. From the student responses the data projector appears to be a worthwhile tool. S3 commented on graphing complicated functions via the projector, enabling display via the computer onto a static whiteboard. Interviewee A (who taught in a sixth form college) suggested that the interactive whiteboard might be more appropriate for younger students. Comments from some of the students showed limited use and problems with using technology.

> *'There was an interactive whiteboard but it was rarely used, as it generally took up a lot of time, and in high ability classes wasn't really very useful. It was good to have variety sometimes, but generally old-fashioned methods were good'.* (S1)

Other students also commented on how it was used.

> *'the interactive white boards were exactly the same as normal ones. The graphing software could just have been replaced by actual graphs held up by the teacher. Most of our lessons were from books anyway, using tables etc.'* (S21)

> *'teachers usually took a preference to show slides so they didn't have to write anything on the board, which in my opinion hampers learning.' Two other revelations came from S37 and S41 who said, when asked if technology made a difference, 'The majority of maths teachers at my school prefer to teach only with a whiteboard' and 'Not in my case anyway. Teachers would mostly go back to using a whiteboard'. Two others gave similar responses. However others did comment on the merits of using a whiteboard. S9 said, 'It changed the way we were taught, in that teachers were able to draw much more accurate (and understandable) graphs, or produce effective and clear diagrams etc.'* (S29)

S21 commented on the ability to keep the class together,

> *'Yes, being able to project things onto a screen allows everyone in the class to learn more simultaneously, whereas from a book is more one-one learning, where I mean if you get stuck you ask for help individually, whereas on the*

board you are likely to ask a question and it will be answered to the whole class.' (S21)

These last comments resonate with those of Miller et al. (2005) regarding improved presentation but do not imply that an interactive whiteboard is necessary. Of the students questioned only five said that there was no interactive whiteboard in their mathematics classroom, but only seven of the thirty-five said that students as well as teachers were able to use them.

7.3 Discussion

This chapter sought to answer question three,' How do mathematics teachers' use ICT in their teaching?' When computers were introduced into schools there seemed to be an expectation that teachers would adopt a more constructivist approach to teaching (chapter 5). However schools have prioritised technical aspects of using technology and subject content over pedagogy (Hennessy et al., 2005). Chapter 5 established that the introduction of technology into schools and the focus on getting the hardware to work allowed little attention to how teachers integrated IT into their teaching.

More recently the government mandated teaching ICT through curriculum subjects and teachers have been left to learn and teach programs as well as use them as a subject resource (Selinger, 2001). Many teachers are unaware of the opportunities afforded by using ICT and alternative ways of teaching mathematics. Studies such as the OECD (2015) report have not found that levels of achievement are significantly raised by ICT, however this report assessed the use of ICT to deliver the curriculum and not as a tool to aid understanding or in motivating learning.

7.3.1 Teacher Beliefs and Pedagogy

7.3.1.1 Beliefs

I suspected there would be a variety of factors relating to personal experiences and interests that would influence a teacher's perspective on using ICT and so asked questions of both the questionnaire participants and the interviewees about their previous experiences of ICT, explored and discussed as chapter 5. Only younger mathematics teachers would have in-school experiences of using computers as pupils themselves. Thus I felt it worthwhile to explore their experiences when evaluating whether using ICT enhances learning. There is, potentially, a self-perpetuating cycle, those who have had positive experiences see the benefits and look for resources and opportunities to use with their students, those with no or negative experiences need convincing of the merits before they contemplate using ICT. The teacher and trainee questionnaires responses also identified themes found by Ruthven at al. (2004) in their study of teacher's perspectives on successful ICT use in secondary mathematics, also mentioned in Swan (2005). Similar benefits such as engagement and pace were reported in both sources.

The data showed a resemblance between two of the questionnaire groups (trainee teachers and teachers) and the interviewees. However, the data also illustrates that teacher/trainee teacher perceptions of benefits to students do not necessarily match that of the students themselves, especially in terms of engagement. The age range of the student sample was low as they were all in the 18 to 23 age range while the teacher (T) and trainee (TT) sets of questionnaires both covered wider age ranges. The data from groups (T) and (TT) presents a picture of a high percentage of existing and potential teachers being unconvinced about the benefits of using ICT for teaching and learning; only engagement (45.5% (T) and 34% (TT)), visualisation (24.2% T) and pace (22.6% TT) were mentioned by more than 20% of each sample.

As Table 7.6 shows the student sample demonstrated the same priorities as the teacher and trainee groups. As these students were studying mathematics at university it is likely that they would have shown more engagement with the subject at school than other pupils. Students expressed a dislike of teachers using PowerPoint and said that they do not always use ICT properly, making learning less effective. One person went as far as to say that teachers were incompetent in using IT and this caused problems with class control. Only 14.7% of students mentioned increased engagement as a benefit and this did not match teachers' and trainees' who rated it as the highest benefit. The students' reasons for this were not explored in this study but would make a useful subject for further research.

For teachers, interviewees and students there was an agreement that using ICT helped with the visualisation of concepts and Autograph software was identified as particularly good at doing this. The student, teacher and trainee ratings for benefits of ICT use were much lower than that of the smaller sample of keen ICT using interviewees. For students, visualisation (55.9%), clarity of presentation (29.4%) and pace (26.5%), scored the highest. Rather than clarity of presentation teachers and trainees were scored on ease of explanation which scored 15.2% and 17%. For interviewees visualisation and interactivity (both 80%), were followed by pace and investigative (both at 70%) with immediacy and engagement (60%). The results from the interviewees indicate more interaction with ICT and an open style of teaching that included pupils investigating in comparison to the trainees and teachers. The data did not indicate that amongst the trainees and teachers there was widespread use of ICT for explanation and problem solving nor were opportunities being taken to develop wider use such as presenting real-life scenarios. This closed approach potentially leads students to have a vision of mathematics as a set of procedures to memorise for examinations, seeing cues and following them. Taking such a stance means that they are unlikely to see the benefits of using ICT in an open-ended investigative way. Their results on the questionnaire of helping to investigate (2.9%), problem solving (2.9%) or to get immediate feedback (5.9%) are thus unsurprising. Looking critically, there may be other reasons for the responses of all groups including their personal confidence with ICT and their educational experiences including the constraints and barriers mentioned in chapter 6.

Benefits of using IT by the student and teacher participants in this research were seen in the data, they included:

- supporting processes of checking, trialling and refinement, such as that seen in calculator use, and dynamic geometry
- enhancing the variety and appeal of classroom activity for example through use of video and internet for resources, presentations, and producing graphs using graphing packages

- fostering pupil independence and peer support illustrated by being able to self-correct to produce a ‘good’ piece of work, and working in collaboration, encouraging discussion, experimentation
- overcoming pupil difficulties and building assurance
- focusing on overarching issues and accentuating important features.

The mathematics undergraduate student sample offered insight into effectiveness of using ICT, some, including S9 and S21, commenting on the change in the way they were taught and that ICT helped them to be able to visualise representations. When asked about the way that ICT helped them to learn comments included that of S5 who said, ‘*Clear visualisations of things and quicker calculations*’. With multi-functioning programs such as GeoGebra, the ability to make connections between different areas of mathematics such as algebra, tables, and graphs without having to spend time in repetitious drawing was seen as important. Clarity of presentation was also important to the students as ICT enabled drawings to be accurate and to be completed quickly. Eleven of the forty students mentioned that using dynamic programs, especially Autograph, for graphing helped their understanding of concepts, whilst others commented on the ability of ICT to help them to do calculations quickly and handle statistics efficiently. As S44 pointed out, ICT removes the tedium of repetitive tasks such as calculations and graph plotting. This was also mentioned in the literature (Selinger, 2001; Ruthven and Hennessy, 2003; Monaghan, 2004; Tanner et al., 2005; Swan, 2005). Many of the comments made by teachers regarding the positive outcomes of using ICT were also mentioned by the undergraduate students. As suggested by interviewee S2 instant feedback offered by programs, some work and revision sites were seen as a definite positive contribution to learning, particularly those that identified weaknesses.

7.3.1.2 Pedagogy

Based on the literature review I anticipated that mathematics teachers who use ICT would use investigative approaches for teaching and learning mathematics as suggested by authors including Duchâteau (1995), and Ruthven et al. (2004) and that the use of ICT would enable a shift in teaching from a transmissionist model to processes and investigation. I looked for evidence to confirm or contradict this in both questionnaires and interview responses. The teachers who were interviewed did not see ICT as an essential everyday approach but used ICT when they considered it would make a difference, whether by using it to illustrate concepts or for encouraging pupils to develop their thinking. Instead of finding a shift to the constructivist model of teaching amongst the interviewee group I found all the interviewees (including A, C, H and W) reported that they have flexible mix of teaching styles including ‘teaching from the front’, adapting their approaches with different classes, subject area being taught or situations which do not fit firmly into a transmissionist or constructivist model of teaching. Neiderhauser and Stoddart (2001) and Levin and Wadmany (2006) expressed the view that there is a continuum between transmissionist and constructivist approaches which would support the findings that the interviewees were flexible in their approaches. The interviewees, as a group, indicated that they chose to use an investigative and less didactic style of teaching and, as illustrated by the data, rated interactivity, pace and the investigative opportunities afforded highly. This flexibility of teaching approaches and a willingness to engage with digital technology does, as mentioned by interviewees, student and teacher questionnaire participants and authors including Selinger (2001), Ruthven and Hennessy (2003) and Monaghan (2004), make mathematical modelling more accessible to a wider range of pupils. The interviewees appreciated using the processing power of programs such as Excel, graphing software and dynamic geometry. Such programs enabled skills and content to be addressed through removing the need for repetitive calculation or drawing while improving lesson pace either through immediate feedback or being able to change variables quickly.

If teachers are to make changes to their pedagogical practice to incorporate more ICT then changes in their pedagogical beliefs may be necessary. Support to identify how coverage of the curriculum can be enhanced using ICT would also be required. Since there is no requirement to include technology, a lack of suitable pedagogical training and little evidence to suggest that student results are improved by using ICT (OECD, 2015, p.3), teachers have no reason or encouragement to change their approach to lesson delivery to incorporate ICT. Interviewees and questionnaire participants (including A, R, T1, T6, T22 and T25) suggested using computers enables subject content to be seen in different ways, leading to a culture of enquiry by the pupils rather than teacher exposition. However, in adopting a more ICT-rich environment, issues such as teacher comfort, class size, the mix of students in the class, time to learn a new approach, time to find or develop new resources and the ability to convince other teachers in a top-down culture that this is an effective way forward need to be addressed. Changing the way one teaches involves an element of risk and may change the roles of both teachers and pupils, especially where pupils are to be given more autonomy over their learning, and reactions will reflect past experiences. Interviewees recounted positive early experiences of using ICT apart from C who remembered using a program (Logo) at school that she did not understand, suggesting that teachers need an awareness of the learning that is taking place and to provide support where needed. This was countered by a very positive experience when she was training to be a teacher.

All interviewees said they were prepared to take risks and to try new approaches of which the outcome was not pre-determined. The risk factor was mentioned by interviewees (including A when working with Autograph) in that they were prepared to let students experiment when the outcome was not always as expected and was also featured in literature McLoughlin and Oliver (1999); Loveless and Ellis. (2001); Ruthven and Hennessy (2003) who suggested that preparedness to take risks reflects a teacher's personality, self-confidence, belief in what they are about to try and their personal situation in their institution. The students' group, including S44, mentioned that 'instant feedback' enabled them to experiment and try out ideas that they would not have the inclination or time to do if working 'by hand'. However, students in the questionnaires suggested that where teachers became more relaxed, some students would take the opportunity to mis-behave and this caused problems (chapter 6). Risk is discussed further in chapter 8.

7.3.2 Curriculum influences

Although many of the topics taught in the English secondary mathematics curriculum are open to the use of ICT, and there are suitable resources available to teach much of the curriculum, constraints and barriers (chapter 6) exist. Examination syllabi are not in tune to the technological world (interviewee H), but are rooted in the days of little access to digital technologies (much of the current secondary mathematics syllabi content at GCSE level is similar to that of 50 years ago). The lack of fit to modern society encourages teachers to ‘play safe’, not seeing the need to change from what, for them, are tried and tested methods which they know, through their past experience, will enable many of their students to pass the high-stakes examinations. Interviewee J reflected that people do not need to do long division in their lives and careers but the curriculum carries an expectation that this has been covered in earlier years of schooling. He felt that the curriculum is about learning topics that are not used in everyday life. As mentioned in chapter 6, the high-stakes examination culture opens the way for programs that ‘test’ pupils on short questions such as MyMaths and Mangahigh as they reflect traditional ways of teaching mathematics in disconnected chunks. Teacher F stated that such programs were used rather than those that support the development of mathematical concepts such as spreadsheets, graphing programs or dynamic geometry as they did not need to be learned by the teacher. Some pupils chose easy tasks to get ticks on such programs although it would be possible to challenge themselves using these programs. In the questionnaire responses, T1 commented that the two ‘testing’ programs might result in overuse as a proper teaching replacement and TT27 stated that pupils who liked to be successful might choose easy options (rather than being challenged to develop their mathematics). F added that he believed examinations have encouraged programs such as MyMaths and Mangahigh and so feel ‘safe’ for teachers to use as they become administrators.

Computer use was identified in the literature (Drenoyianni and Selwood, 1998) and the data as having two purposes, firstly as a tool and secondly as ’something to learn with’. It is how this second purpose is addressed that provides a challenge to teachers and students themselves. The students identified often negative changes in how lessons were conducted; they cited problems such as the lack of knowledge and confidence by teachers and how they were not always equipped to deal with technical issues. Other comments mentioned that teachers would give individual support resulting in long waits and un-productive time (also a chance to misbehave) as computer use tended to be at an individual rather than whole class level. This lack of teacher confidence, ability to provide pupils with timely support and enthusiasm diminishes the effectiveness of using ICT. Ofsted (2002) found much the same and stated that that it is ‘the effective application of ICT across subjects that needs to improve most’. In the last few years mobile technology has been introduced in the form of netbooks, tablets, ipads, smartphones and wireless communication so potentially making ICT more accessible within the classroom. The rise of social media such as Twitter, Facebook and YouTube has allowed people to share their opinions, experiences and resources more widely so bringing discussion to a wider audience.

7.3.3 Integrating ICT within mathematics teaching

7.3.3.1 Software

In considering the reasons for the integration of ICT into mathematics lessons benefits such as raising achievement and preparation for life after school should be included, as well as ICT’s role in assisting teaching and learning to become more efficient. F said that ICT activities are ‘bolted-on’ in many widely used texts either within a chapter or as a separate chapter at the end, neither of which supports integration. This was illustrated in the reference to Key Maths and Cambridge Interact texts in the literature review (chapter 2 section 2.4).

This study found that mathematics teachers only use a limited number of mathematical programs (Table 7.7 and 7.8), which ties in with work done by Forgaz (2002). The list of software suggested by the teacher participants does not suggest any enthusiasm to discover the availability of wider resources. Logo and graphical calculators, once a named part of the curriculum, were rated as being used rarely. The limited range of software teachers in the questionnaire and interview samples mentioned illustrate the narrow experiences of ICT in school mathematics students are offered. In the questionnaire sample the use of word processing and PowerPoint by the teachers in mathematics was high (68.75% and 75%) compared with pupil use (46.88% and 43.75%) which could be accounted for by use for lesson presentation. Drill and practice programs e.g. MyMaths and Mangahigh were also listed as widely used. These are designed to need little input from teachers when running a session and pupil performance is recorded digitally. Greater pupil use than teacher use might be expected but from the teacher data it was 65.62% to 62.5% whereas the only use reported in the student data was by a teacher.

The questionnaire participants showed only 50% were using dynamic geometry software that enables visualisation via accurate drawing, instant feedback when changing variables and links geometry with algebra. All the interviewees were using at least one of dynamic programs, free-source GeoGebra was used by 70%. Amongst the other software Excel was used by over half the teachers and their pupils in the questionnaire sample, and by all interviewees.

7.3.3.2 Interactive whiteboards and learning platforms

Not all the comments by the students were positive regarding teaching and some reported not using ICT in lessons. Watson (1993) mentioned that teachers' enthusiasm for ICT is important, where teachers have had poor experiences of using ICT, suffer from a lack of confidence or negative feelings, they will be reluctant users. Although the negative comments (made by 26 out of 40 students) reflected a range of issues, such as the use of ICT when the teacher had not planned a lesson, some described IWBs being used as blackboards or a display tool for pre-prepared work or resources, rather than making use of the included tools. This led several to feel that using ICT was a waste of time for both teaching and learning. It seems likely that these negative viewpoints will contribute to their beliefs if they should become mathematics teachers in the future.

There has been an expectation that IWBs and VLPs are used with little or no training for teachers considered necessary. As with much of the technology placed into schools, and the potential of whiteboards is frequently under exploited (Cuban, 2001; Rossi, 2015). Such use frequently does not meet the criteria for quality ICT use as described by Back et al. (2009) as the interactivity is not used. Comments made by interviewee W suggested that IWBs could be liberating for teachers as they enabled teachers to face the class when putting work onto the board. Wireless input devices mean that inputs could be made anywhere in the room which was mentioned by W and D in their interviews. The availability of 'visual manipulatives' in the IWB package, e.g. measuring tools and geometric shapes, enabled more accurate representation than can be achieved by hand and produces a higher quality and understandable display. None of the teachers or trainees mentioned the in-built IWB tools but as interactive board training was not widespread, they may have been unaware of their existence.

Virtual learning platforms/environments were also part-funded by the government through Becta and provided opportunities for communication within school, between colleagues and students, within school and off-site, parents/carers and the wider community as shown in Figure 2.2. In real terms school websites tend to be used for general information and showcasing the work of the school along with email communication with parents. A school-based intranet can be used in a similar fashion with external access via passwords. Little mention of VLPs was made by the participants in this study apart from the lack of training to set one up and use it, schools changing from one provider to another within a short space of time and schools being left to 'do the best they could' (interviewees K and S). This raises the issue as to how much of a teacher's time should be spent on setting these systems up and managing it and whether there are real benefits for teaching and learning above those of the simpler systems. This again points to top-down management.

7.4 Summary

This theme sought to answer research question 3 **'How do mathematics teachers' use ICT in their teaching?'** Teachers' beliefs about using ICT are affected by their experience of learning about ICT both formally and informally and vice versa. Teachers highlighted positive and negative aspects of using ICT. The barriers and constraints mentioned in chapter 6 included the role of textbooks, examinations and government, school and departmental policies. Where teachers were engaged with ICT they worked to overcome any barriers, adapting pedagogy to the situation and looking at how ICT could support learning, for example using dynamic programs, including Autograph and spreadsheets, to investigate the effect of changing variables making more complex ideas accessible. From the data it was seen that the use of ICT did not have the effect on pedagogical approaches that early pioneers expected, and was more in line with that suggested by Cornu (1985) and Neiderhauser and Stoddart (2001) as even those teachers who use ICT regularly in teaching mathematics said they transferred between transmissionist and connectionist teaching approaches according to circumstances, such as subject content and the class context.

The top-down conformity to national, school and department expectations including public examinations discussed in chapter 6 seems to have reduced risk taking and creativity. This coupled with the lack of adequate training on software and technology itself, including the introduction of and changes to VLE (VLP), has meant that there is an under-utilisation of resources that can enhance teaching and learning. Teachers do not know how to use the resources available. Time is needed to learn to use resources and this did not appear to have been provided by the participants' schools. Training to using mathematical software was rarely paid for by the school and several teachers had to pay for courses themselves or self-teach so that they could use software effectively.

Participants said that they use few of the available ICT resources (Appendix A7) including those which are content free such as Autograph and GeoGebra. Generic programs including PowerPoint and those sold as pupil "testing" tools or integrated learning systems (Table 7.7) were in use. Teacher use was reportedly higher than pupil use apart from programs designed for pupils (e.g. MyMaths, MangaHigh). For generic programs teachers said they used them more than their pupils, particularly PowerPoint. Teachers used the internet, including YouTube, to find resources, information and for demonstrating techniques enabling presentations to include material not available in non-digital classrooms.

Opportunities to use ICT are not highlighted in the national curriculum, examination syllabi or textbooks so many teachers are unaware of the potential support that using ICT can afford. Sharing of resources and files with colleagues via IWB and the VLE(P) can reduce workload but the time taken to create resources and learn to use the software often makes this inefficient unless the time is provided by the school. This is referred to as 'perceived usefulness' in the technology acceptance model (Davis, 1969) and subsequent iterations including those by Taylor & Todd (1995) and Venkatesh and Davis (2000).

While all participants highlighted benefits to using ICT, students and teachers did not agree that engagement was the most positive factor, but rather agreed with the interviewees that visualisation was the chief benefit. Students highly rated clarity of presentation whilst criticising over-use of PowerPoint. Using manipulatives such as Autograph and GeoGebra to assist understanding were considered positive as were the online MyMaths and Mangahigh programs. These programmes would be used by pupils rather than teachers.

Chapter 8 The teacher as a learner, from ITT to CPD

Research question 4 – 'What training have teachers had in the use of digital technology?'

In chapters 5 to 7 the issue of access to professional development was raised. This chapter addresses the question of how teachers learn to use ICT by considering the teacher as a learner from initial training to continuing professional development. The discussion in this chapter seeks to answer the research question: What experiences of digital technology training have teachers had? This study recognises that CPD is more than courses and that it includes self-teaching, working with peers and reflective practice. It considers how and when learning might take place and the effectiveness of different formats from the viewpoints of participants. The study looks at one course in particular (Technology for Secondary/College Mathematics (TSM)) and considers the approaches used by the tutors, including interviews with two successful trainers (B and M) who facilitated the course.

Two of the interviewees (L and R) offered training in their previous roles as local authority advisors while others (notably B, D, M and T) were doing so at the time of the research. As part of my research I became involved in CPD for mathematics teachers in the use of ICT, notably dynamic geometry and Grid Algebra for new users. I reflected on the type of information that they found useful from their verbal feedback given during the sessions which I recorded in field notes. Subsequent sessions were adapted in the light of this information. I also attended courses at conferences including sessions at TSM led by B and M to put myself in the place of a learner experiencing self-directed learning and a taught course. This course was mentioned by participants as being especially useful in their subsequent teaching.

What makes good ICT training?

As an example of an effective course mentioned by teacher interviewees and a NCETM report (2010) I will review TSM. This course illustrates how teachers can be successfully trained to use software in their classrooms. Two presenters commented that they had learnt from personal experiences and adapted their presentation style in an effort to accommodate all attendees by using mixed methods.

The groups were ‘mixed ability’; the tutors were experienced and had developed strategies to enable everyone access to at least part of the tasks i.e. there was differentiation, for instance, newcomers learnt how to set up macros, more advanced users used them to develop own resources. The availability of ‘friendly - experts’, attentive to what learners could do, rather than not do, encouraged learners to experiment without feeling judged. Use of pre-prepared instructions on paper at the session, also accessible via the internet with tutor contact details, enabled learners to start to learn tasks and then revisit later as required.

B, a TSM trainer, was asked about engaging learners:

‘*When I set up Teaching Technology in Secondary Mathematics, (TSM), it was very important thing to realise, that if you're going to do any training you must base it on your own experience… I think the absolutely critical thing to realise if you're using technology in the classroom is that it must be done interactively, you cannot just sit there and do it, because you might be having a lot of fun, but if pupils just watch it's no good, they've got to interact. I still think the overriding principle is that pupils must be engaged, all the time, and all of them, not just the few who are following you*.’

The TSM courses included sessions on using Microsoft Office tools and specialist mathematics software as well as training participants to become trainers themselves. B and M were asked what made them become interested in training other teachers. B explained:

‘*Well, I could see that the potential was just so enormous, and yet so many teachers ... strangely enough, you would expect mathematics teachers to be the first to embrace this, but I gather research suggests that only about 25% of maths teachers are using IT at all in secondary, which is scary. I mean, the other 75% are really missing a trick. But I think most of them are scared of it. They're scared of it* *going wrong, and being compromised by something not quite working where it should, and of course the extra practice they've got to do is not something they're prepared to invest the time in. And if it goes wrong, you must have a plan B…Support was minimal really, which again is the other problem. I mean, a lot of schools struggled to get adequate support. A number of schools I visit now, because I do quite a lot of that, and it's just not set up right, the screen resolution's wrong, thing's out of focus, aspect ratio is wrong, circles for ellipses, I've seen them all. ... I think the thing that really does disappoint me is that people don't realise that mathematics has special needs for IT*.'

M said his involvement followed a grant from the Gatsby Foundation to develop mathematics resources using Excel and included the condition he disseminated his work. So he shared the resources, following an invite by B, at a TSM conference, where he was inspired by another presenter who was running an investigative workshop. He eventually ran his own sessions using the same model.

All TSM presenters were asked about their audiences, and how they coped with the different levels of competence and confidence. MH said,

'*you can get anyone from someone who's actually quite a beginner to someone who's got a huge amount of knowledge, you know, I mean it's such, … it's such a wide range, so you have to be prepared for almost anything*.'

B stated that recently delegates are often self-funded and had obtained 'permission' to be out of school. Therefore it can be assumed that the course was populated by people who already had an interest in using ICT.

'*I remember particularly one guy who said "I came to your workshop and thought I knew a lot about Excel, now I realise I don't. You've totally blown my mind". So you get that, people think they're advanced and then they realise they're not.*'

8.1 Literature links

Including ICT in teacher training was suggested by Cornu (1995) and Stevenson (1997). There is evidence that this has not been the case (Wild, 1996) and NCETM (2010). Hammond et al. (2009a) suggested that pre-service training was influential but that its effectiveness also related to the teacher's experience on placement. For teachers in-service Hodkinson and Hodkinson (2005) found that there were different approaches to professional development, restrictive and expansive (Table 2.1, section 2.5.2), and depending on which was adopted by their schools the teachers would have very different experiences. In the RECME report (NCETM, 2009) there were five recommendations for CPD including time to be given to teachers and that schools should support teachers in trying out new ideas.

Teaching teachers to use resources with pupils demands particular skills, especially as adults expect to know why they need to learn something (Ablea, 2009) so teachers should be included in planning for their needs (Holmes et al., 2002) to give ownership with training tailored to preferred learning styles (Honey and Mumford, 1982; McLeod, 2010). Learning needs depend on where the learner sits on the adopter-laggard spectrum (Rogers, 1983), their confidence with technology, attitude to risk illustrated by Vygosky's zone of proximal development (Tinsley and Leback, 2009) and resilience (Gu and Day, 2007). Past courses, a facility to follow-up (Holmes et al., 2007) and their own competence will influence teachers attitude to integrating ICT and taking further training.

For some teachers who would, according to Rogers (1983) be innovators, the option of 'informal learning' is likely to be selected. Hoekstra et al. (2009) considers informal learning should receive workplace support through interaction with colleagues which should ideally be recognised as a community of practice. This interaction could be virtual as well as face-to-face (Boud and Middleton, 2003). Knowles (1975) also described the self-directed learning route where pro-active learners take ownership and responsibility for their training. More recently Zimmerman and Schunk (2008) have shown how accessible help or support can lead to an increase in both motivation and persistence. The in-house cascade model is now commonly used due to increased financial pressures but has limited impact (Harland and Kinder, 1997) in developing teacher's skills.

8.2 Data

In this section, I present data from the responses to the questionnaires and interviews related to the question, 'What training have teachers had in the use of digital technology?' The first part, data from the initial teacher training cohort, is from questionnaires given to two groups of trainees who have completed a first placement of in-school training plus data from two local authority teacher trainers on school centred initial teacher training or SCITT (N, R), two involved in PGCE training at a university (L and D) and five tutors involved in five university-based ITT (four secondary (BB, NN, RR, SS), one primary (PP)). The data looks at their experiences of training in ICT related areas, the amount of training they received, the types of software they have met and how they have found out about any software they use. The second part moves onto teachers in-service, and follows similar themes, looking at the experiences of training and the software used by two sets of teachers through questionnaires and ten teacher interviews. The third part focuses on the interviewees as learners and trainers and on teacher interviewees.

8.2.1 Participants involved in Initial Teacher Training

The interview participants based in university departments provided initial teacher training (ITT) for undergraduates studying a BA degree or a one-year postgraduate certificate in education (PGCE). Another interviewee was involved in SCITT. The questions asked what experiences trainees would have in the use of ICT as part of their courses.

8.2.1.1 Expectations of use, trainees

In response to a question about the current expectation of use of ICT by mathematics trainees tutor L commented in 2010 that, *'TDA says trainees are to use IT as much as possible in any subject'*. Other comments included:

> *'Mainly presentation, Interactive Teaching Programs (ITP) and modelling on whiteboards. Some use video clips to support learning. Trainees share their*

experiences and ideas for resources. There is a section on IT on the course and this includes Logo and control. This is led by the IT person, but there is a move to integrate IT within the course subjects. Presentations including use of ITPs and videos, use in problem solving including calculators and control (use of robots). Their assignments can be done using ICT and their audit is done on line. There is an expectation that they will use the internet for their research. The maths element amounts to 9 days, of which 3 days are admin so there is not much time to extend the student's knowledge. There is an expectation, e.g. using whiteboards to develop skills. It is easy to enthuse about the use but there is also a need to remain focussed on how it is to be used with pupils. Yes, Logo and spreadsheets, but not on dynamic geometry at the moment.' (N)

'In the PGCE course at Cambridge, I taught Excel and Cabri. … I downloaded GeoGebra and played with it, using my previous experience of Cabri, and reflected on my use of IT.' (D)

In answer to the question whether it is expected that training be offered on both generic and subject specific software, the following replies were offered:

'In the early days, teachers didn't know much about computers, I had to be very patient and most of the training was technical rather than pedagogical. The idea was to get fluency using machines rather than spreadsheets or Autograph or Geometry. Latterly there has been a reluctance to use IT. There is an assumption that it is more than a book – it is an aid to make life easy. Trainees do not have knowledge of elementary geometry to enable them to use Cabri. They are not seeing opportunities for using IT. The usage will go down – or it will be trivialised as they go through the motions of following a recipe. Pupils need proper tasks to get them going. '(L)

'Training on generic software is not really needed, where someone does need help other students offer support, i.e. collaborative learning. Generic training is needed more by existing teachers than the recent students. I do show Excel in a problem-solving context along with Logo and control, software for tessellations and also use the Primary Strategy materials but show pitfalls as

there are good and poor ITPs. This evaluation of resources is an important part.' (N)

In the five short interviews with tutors of ITT courses question 1 asked if the trainees were experienced in the use of ICT before the course. Responses included: *'Completely mixed, some are ex-IT people while others are straight from college'* (NN), *'Very mixed, some second to none, to people who are very confident. We use the confident ones to help the others.'* (BB). Question 2 asked about the age range of the trainees, to which the four responses were 22-50+years, 22-52 years, 23-43 years, 22-25 (primary tutor did not give age range) with gender being approximately half male and half female. The first two were similar to the two groups of students who took part in the questionnaires (although set B were biased towards the older age group). These tutors were asked about the amount of mathematics specific tuition that would be provided on their courses. Responses were very variable from:

> *'It is built into the teaching and includes geometry and spreadsheets... We use YouTube which can provide amusement so sticking in the mind.'* (BB)

> *'Timetables – virtually zero, it is up to the tutors. There are 16 ½ days for everything. There are voluntary sessions for about 10 hours where they can play.'* (RR)

Once on placement there was no expectation that schools would encourage ICT to be used. When the interviewees were asked about training (Q7) two out of the four (NN and SS) mentioned training to use interactive white boards, a third (RR) stated there was not enough training. The fourth did not specify if there was any expectation of using ICT.

The next question asked the secondary tutors what software they used giving a choice of spreadsheets, dynamic geometry and graphing package. Two (SS and BB) said all, one (RR) said only generic software while the fourth (NN) said, *'Logo is covered briefly but not Autograph as our institution will not put it on'*. One (NN) said that tutors modelled using ICT to present and two used mixed methods, such as showing followed by hands on, another used peer teaching (BB). When asked if the students were able to get support only one (NN) said they could make contact by email, phone or return to the institution. (Table 8.1).

All five tutors responded to the question did they know if the trainees had opportunities for training while on placements? All said they had access to training to use IT as part of a demonstration, but only three out of five said they had training to use IT with pupils working in small groups and whole class.

Table 8.1 Support to trainees

	Software	Presentation style	Support
SS	spreadsheets, dynamic geometry, graphing package	Mixed methods, incl. hands-on	In principle yes
BB	spreadsheets, dynamic geometry, graphing package	Peer teaching	Informal, do need link post-qualifying
RR	generic	Mixed methods, incl. hands-on	Up to tutors
NN	Logo	Tutor modelling	Email, phone, return to institution

The next question queried if school factors played a part in the level and quality of trainees' experience when using IT. The responses included, *'Lack of modelling and inconsistent support'* (NN), *'Some see good stuff, but this is a small minority'* (RR), *'Very varied. Some don't have software, ICT does not always work, staff not confident. Some do notes on PowerPoint, MyMaths might be used as homework rather than being interactive'* (SS). This contrasts with the comment from the primary tutor who said, *'Lots, opportunities to share when back from practice, i.e. supporting each other'*. School experience of using ICT was mixed, one secondary (BB) and the primary (PP) reporting that it was positive, one that there was a range

(SS), a small minority found it negative (RR) while the fifth said experience was neutral (NN).

The final question to the secondary tutors asked for the most influential factors on ICT use in lessons. The comments were as follows:

> *'Whether they have a keen mentor who models and expects the use of ICT. Whether they are/have been enthused by a tutor and have the mindset to put in the time and energy to use it.'* (SS)

> *'Mentors pushing the use of ICT and expecting it to be used. Only having an IWB so forcing people to use it. Down to time!'* (RR)

> *'Confidence in package. Need to see benefit e.g. visualising, as IT has both obvious and hidden learning.'* (BB)

> *'They need to be sufficiently strong minded and independent to get past the 'fuddy' teachers. They need confidence.'* (NN)

The lack of time for IT in the course does not appear to be a new situation. One of the teacher interviewees (D) recalls '*I did my PGCE in '95 my tutor led a session on Logo. That was the only ICT I did. I did program a clock in Logo – it would draw a face and the numbers*.'

8.2.1.2 Teacher trainees

I was interested in determining how the trainees on ITT courses viewed their self-confidence in ICT as the amount of time devoted to working on ICT skills was limited. I asked whether current ITT trainees felt competent to use ICT in the classroom and what software they knew about. In the two sets of trainee teacher's questionnaires I asked whether they had received any ICT training post school or college. Both samples included people who had previously been in different occupations as well as those for whom teaching was their first career. Of the first set of 25 (Set A) thirteen had received previous training. The trainee questionnaire data included a question asking how competent they felt after their first placement in the five scenarios. Table 8.2 shows how Set A (n=25) perceived their own competence.

In the questionnaires given to a second group (Set B) of 23 trainee teachers (who had just received an hour of training on GeoGebra) ten had received some formal IT training since school or college, one having done a joint mathematics/IT degree and had gone into computing as a career, another was a programmer. They rated their level of ICT competence as shown in Table 8.3.

Table 8.2 Confidence when using computers (trainee set A)

	Very competent	Competent	Fairly competent	Not competent	Don't know
Own use (n=25)	10	10	5	0	0
Presenting to others (adults)	5	14	6	0	0
Presenting to others (pupils)	4	15	6	0	0
Demonstrating programs to pupils	3	11	9	1	1
Pupils interacting with activities	2	12	6	2	3

Table 8.3 Confidence when using computers (trainee set B)

	Very competent	Competent	Fairly competent	Not competent	Don't know
Own use (n=23)	7	9	6	1	0
Presenting to others (adults)	3	7	10	3	0
Presenting to others (pupils)	2	6	9	5	1
Demonstrating programs to pupils	1	4	7	4	7
Pupils interacting with activities	0	3	9	3	8

In judging personal competence there is no scale by which the trainees are measuring, so in some ways this can also indicate a personal view of confidence in using what they already have working knowledge of.

The trainees were asked about their familiarity with different programs and software packages, whether they would use them in the classroom and how they found out about appropriate software. Table 8.4 shows Set A results and Set B results are shown in Table 8.5 with combined results from sets A and B in Table 8.6.

Table 8.4 Familiarity with programs and software (trainee set A)

N=25	Internet ideas for teaching	Internet resources with students e.g. NRICH,	Spreadsheets	Databases	Word processor (incl. showing the task)	PowerPoint	Dynamic software e.g. GeoGebra	Graphing package e.g. Autograph	Integrated Learning System incl. MyMaths	Grid Algebra (ATM)	Mathematics games
Familiar with	24	24	24	19	23	24	21	21	12	2	23
Would use	22	21	21	10	19	21	19	17	7	3	20

Table 8.5 Familiarity with programs and software (trainee set B)

N=23	Internet ideas for teaching	Internet resources with students	Spreadsheets	Databases	Word processor	PowerPoint	Dynamic software e.g. GeoGebra	Graphing package e.g. Autograph	Integrated Learning System	Grid Algebra (ATM)	Mathematics games
Familiar with	17	15	15	10	17	18	9	6	14	1	8
Would use	11	12	15	11	10	10	13	15	15	7	12

Table 8.6 Familiarity with programs and software (all trainees) as %

n =48	Internet ideas for teaching	Internet resources	Spreadsheets	Databases	Word processor	PowerPoint	Dynamic software	Graphing package	Integrated Learning System	Grid Algebra (ATM)	Mathematics games
Familiar with	85	81	81	60	83	88	63	56	54	6%	65
Would use	69	69	75	44	60	65	67	67	46	21	67

In both sets I noted that the respondents were familiar with programs or software that can be used productively in mathematics teaching. However, there were those who stated they would not use such programmes. The two sets were asked, 'How do you find out about programs or files that might be useful to you?'

Table 8.7 Finding out about programs and software

Finding out from:	TT Set A	TT Set B	Total
Other people	23	22	45
Course	23	17	40
Internet	23	17	40
Computer magazines	3	2	5
Teaching magazines	15	12	37
N =	25	23	48

The two groups of trainees and the teacher participants were asked about the efficacy of different training methods they had experienced. Although I expected training sessions were only one type of training experienced, trainees were asked to consider the different elements of training sessions and rate them. The responses from the trainees seem to indicate that sessions could start with a demonstration, followed by an electronic or printed sheet of instructions which the participant follow as part of the learning process. For those self-teaching, instructions might be presented electronically (video, e-manual, on-line tutorial) or be paper based. Use of these instructions may or may not be preceded or followed by a period of exploration.

Both trainee and teacher questionnaires gave six or seven methods used in ICT training and they were asked to rate them on a five-point scale, including no experience of that method. The criteria were as follows:

- Excellent – able to use program easily afterwards
- Good – able to use afterwards with a little more help
- Poor – needed to use another method afterwards
- Ineffective – not able to use the program
- No experience of this method.

The six methods given to all were:

- Exploration (experiment with the program yourself)
- Demonstration (just watch a presentation)
- Hands-on session (shown program by someone familiar with it and try under their guidance)
- Following a manual or printed sheet of instructions
- One to one tuition (peer or teacher)
- Video clips and help files while trying out a program

A seventh (On-line tuition) was added after a participant pointed out they used this method which is becoming more commonplace. Trainee Set A (Table 8.9) were not asked about on-line tutorials and no-one mentioned it as an alternative approach. Results are shown in Tables 8.8, Table 8.9, and Table 8.10. In both sets there were 2 nil responses to this question. These results were then combined and presented as a percentage to adjust for the different sample sizes producing Table 8.10.

From these tables, exploration and hands-on with others were shown to be more effective in a training environment than being passive and working in isolation. The opportunity to work one-to-one with a friend or mentor was highly rated. This will be discussed further in 8.3.2.

Table 8.8 Training format (trainee set A)

Training format set (A) n= 25	**Excellent**	**Good**	**Poor**	**In-effective**	**No experience**	**Total**
Exploration	9	8	2	1	3	23
Demonstration	2	6	10	1	4	23
Hands-on	9	10	1	0	3	23
Manual	1	10	7	1	4	23
One-to-one	9	3	3	0	8	23
Video tutorial	3	4	9	0	7	23
On-line tutorial						0

Table 8.9 Training format (trainee set B)

Training format (set B) n = 23	Excellent	Good	Poor	In-effective	No experience	Total
Exploration	8	10	2	1	0	21
Demonstration	0	13	6	0	2	21
Hands-on	9	11	0	0	1	21
Manual	1	12	7	0	1	21
One-to-one	4	12	1	0	4	21
Video tutorial	2	11	4	2	2	21
On-line tutorial	2	12	4	1	2	21

Table 8.10 Training format (all trainees) as a %

Training format (all trainees) n = 44	Excellent	Good	Poor	In-effective	No experience
Exploration	39%	41%	9%	5%	7%
Demonstration	5%	43%	36%	2%	14%
Hands-on	41%	48%	2%	0%	9%
Manual	5%	50%	32%	2%	11%
One-to-one	30%	34%	9%	0%	27%
Video tutorial	11%	34%	30%	5%	20%
On-line tutorial	10%	57%	19%	5%	10%

8.2.2 Teachers in service

As with the two trainee samples, two groups of teachers (TW and TS) were asked the same questions about where they found out about software or programs and how effective they found different formats of ICT training. The results are shown alongside the trainee results (TT set A and TT set B) from Table 8.6 and shown in Table 8.12.

Table 8.11 Finding out about programs and software, trainees and teachers combined

Finding out	TT set A	TT set B	TW	TS	Total
Other people	23	22	15	11	**71**
Courses	23	17	12	8	**60**
Internet	23	17	12	9	**61**
Computer magazines	3	2	1	0	**6**
Teaching magazines	15	12	5	7	**39**
N =	25	23	16	11	**75**

These figures demonstrate the power of courses and the internet and especially ‘word-of-mouth’ to spread possibilities for using ICT.

For teachers the same criteria for inspecting the types of training were used and the results are shown in Table 8.12.

Table 8.12 Training format (all teachers)

Training format (teachers) n = 29	Excellent	Good	Poor	In-effective	No experience
Exploration	6	15	3	4	1
Demonstration	5	8	5	11	0
Hands-on	16	11	1	0	1
Manual	3	15	7	1	1
One-to-one	9	17	0	0	3
Video tutorial	7	13	6	1	2
On-line tutorial	4	10	7	2	6

The teacher responses were combined with those of the trainees to give a larger sample as this related to learning of adults rather than whether they were in training or teaching and presented as a percentage n=73 for all six, with the on-line n=50. This is shown in Table 8.13 and Figure 8.1.

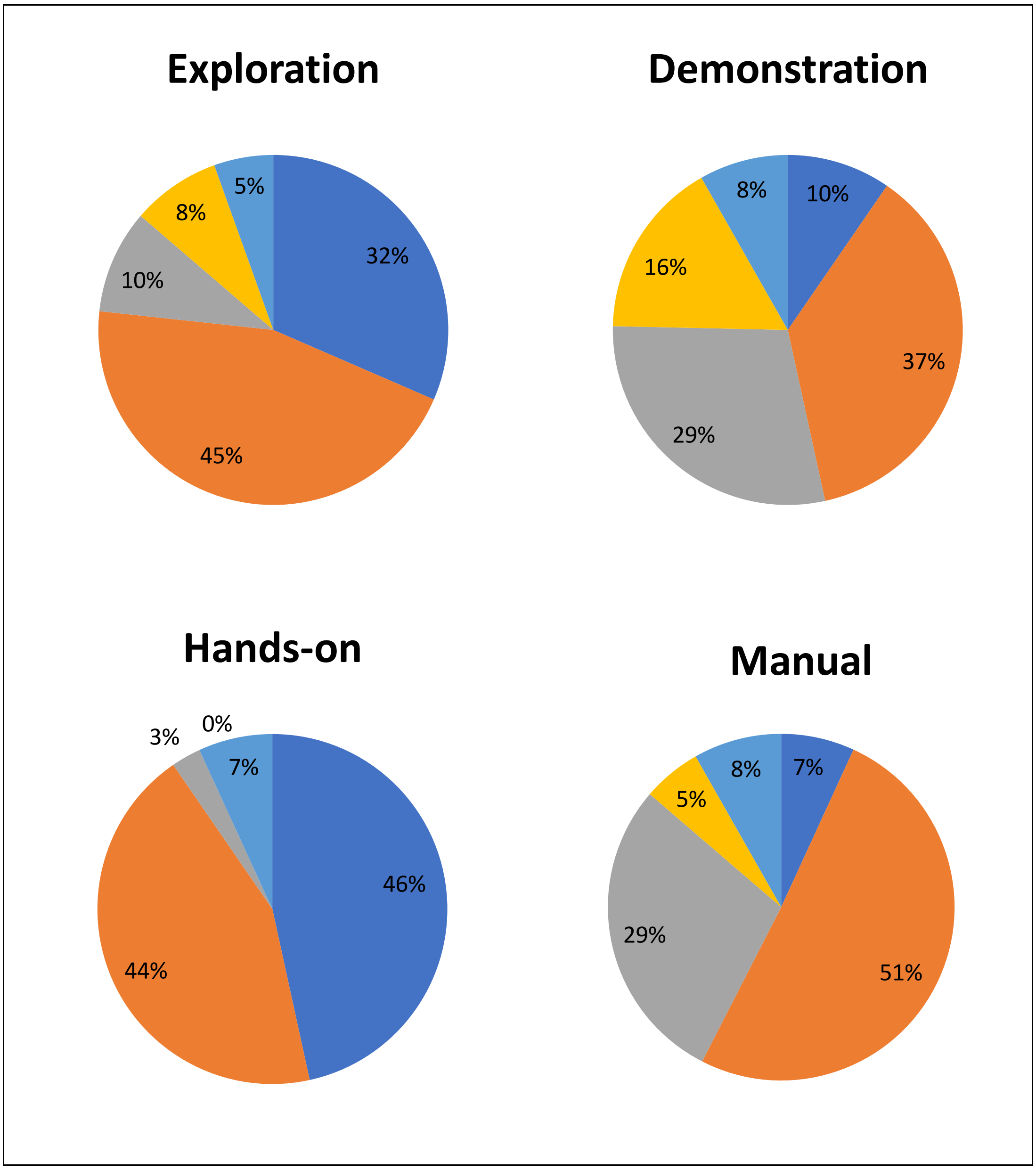
Table 8.13 Training format (teachers and trainees combined)

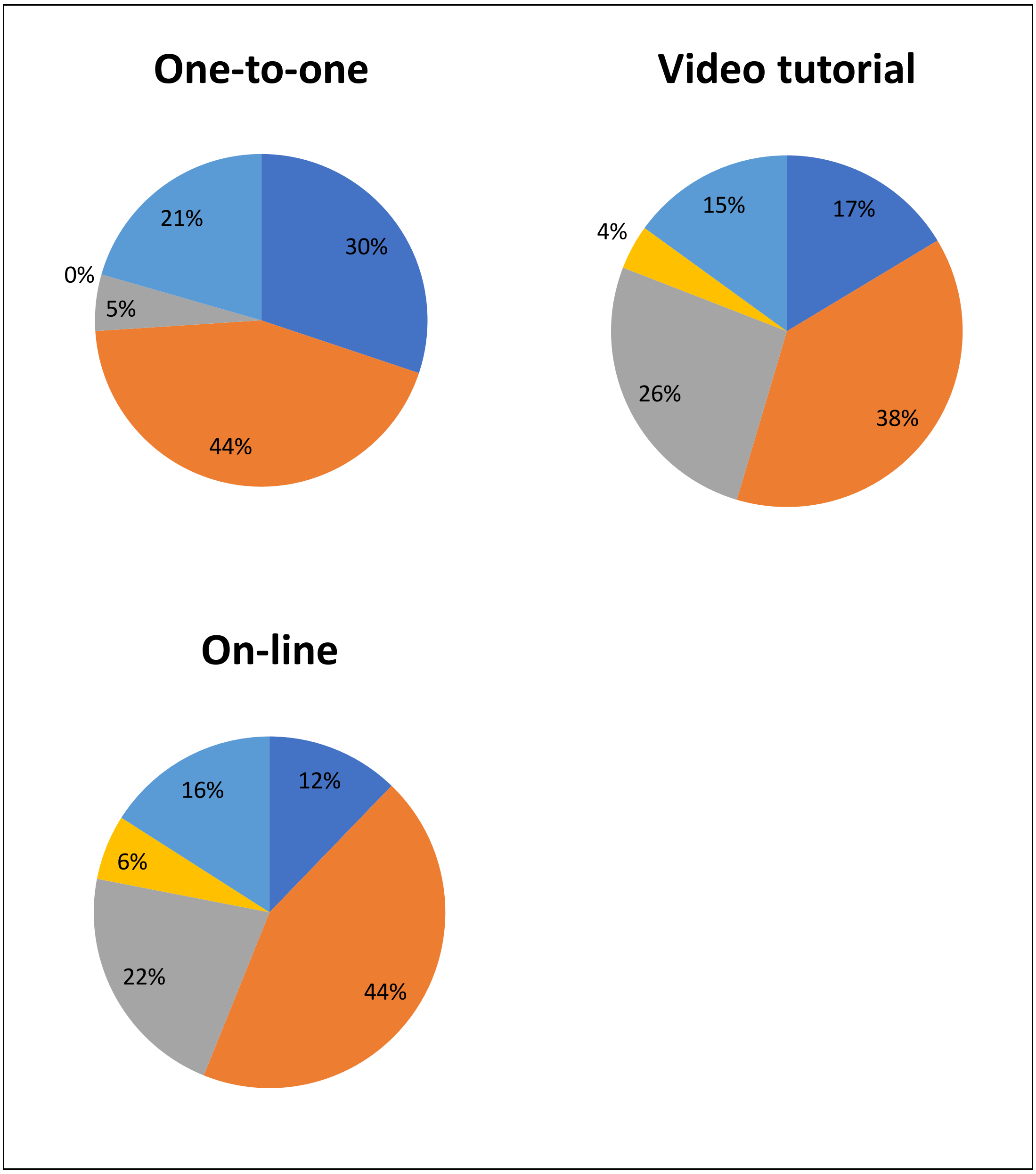
Combined n = 73	1 Excellent	2 Good	3 Poor	4 In-effective	5 No experience
Exploration	32%	45%	10%	8%	5%
Demonstration	10%	37%	29%	16%	8%
Hands-on	47%	44%	3%	0%	7%
Manual	7%	51%	29%	5%	8%
One-to-one	31%	44%	5%	0%	21%
Video tutorial	16%	38%	26%	4%	15%
On-line tutorial	12%	44%	22%	6%	16%

These figures produce the following charts with the numbers corresponding to the five criteria shown above which are:

1. Excellent – able to use program easily afterwards
2. Good – able to use afterwards with a little more help
3. Poor – needed to use another method afterwards
4. Ineffective – not able to use the program
5. No experience of this method.

Figure 8.1 Training formats (teacher and trainee combined results)





The number of participants who had no experience of the different methods was not consistent so the combined percentage was recalculated to account for this (Table 8.14).

Table 8.14 Presentation methods (all trainee and teacher questionnaire participants)

Combined	Positive		Ineffective		No experience		N=
Exploration	56	76.7%	13	18%	4	5%	69
Demonstration	34	46.6%	33	45%	6	8%	67
Hands-on	66	90.4%	2	3%	5	7%	68
Manual	42	57.5%	25	34%	6	8%	67
One-to-one	54	74.0%	4	5%	15	21%	58
Video tutorial	40	54.8%	22	30%	11	15%	62
On-line tutorial	28	56.0%	14	28%	8	16%	42

In this study, teacher participants were invited to take part as they believed ICT had potential, and were interested in continued learning, as demonstrated by attendance on courses or participation in conferences. This led me to wonder how the teacher interviewees, who were all experienced users of ICT for teaching, found out about the potential of software. The questions provided the opportunity to explain how they first became involved with computers (Table 8.15). Eight of the teacher interviewees recalled that they had computers or graphics calculators at home when they were young and were influenced by parents. Some (including A, F, H, J, K, M, and P) followed a computing course at school or as part of their first degree or HND. Several (including A, C, D, F, H, J, K, M, P, W, and S) mentioned either ATM or TSM conferences as being places they had learnt techniques. However the percentage of secondary mathematics teachers (35,200 registered in 2011 and 32,800 in 2012 (DfE, 2012b, 2013c)) who attend such events is very small. In 2012 there were 180 delegates at MA’s annual Easter conference, 246 delegates at ATM’s Easter conference and 112 at TSM conference in July (figures provided by conference organisers). Not all delegates at MA and ATM conferences were secondary mathematics teachers and some went to more than one conference. Taking all these possibilities together the number of teachers receiving this training is a very small proportion of the whole teaching force and for this reason the interviewee sample is not typical of the mathematics teacher population.

As with questionnaire respondents the interviewees mentioned learning from friends and colleagues, also former work experience (prior to entering teaching) and self-tuition.

Table 8.15 Training sources of interviewees

	Home	School	Ist degree /HND/MA	PGCE	ATM/MA Associations	TSM	Friends/ colleagues	Work	Self- taught
A	✓		✓	✓	✓				✓
B						tutor	✓	✓	✓
C		✓		✓					
D	✓			✓					✓
F	✓		✓		✓		✓		✓
H	✓		✓			✓			✓
J	✓		✓	✓ school	✓	✓	✓		✓
K	✓		✓		✓			✓	✓
M			✓			tutor	✓		✓
P	✓		✓			✓			✓
S		✓	✓			✓			
W	✓		✓	✓			✓		✓

Only P and S stated their school paid for the TSM training, F and D stated that they had had no paid-for ICT courses since qualifying to become a teacher. The majority of interviewee teachers said that they were self-taught, often by exploration but they had also attended courses or sessions on particular pieces of software at conferences. M said that he saw someone at school doing some interesting things in Excel. When he obtained a Gatsby foundation grant to develop materials he approached this, as other interviewees have also done, by thinking of something he wanted to do, then searching for advice using the internet. S attended the 2012 TSM conference to upgrade her skills in Autograph and Excel; she explained that although she had used IT to teach primary age pupils, she was not a confident user and liked to work with others and talk about how they used it in the classroom. D was inspired on his PGCE course and has since been tutoring on a university PCGE course teaching Cabri and GeoGebra to trainees as well as teaching in a school mathematics department which he considers have a good community of practice. He is self-motivated and learns to use features of programs by experimenting. He says *'I downloaded GeoGebra and played with it, using my previous experience of Cabri, and reflected on my use of IT.'* Asked about his training experiences H said,

> *'I did three days at TSM probably ten years ago which I suppose was a lot of Autograph so maybe that's pushed me towards using it myself a bit more… I'm very good with Excel, but that is entirely self-taught and I think a lot of just kind of seeing what other people can do and asking them how they do it, but that's not with any particular purpose so much as just wondering what other people have managed and realising I could use it too. I guess… the teachers I see in school that are better with IT are brave enough to try things themselves and, I mean, they'd like some training to get them started but they are prepared to go away and figure things out a bit and play a bit and see what happens. And those that aren't making much progress aren't trying much in-between times. I teach myself and ask others – but usually discover I know more than them!'* (H)

P attended the TSM 2012 conference, his school had had Autograph trainers brought in. Asked about how he learnt programs he said, *'Mostly, 95% of the IT I've taught myself. I'd always been aware that you could add functionality and customise things using programs, exactly why you want. I actually first sort of got into it when I sort of exhausted other things and I just learned, pretty much mastered, just about everything in word and then in PowerPoint, and then I'd sort of gotten into using Excel, and I was aware you could write macros which could add a new level of sophistication and somebody brought back from some, some training he brought back this little thing that sort of got you started on macros, literally just a couple of sides, just getting a start with a very, very simple macro explaining the first stages and I, so I, I took that as, you know, I grabbed that as soon as I could and he said 'oh, you'd be interested?' and I said 'yeah, give it here, give it here so I grabbed that and digested it and then just basically went from there and just gradually got more and more ambitious, writing more and more complicated programs, so, and you know, just seeing, well I just liked pushing boundaries and seeing if I could do something that, that seems a bit insane.'* (P)

The influence of a PGCE course where use of ICT was included encouraged W and now friends and colleagues play a part.

'I've got a number of good friends who are maths teachers, some have used it [Excel]. I say "It's nice can you show me how??" and now I've shown it to some other people and things just filter through.' (W)

J is another person who attended a TSM conference and found it 'a lot of fun'. He had also experienced some in-house training at his school run by other teachers.

'…but in terms of some specific training for, for programs to use in teaching, we haven't really had all that much. There was, you know, you, you get a little bit of internal staff training at this school, for example there've been a couple of sessions, not run by external people necessarily but run by other teachers in the school on things like using interactive whiteboards, using equations into Word nicely, or how to use the new version of Word or all these things. Rather than ones that are, they're not training sessions. Or someone in a department

meeting might say 'here's a nice computer program I use'. Or someone at a maths conference might try and convince you that, the program they use or the program their stand is selling is the best thing ever. Or ones that I've just found by browsing round the internet and seeing interesting things that have come up. Um, must have been, for example, how I found um, GeoGebra, which is a piece of software, well that and Autograph are probably the two pieces of software that aren't just office programs that I use most often.' (J)

J also goes onto say that his department are individualistic so will only use what is right for them:

'How do I learn to use new resources? Um, it is mainly through you playing with them yourself but I'm, I'm aware that even with the stuff I currently use, there is a, they have a lot of capabilities that I just don't have time to properly get to grips with. Um, interactive whiteboards and interactive whiteboard software, for example, do a lot of quite interesting things. The issue is, not just that um, sometimes they're not very discoverable, they're not very easy to learn, but that to use them properly you have to put quite a lot of time into preparing things before you use them. And the amount of time you have to spend preparing them is often out of all proportion to the amount of time you spend using them. But in terms of what encourages me to use it, I'm not sure. In terms of teaching, I would use IT if I think it will actually enhance what I'm doing in the teaching situation.' (J)

The next four interviewees attended an ATM Easter conference. A said that he did not recollect any specific training after his PGCE apart from training to use the college learning platform. He said that a lot of his CPD has been at ATM conferences on software such as Autograph and Geometer's Sketchpad. He said that he learnt from seeing them being used or presented then deciding on what he wanted to achieve and seeing how he could do it. He said that he tended to 'have a go' and see what happens.

‘Some interesting things have come out of it that I have not expected sometimes, so I learnt a bit of geometry about the senses of maths from playing around with something I wanted to do for one of my lessons.’ (A)

K has also had no formal training since PGCE although she did receive some training on Autograph and Excel at the time of the NOF initiative (1999-2002). She also said that it has been at ATM conferences where she learnt how to use Cabri, otherwise she has been self-taught, including how to use GeoGebra. C trained more recently than the others and training in Autograph and GeoGebra was included in her PGCE. She has found her department supportive in the use of IT,

‘…people find nice things on the internet, see there was a thing that reflected something in four different quadrants and you knew that and it copied it in the four, and people are sharing things and using them or they got a set of YouTube videos of a lady doing amazing stuff with Fibonacci sequences and stuff all on YouTube and very, very fast and that was exciting.’ C

She also mentions that she ‘*plays around with systems’ when they change.’* When F was asked about paid-for training:

‘I don’t think so, no, everything I’ve learned I’ve learned myself or I’ve been shown by somebody, I guess, but not, not for money. It’s just experimenting, really, I suppose I’ve seen sessions at conferences where people have done things and thought oh I could try that, mainly by experimenting and articles in Mathematics in School. Mathematics Teaching have often had lots of ideas, I think of Adrian Oldknow’s articles particularly, his use of curves to fit real-life scenarios often interested me… I was involved in a Becta project where it was sort, it was, I think it was teachers writing up good practice and [name] organised it and a number of us went up to London and spoke about something IT-wise that we’d done in the classroom, and so I picked up quite a few interesting ideas there. I think mostly from, from seeing what colleagues do or reading about lessons in, in professional journals.’ (F)

Asked about how he would approach learning to use a piece of software A said, *'I think a lot of it can come down to just deciding on something I've wanted to achieve and seeing how I could do it. I'm quite a big believer in starting with what you want to achieve and working out how the software can do it for you rather than getting a piece of software and trying to work out what you can do with it. I tend to have a bit of a play with it, to be honest on the grounds that most things that are well-written, you can't really do much to break them anyway, so, you know if it's written well you have to try really hard to actually break it, you have to be trying to do it, so I tend to just have a go and see what happens. Some interesting things have come out of that that I've not expected sometimes, so I learnt a lovely bit of geometry about the senses of maths from playing around with something I wanted to do for one of my lessons, which was good, I tend to [teach more or less yourself] when it's my teaching. I do tend to work out what I want to do for myself.'* (A)

M responded to the question by saying,

'Yeah. With the aid of internet forums and things like that, and some experimentation. The disadvantage is sometimes it takes you several years to find out something that's really useful, you know.' (M)

M also described how producing video clarifies ideas in his own mind. He also commented on the need to be persistent and to be able to know how to research something including using forums to find out a way to achieve his vision. K commented on her learning, *'So a lot of it has been self-taught and finding stuff and seeing what other people are using.'* As mentioned in the previous section the majority of interviewees had learnt about different programs and software from friends and attending courses, particularly ATM and TSM conferences. J reflected on his experience,

'Before I started the job here, I went to the TSM course … Douglas Butler's, course which is a three-day course on Autograph and Excel, effectively and that was a lot of fun.' (J)

He went on to describe how at his school they had internal staff training and colleagues might suggest a computer program. He said that he also came across programs on the internet and that is how he came across GeoGebra. On learning new resources F said,

> *'… a mixture I suppose, I think courses haven't played a very big part, really, sometimes they've, things like ATM sessions where someone's done something I've often thought that looks quite nice, but mainly really by reading and just playing around seeing what's possible, trial and error experimenting.'* (F)

ATM conferences were mentioned again.

> *'It was an ATM conference where I learned how to use Cabri. I mostly used it through the conference and persuading the school to buy it when they were buying things.' (K)*

Communities of practice were also important and are mentioned by D who ran an interactive whiteboard network in his county while H spoke about his department working together.

> *'I think, a kind of culture for the department that we're all meant to make things and share them and it's not meant to be the leader who does all of the creating and the rest of you just take it away and use it. My current school's a lot better in that aspect of, of believing that we're in this together and, you know, it doesn't have to be perfect to make it worth sharing and we know that even something you write, when you use it again with a different class, you think 'oh dear, what was I doing with that? I'll, you know, I'll need to' and I think once you've done that yourself with your own resources you, you worry a bit less that somebody else's isn't quite what you had in mind either. Yes, and electronic ones are usually easier to edit, and, and skip bits, and it's not like a worksheet you give out and then realise you didn't like half the questions, at least on the screen it's must easier just to gloss over a page or something if, yeah, you don't really want to use it so much.'* (H)

Working with friends is another source of information.

> *'I've got a number of good friends who are maths teachers, some have used it. I say, "It's nice can you show me how?" and now I've shown it to some other people and things just filter through (umm) which is quite good… I am lucky with friends and colleagues and staff who are also keen, very IT literate, so we can share ideas and resources and experience.'* (W)

When looking at the transcripts certain characteristics seemed to appear. All interviewees had done some programming in the past, whether Logo or BASIC at a home/school level or a higher order programming language such as Fortran, Pascal or C++. They were all self-motivated and, apart from one (S), said that they were confident in the use of ICT in their classrooms. The results are shown in Table 8.16.

Table 8.16 Teacher interviewees-self-analysis

	Program writer	**Creative/ creator**	**Risk taker**	**Experimenter /explorer**	**Flexible**	**Self-motivated**	**Confident**	**Musical**
A	✓	✓	✓	✓	✓	✓	✓	✓
B	✓	✓	✓	✓		✓	✓	✓
C	✓	✓	✓	✓	✓	✓	✓	✓
D	✓	✓	✓	✓	✓	✓	✓	✓
F	✓	✓	✓	✓	✓	✓	✓	✓
H	✓		✓	✓		✓	✓	✓
J	✓	✓	✓	✓	✓	✓	✓	✓
M	✓	✓	✓	✓		✓	✓	✓
P	✓	✓	✓			✓	✓	✓
S	✓	✓	✓	✓		✓		
W	✓	✓	✓	✓	✓	✓	✓	✓

The absence of a ✓ in table 8.16 only signifies that this was not mentioned in the interviews which were semi-structured, some choosing to talk more freely about themselves and their work in the classrooms. As such, an analysis of the word frequency would not be a valid comparison of the interviewees' traits. There were other similarities between the interviewees. Two key ones were that they did not feel intimidated by technology-aware pupils and their preferred teaching style. When confronted with pupils who were skilled, they said that they learnt with or from them, engaging their skills through checking files before presenting them to the class (J, P) or helping to explain to other members of the class (K). Five of the interviewees described themselves as facilitators or guides rather than placing themselves on the transmissionist / constructivist scale. Six commented that they do use a mix of transmission and constructivist approaches with their class with a leaning towards the constructivist approach. W commented that he changes according to the class, and others (F, D, S and K) describing themselves as constructivists while A described himself as connectionist, i.e. seeing the bigger picture, and using connections across subjects or in the wider world in his teaching. This approach was mentioned by other interviewees.

In the last section I did not include L and R as they had taught mathematics before transferring into ICT advisory roles when ICT in schools was in its infancy. Both had retained an interest in mathematics education. Their profiles closely match those of other teachers interviewed (Table 8.17).

Table 8.17 Interviewees L and R self-analysis

	Program writer	**Creative/creator**	**Risk taker**	**Experimenter /explorer**	**Flexible**	**Self-motivated**	**Confident**	**Musical**
L	✓	✓	✓	✓	✓	✓	✓	✓
J	✓	✓	✓	✓	✓	✓	✓	✓

L and J were both self-taught and drew on experiences of others, including pupils and other teachers as part of their own learning. As their roles included subjects other than mathematics they included these in their exemplars.

8.2.3 Teachers as Learners

The data from the two previous sections shows that teachers and teacher trainees express a preference for learning in many different ways. The issue for trainers is coping with these differing preferences for learning and the different experiences that the attendees have previously had.

L and R were employed by their respective local authorities in the early days of computers in schools, they were allocated very limited funding for training, L recalled that, in his county, only two teachers (often not volunteers) from a school were trained. On return to school these teachers were meant to act as trainers for the rest of the staff.

> *'In the initial stages no, there was no willingness at all, but people were forced into these courses, because it was that business that you've got to have people who could work these. And they were not volunteers, these were people who'd been conscripted. But that conscription grew less, and once the trust was built up … genuine in-service actually took place. … Instead of a one-day course, we should have done residential courses, two-day courses … But those days are over, that level of service is over. It's about being trained rather than educated.'* (L)

Question 16 on the teacher questionnaire asked teachers about preference for training times, whether one day or two days and whole, half or twilight sessions. They were asked to rank their preferences on a 1 to 8 scale, 8 being preferred option. Of the respondents 17 completed the 1 to 8 scale and a further 9 showed their preference (shown right and in bold). Their first and second choices were considered together and their seventh and eighth. The whole day was considered as two sessions, i.e. one morning and one afternoon (Table 8.18). This data would have been affected to some extent by the personal situations of the teachers e.g. ease of attending courses.

Table 8.18 Teachers' preferred time for ICT training

One session			Two sessions				
morning only	afternoon only	twilight	two mornings	two afternoons	two twilights	all day	two days
6	5	4	8	7	3	2	1
4	3	1	6	5	2	7	8
6	5	2	8	7	3	4	1
2	4	3	5	8	6	7	1
4	5	2	7	8	3	6	1
4	5	2	7	8	3	6	1
7	8	2	6	5	1	4	3
1	2	7	5	4	8	3	6
4	5	3	1	2	6	7	8
2	3	7	5	4	8	1	6
3	4	6	5	7	8	2	1
4	3	1	6	5	2	8	7
4	3	1	7	5	2	8	6
5	4	2	7	6	1	8	3
3	4	2	6	8	1	7	5
5	4	6	2	1	8	3	7
8	7	2	6	5	1	4	3
8				**8**		**8**	**8**
				8		**8**	
						8	
						8	
						8	

This illustrates a preference for two sessions by 19 of the participants with three opting for two days or only one session as first choice. Two people opted for twilight sessions for both their first choices but this could reflect the difficulty in attending courses in school time. Table 8.19 looks at the least desired training times.

Table 8.19 Teachers' least preferred times

One session			Two sessions				
morning only	afternoon only	twilight	two mornings	two afternoons	two twilights	all day	two days
6	5	4	8	7	3	2	1
4	3	1	6	5	2	7	8
6	5	2	8	7	3	4	1
2	4	3	5	8	6	7	1
4	5	2	7	8	3	6	1
4	5	2	7	8	3	6	1
7	8	2	6	5	1	4	3
1	2	7	5	4	8	3	6
4	5	3	1	2	6	7	8
2	3	7	5	4	8	1	6
3	4	6	5	7	8	2	1
4	3	1	6	5	2	8	7
4	3	1	7	5	2	8	6
5	4	2	7	6	1	8	3
3	4	2	6	8	1	7	5
5	4	6	2	1	8	3	7
8	7	2	6	5	1	4	3
8				8		8	8
				8		8	
						8	
						8	
						8	

When questionnaire participants were asked what time they preferred, 12 out of 22 preferred a whole day, four two morning or afternoon sessions with two morning and five two afternoon sessions only. Five people said they preferred only one half-day session. Twilight was not popular (11 out of 22) nor was the notion of having a two-day course.

No one format for training teachers stands out as popular and therefore mixed approaches are necessary for maximum engagement. One of the questionnaire respondents (a head of department) responding to the question about times of training sessions wrote, *'I don't like training sessions because out of school training rarely has a lasting effect. Better for training to be delivered by someone at school'*. The quality of that training for staff would need to be assessed against the competence ladder (Figure 2.3).

8.3 Discussion

In this section, I discuss different aspects of teacher education, i.e. initial teacher training, teachers in service and teachers as adult learners in light of the literature and my data.

8.3.1 Initial Teacher Training

Initial teacher training is important in developing the ICT skills of trainees (Hammond et al., 2009a), however my interviews with trainers indicate that despite significant variability in training, it is almost always short, with limited demonstration of available resources. The responses from people working in training establishments, people involved in teacher training and the trainee teacher questionnaires showed that it cannot be assumed trainees will have received the same training on ICT use in the classroom and that any received will be subject related rather than generic. While the students for the most part gauged their personal level of competence to be high (36:12) the picture of self-assessed competence in using ICT in teaching is not sufficiently strong to presume that trainees do not need support. This suggests that there is a case for enabling trainees to attain a higher level of competency at initial training stage, with those who are more competent assisting their peers in learning, so developing their teaching skills. While to some extent a willingness to use ICT (other than an IWB for display) will be based in a person's self-efficacy, as the tutors mentioned, becoming proficient and confident to use ICT when in front of a class or knowing what resources may be available requires training. Placement schools and mentors may or may not be keen on using ICT to teach mathematics, hence consistent experiences are not assured across a cohort, even within a training establishment. To develop skills on placement requires time, energy and motivation on the trainees' part when they are already under pressure to learn many different aspects of teaching. Even where institutional training is available, because of the time involved to build knowledge and skills, trainees can often only receive a superficial amount or a 'taster'. Those who ran the TSM course (B, and M in particular) estimated that at least six hours per programme was the minimum time that was needed to attain some confidence in using software. The Stevenson Report (1997) suggested that the time which was in place then (i.e. 20 to 30 hours) overall was only half the time required.

Although the ITT tutors said there was little time to devote to training in using ICT this is not the situation in all establishments. Hammond et al. (2011) describe a university department where subject ICT training was included, also Hyde et al. (2014) demonstrated that it is possible to engage trainees and placement schools in developing personal and classroom confidence through integrating ICT within training and this possibility was also mentioned by D and L in their interviews who further suggested that most trainees now have a familiarity with generic software. One comment by L indicated the lack of trainees' knowledge in geometry caused problems when learning to use dynamic geometry, preventing the understanding of dynamic and interactive facilities afforded by the software.

The samples A and B also illustrate the variation in trainee cohorts. Set A said they were more competent in using ICT in different situations and as a group were more familiar with software and use of the internet and willing to use it in the classroom than Set B. Thus it cannot be assumed that trainees will have the necessary personal and classroom confidence and skills to include ICT in their teaching in their NQT year. If this is to be achieved more support and training will be required prior to taking on the full workload of a classroom teacher to allow time for consolidation and enhancement of skills. There was no widespread evidence from the data that there would be something in place via training providers once they had completed their training. This resonated with the findings of Hammond et al. (2011).

8.3.2 Teachers in service

Once a trainee enters service there are limited opportunities for undertaking ICT-based training involving release time. The demise of Local Authority training also means there are fewer low-cost courses available and those that are provided are not necessarily open to all teachers in a department. The lack of ICT training provided by schools (internal or external) is pointed out by several of the interviewees, no-one said they had regular access. Short courses, of maybe half a day or after school, are stated to not allow sufficient time to fully engage with the resource and the pedagogy required. The preferred course length and timing as shown in Table 8.18 and Table 8.19 does not fit in with the suggested approach by the Stevenson (1997); McKinsey (1997); Conlon (2004); NCETM (2010) or the TSM three-day conference model suggesting that much longer time is needed.

Courses were mentioned by a head of department in a questionnaire as not providing any lasting benefit, however this conflicts with statements by the interviewees and Hodkinson et al. (2003) who said that they are considered to play a small but significant contribution in enhancing teachers' skills. The belief of that head of department would be seen as a constraint to other members being permitted to take training within school time. The network model that D has set up within his locality, where membership is open to all teachers, provides those interested in technology an opportunity to take ownership of their development and opportunities to meet and discuss with others in a similar situation but with fewer local courses the chance of forming local informal networks with like-minded colleagues is reduced.

It seems that only a small proportion of in-service teachers find out about using technology for teaching mathematics by participating in training courses or conference sessions. Finding out about resources from other people (71/75) featured highly followed by courses (60/75) and the internet (61/75). This suggests that it is possible to reach teachers without them necessarily having to attend courses through contacts with users and the internet. The interviewees said that seeing others doing interesting things in school (M, P and W for example), at a conference or on the internet (J, K and C) led them to try something different. Here subject networks and social networks might have a part to play rather than the more formal setting of conferences. For these networks to work the teacher needs to feel motivated to participate. On the other hand, as mentioned in chapter 6, this does raise the constraint of time availability for the teacher where their institution does not allow time for this form of CPD.

From the interviews, it appears that the majority of those who use ICT have had some previous knowledge of programming, whether in BASIC or languages such as Fortran or C++. Several of these teachers also report that they experienced an element of programming outside the school environment, for example at home or working with others to produce games so were well equipped to deal with a pragmatic, exploratory approach to learning (Honey and Mumford, 1982; Hennessy et al., 2005) that did not always bring immediate success (A, C, J and K). These users of ICT also say that they are self-taught, or have taught themselves how to use fresh pieces or features of software, perhaps in conjunction with others or sharing ideas rather than being trained in its use, i.e. they were, using Knowles (1975) description, self-directed. Those people who were early adopters and innovators (Rogers, 1983) according to Robinson (2009), look for advantages and see the risks as low. Within the interview sample it was found participants were willing to take risks and try out new ideas with their students, this requires self-confidence, self-belief and being well-informed about the product. These attributes have been identified in other research (e.g. Cox et al., 1999 and Hennessy et al., 2005) as being key to the adoption of ICT. These 'early adopters' of new technology are able to look objectively at how a given piece of software enhances teaching and learning and will diffuse what they have found to the next of Rogers' groups, the 'early majority' as described by D and the local whiteboard users group, within a school as mentioned by H or an informal group of friends (W) to develop their own skills. However the influence of 'laggards' i.e. those who see innovation as high risk and are more comfortable in keeping to their traditional ways, can mean that innovations are slowed and may never happen, a theme that was included in chapter 6 as a constraint.

The NCETM (2010) report highlighted the narrow range of software used and even though the interviewees said that they were confident in using ICT their range of use is limited to a few key applications, chiefly Excel (100%), Autograph (80%), dynamic geometry (80%), MyMaths (50%) and internet (100%). They also mentioned the graphics calculator (40%). These figures are much higher than the questionnaire samples which were Excel (53%), Autograph (41%), dynamic geometry (25%), MyMaths (56%), internet (72%). Excel is useful in visualising number and algebra, particularly in seeing the consequences of changing figures in formulae. Although Excel can handle statistics, graphing packages such as Autograph have been written for education and have a far better range of options for statistical analysis and drawing graphs of functions. Autograph also includes elements of dynamic geometry and can be used for 2D and 3D work, Dynamic geometry such as Cabri II and Cabri 3D plus the open source GeoGebra cover the geometry aspect of the mathematics curriculum with the internet providing resources that can be used interactively in any aspect of the curriculum in addition to being an information source. MyMaths and Mangahigh are used for more individualised learning and homework with information and practice pages.

8.3.3 Teachers as Learners

The stages in Bloom's Taxonomy (Anderson and Krathwhol, 2001) can be seen in the descriptions of learning offered by some of the interviewees notably J, M and W as they describe their developing use of ICT. They stressed that to use ICT for teaching, teachers need to be able to instruct and problem solve which are Bloom's (Anderson and Krathwhol, 2001) 'applying' and 'analysing' stages. Thus the learning offered to teachers must motivate and support them to build confidence and become secure before moving to the upper two stages of 'evaluating' and 'creating' their own materials.

When training teachers, experienced trainers such as B, L, M and R recognise that adults are more able to reflect and analyse the worth of their experience indicating a different approach to that adopted when teaching children. They say that the atmosphere should be one with community spirit, rather than a hierarchical teacher/learner one in order to build confidence and trust. The interviewees discussed the particular challenge for trainers of how to engage and motivate all the people in the group who have diverse needs in terms of beliefs, understanding and mathematical content and the need to not waste anyone's time. They said that there must be a variety of formats such as demonstration, hands-on experience of a task, and time for exploration, with time included for reflection (Felder and Silverman, 1988). The trainees and teachers were asked how they preferred to learn ICT. Trainee responses showed they preferred more interactive methods such as exploration (85.4% rating good or above), one-to-one (87.5%) and hands-on (97.5%) of those who had experienced those forms of training. Poor or ineffective methods were topped by demonstration (44.7%), video tutorial (42.9%) and using manuals (38.5%). The tables for the teachers also showed a preference for hands-on (93.1%), exploration (72.4%) and also for one-to-one tuition (89.1%). Manuals were valued by 62% of the teachers. As for trainees, demonstrations (44.8%) did not score well. When the two sets were combined it illustrated that less people had experienced one-to-one, videos and on-line tutorials but of those who had the majority thought they were good or better.

When only the combined responses of those who had experienced the different formats of training are considered, hands-on (90.4%), exploration (76.7%) and one-to-one (74%) are highlighted as excellent or good training experiences. Demonstration, a more passive experience, was rated as a poor or ineffective (45.4%). These figures suggest that interactive training sessions and working with colleagues or friends in small groups rather than in a conference or workshop session, are those that potentially give better experiences. It further suggests that many of the participants were active learners who liked to be involved. These figures have implications for the format of training and suggest that a mixed approach to learning rather than using one particular method, is more beneficial to learners along the lines suggested by Pashler et al., (2009); Coffield et al., (2004); NCETM, (2010) and those used at TSM conferences. Using mixed approaches allows different types of learner to be accommodated, the 'active' who desire to be 'hands-on', others preferring to be 'passive' with a lecture or demonstration, and time for ‘reflection' to think about what is being shown. Space is also needed for ‘sensing learners’ (Felder and Silverman, 1988) who, when given a set of instructions to follow, have a tendency to need to read them several times in order make sense of them. The TSM conference model is an example of the ethos of inclusion and by splitting sessions over three days they allow time for reflection and the building of a sense of community that did not stop at the end of a conference as everyone was invited to join a group with support by the provision of extra files and updates. The organiser was also contactable for further help. These conferences also provide an example of what Hodkinson and Hodkinson (2004 p.252) described as collaborative learning and ZPD with the inner zone representing delegates before the conference, confident in what they know. Attending sessions allowed them to move into the growth zone as their knowledge and confidence grew in the company of others where they found that others also felt unsure so felt less isolated.

The interviewees had a history of learning and using digital technology (Table 8.15) and belonged to communities of practice such as their workplace and a group of friends, and organisations such as ATM where they were able to share knowledge, values, interests and constructs. This gave them a feeling of inclusion and helped them to feel that when trying out new ideas in that they were not alone. Working within a community rather than as an individual gives a feeling of agency, knowledge of what to do when stuck and support in developing resilience. In terms of Maslow’s Hierarchy of Needs (McLeod, 2007) the motivation to learn how to use software can be influenced by the situation in which the teacher finds themselves. Where there are other teachers who are using ICT and there is support within the school, the teacher has a sense of belonging, and being able to share which adds to their feeling of competence. With support of colleagues, they are able to increase their self-esteem and recognition that they are able to use this resource. This increases motivation to continue to develop their skills. However, as mentioned in the case of trainee teachers (section 8.3.1), this is not always the case when a teacher joins a new school where digital technology use is not embedded in the department ethos. Whilst 36 out of the 48 trainee teachers said that they felt competent in their own use of digital technology this fell to 29 and 27 when presenting to adults and pupils respectively. Only 19 out of the 48 felt competent to demonstrate programs to pupils and 17 out of 48 when allowing pupils to interact with activities. This suggests that much support will be needed once qualified for them to willingly use ICT in lessons.

Some teachers in the questionnaires and interviews, mentioned an alternative to face-to-face experiences being formal online training or self-training. This also requires time, commitment, self-organisation and, for some teachers the need to believe that there will be a positive outcome. As H said that you need to be brave enough to try things. Interviewee J commented that learning how to use digital technology is not necessarily time efficient nor intuitive and as described by the technology acceptance model (Davis, 1969) perceived usefulness is a key motivating factor. Amongst questionnaire participants using manuals was not highly rated (57.7%) nor were on-line tutorials (56%). It was also noted that 54.8% who had used video tutorials rated them good or better and with the rise of YouTube this suggests another way forward to engage teachers in using ICT. Self-training covers use of media, such as DVDs, books or manuals (printed or online) and just experimenting with the resources. All but two of the interviewees described that they were self-taught. All the interviewees said that they wrote programs, took risks and were self-motivated, all but two described themselves as both creative and experimenters, only one did not feel totally confident with digital technology and over half thought they were flexible. Self-learning acts as a constraint for busy teachers, especially for those who are not self- motivated or willing to take the risk that what they try will not always work.

8.4 Summary

Research question 4 - **What training have teachers had in the use of digital technology?**

Teacher confidence in the use of software has an immense effect on how well they are able to use software with pupils and how likely they are to use it. Confidence in using software is built through many complex aspects, significant amongst them is training. Thus specific training and opportunities to observe others using software in a teaching situation are important if teachers are to use ICT in teaching mathematics. The data shows that teachers receive minimal training throughout their careers.

Trainees and teacher trainers reported that little to no subject specific digital technology training was included in their teacher training courses, although the majority felt competent in using it for their own purposes. The teacher trainers stated this lack was partly due to course time constraints. Trainees were not necessarily exposed to the use of digital technology for teaching by school placement staff. Despite many reporting they were familiar with programs and software, they said they would not use it to teach, although describing themselves as competent users. Once in-service, teachers had little access to 'paid-for' training, the cascade model was most often used in attempting to disseminate information. Access to training has been limited since the first computers were placed in schools (chapter 5) and that which was given, e.g. NOF training, was not considered effective, as it lacked subject specific training or paid time to undertake the training and teachers were not consulted about their needs.

Trainees and teachers found out about software most commonly from other people and the internet, rather than courses. In this study trainees and teachers were familiar with the internet and software that could be used for teaching mathematics unlike Smarkola's (2008) sample (section 3.1). The growth of social media means this source of information is likely to grow in importance. A preference was shown for exploration or hands-on learning, tool sharing and forming on-line communities of practice. Training through social media will reduce the control of schools on the skills and resources teachers come across and decide to use. The interviewees, apart from two, stated they were all self-taught and two said that they had had no school paid-for training. This suggests that being motivated to use digital technology comes from a personal disposition or motivation to find something useful rather than training offered.

In spite of recommendations for up to 60 hours of training in reports by McKinsey (1997); PricewaterhouseCooper (2004) and NCETM (2010) teachers in this study considered two sessions either as a whole day or split to be adequate to fully learn a piece of software rather than needing two days. The organiser of the TSM course states that 6 hours per program or software should be regarded as the minimum. This indicates that teachers do not fully appreciate the potential time needed to master digital technology. Furthermore the data indicated that training needs to be built around adults needs, adults needing to know the purpose of the software and why it might be relevant to their teaching situation. Effective training should include different activities for different levels of prior knowledge in order to build confidence, competence and resilience.

Chapter 9 Discussion

This study set out to explore whether looking at the engagement of some mathematics teachers with using ICT in mathematics lessons could lead to the development of ways to facilitate other mathematics teachers to do so. The research question was 'How might more English secondary school mathematics be encouraged to use digital technologies in their teaching? The data was explored using a thematic approach. I found clear evidence of the problems facing teachers when they use digital technologies. One of the most striking findings in this study and in BESA reports (Rossi, 2015) was that since the 1980s the digital technologies available in schools have changed drastically. Especially dramatic is the installation of networks and the internet around the turn of the century. However, inspection and other reports (Ofsted, 2002; 2008; Becta, 2004; Smith et al., 2008; NCETM, 2010; JMC, 2011), while recommending that schools should be using ICT/digital technologies as a tool for learning mathematics, also point out that that many teachers of mathematics make little or no use of digital technologies in their teaching. The limited improvement has been attributed in the data to poor provision of and access to digital technology resources and to related professional development. Teachers were not only unaware of what software was available and how it can support their teaching, they also had no access to training that might help them remedy this. NCETM, (2010) categorised the problems faced by teachers into school-related, teacher-related and professional development. However none of these are independent, so solving the question of how to engage more teachers with digital technologies presents complex issues.

In the analysis there were several themes which emerged within each theme heading, as shown in Table 9.1.

9.1 Key Findings

Table 9.1 Key findings in the themes

Theme	The three most important findings in each chapter	Comment
Reflections (chapter 5)	Haphazard introduction. When computers were introduced into schools the focus was on hardware training and not software. The money to support schools with the purchase came in part from the Department for Trade and Industry.	There were few machines in schools. Computers were temperamental and there was limited technical support, teachers had to learn to fix them. By limiting the models schools could purchase to three British companies the Government supported the emerging British computer industry not primarily education.
	Lack of commitment to education as demonstrated by lack of available software and teacher training.	Machines were sold without software. Those enthusiasts who engaged with technology learnt basic programming, wrote their own programs and shared them. Apart from a few teachers being shown how to connect and troubleshoot the computers there was no other widespread training.
	Teachers had more agency as there was no national	Schools were free to decide their own curriculum with

Theme	The three most important findings in each chapter	Comment
	curriculum, Ofsted or internet, no performance management targets.	the marker being the examination syllabi. At this time there was the ability to innovate and try out new materials. There was also less record keeping and administration affording teachers time to develop interests.
Barriers, constraints and disadvantages (chapter 6)	Lack of reliability of the hardware, access to it and technical support	Owing to the cost many computers were not replaced but left in use. Besides hardware problems, the computers are continually used by 'non-experts' who inadvertently change program settings or otherwise render computers unusable. Classes are left without sufficient machines for the planned activity. Insufficient technical support delays the fixing of problems. Loading mathematics specific software onto the system can be problematic and without administrative

Theme	The three most important findings in each chapter	Comment
		rights, teachers are unable to do so themselves. This may apply to the use of YouTube demonstration videos.
	Engagement of pupils and class control is seen as problematic.	Teachers are judged on the achievements of their pupils within schools via external examinations. Teachers feel under time pressure to deliver the curriculum. Ofsted inspections mean they must show that they are in control of the classes' behaviour and work rate at all times. They do not feel they can 'afford' time to try out new approaches or new resources. Therefore teachers use "tried and tested" methods.
	That there is a top-down nature to most provision of ICT. School management make the decisions with little or no reference to teachers who will use the resources purchased.	This seems to be the single most important finding in this section and it is one not discussed in the literature on ICT use. The lack of consultation with those who would use the ICT is

Theme	The three most important findings in each chapter	Comment
		surprising and results in “dusty hardware in cupboards”.
Beliefs and opportunities (chapter 7)	The lack of inclusion of ICT within the mathematics curriculum and examination syllabi preserves the perceived low status of digital technologies in mathematics teaching.	Since the recent (2015) national curriculum and the abolition of the national strategies there has been a decline in the expectation to use digital technologies, leaving only superficial curriculum mentions in data and number. The use of ICT is not tested in public examinations.
	The lack of experience of teachers as pupils or trainee teachers in using digital technologies to support learning.	Without personal experience of digital technology being used to enhance learning through investigation and ‘open-styled’ teaching it is unlikely that teachers will know the potential of ICT software - they do not know what they do not know. Many of the trainees and teachers made no mention of digital technologies for problem solving, although the use of the IWB was widely

Theme	The three most important findings in each chapter	Comment
		mentioned - suggesting a 'closed style' of teaching. University students mentioned the benefits of visualisation through using dynamic features which also helped understanding. This suggests that teachers will need support and encouragement to develop a more 'open styled' approach if the use of digital technology is to increase.
	There is often low teacher confidence and a lack of support within a school or department.	It seems that becoming a user of ICT requires an element of risk taking. The reaction of pupils is viewed as unpredictable. Schools purchased interactive whiteboards and learning platforms and, while expecting teachers to use them, provided little or no training. Thus pupils could be more knowledgeable and more able to engage with the products than the teacher. Such a reversal in

Theme	The three most important findings in each chapter	Comment
		roles can leave the teacher feeling de-skilled. Where there is support, such as in a community of users, sharing ideas, resources and support both confidence and competence may be built.
Training (chapter 8)	As trainees, teachers are rarely given the time and support they need to develop confidence and competence with software within universities and placement schools or the encouragement to investigate different software and pedagogy with classes.	Little time is allowed for dedicated software training within teacher training courses and once on school placement access and support is linked to the school's own view on using digital technology. As the use of ICT is seen as optional the use of digital technologies within teaching as part of their training is rare. Where they are placed in a school with good facilities they have the opportunity to become familiar with available software. Thus the experience of ICT during teacher training is variable.

Theme	The three most important findings in each chapter	Comment
	There is no entitlement to quality CPD within allocated hours for reasons of cost, time, support from school/ departmental management.	Although identifying CPD need may be part of performance management most targets set in this process are steered to ‘whole school’ needs and issues. Such funding and support as may be available is focussed on whole school priorities which are rarely digitally based. Hence even if a teacher was keen to use ICT in their classes they are unlikely to get funded training. The courses that include digital technology sessions provided by the subject associations and TSM have a low proportion of their attendees funded by schools. Where training is given in-house it pre-supposes that the person leading is knowledgeable and competent which may not be the case. To save costs training will often be after school or during a development day.

Theme	The three most important findings in each chapter	Comment
	Courses are not always designed with the participants needs to the fore.	Adults tend to reflect on situations and draw on previous experiences, so courses that build on these qualities by involving participants in planning the activities are likely to be more relevant. On any adult course prior experiences will differ and differentiated activities should always be available. As adults do not all learn in the same way a mix of presentation style and support material is desirable, as is having a knowledgeable ‘other’ to help with problems. Time for experimenting and follow-up sessions should also be built in.

I used participants who were familiar with digital technologies and who recognised how it could enhance teaching and learning. This was a deliberate strategy to enable me to find out the difficulties they encountered and, in some cases, overcame. With participants that did use ICT/digital technologies to teach mathematics, it indicated such use was not impossible. Even these enthusiastic users recognised the difficulties that the organisation of a standard school could put in the way of efficient and effective use of digital technologies.

9.2 Recollection of early experiences with digital technologies

Research question 1 - How did teachers experience the introduction of ICT into teaching mathematics and what support did they receive in using it?

By including recollections I was able to view the current situation in the light of past events and found that the problem of teachers not using digital technologies in mathematics education was not new. It began soon after the first introduction of computers. Insufficient computers, lack of software and training were an initial and continuing problem.

Reports such as those of Ofsted (2002) included recommendations for developing the role of ICT by developing a curriculum that built on pupils' ICT experiences out of school, supporting teacher development and sharing of experiences. In 2008 Ofsted commented that pupils had too few opportunities to use ICT and opportunities for teachers to improve their subject knowledge and pedagogy were infrequent. Secondary schools should, 'improve pupils' use of ICT as a tool for learning mathematics' (Ofsted, 2008 p.8). Initially teachers did not have experience of using ICT either as pupils, students or in their teacher training and therefore were ill-equipped to know how ICT could support teaching and learning. Four years later Ofsted wrote, 'develop the expertise of staff' and 'the potential of ICT to enhance learning in mathematics continues to be underdeveloped' (Ofsted, 2012 p.10 and p.28). Over the years, inspection reports have repeatedly recommended that schools should include ICT as a tool for learning mathematics but there has been limited improvement in the use of the wide range of technologies available and the participants in this study have indicated that this still a major issue. Much of this advice was repeated in the NCETM (2010) and JMC (2011) reports.

9.3 Barriers, constraints and disadvantages

Research question 2 - What are the barriers and constraints that mathematics teachers meet when contemplating the use of ICT?

As in the Ofsted (2008, 2012) and NCETM (2010) reports, this study found that the potential of digital technologies as an enabling tool for teachers was not being realised. Many barriers and constraints were said to prevent or dissuade teachers from using digital technologies. They mainly arose from three interlinked sources, personal, institutional and governmental. It was also stated that whilst some of these barriers could be reduced or mitigated by teachers or schools, increasing the use of digital technologies in schools would not be a straightforward task. As an example, computers are often kept together in one room and which limits access. This barrier could be mitigated by the purchase of a set of laptops which could be used for all or part of a lesson without having to move pupils. Ensuring that laptops were charged, loaded with appropriate software, updated and repaired requires someone's time, preferably that of an IT technician. Traditionally mathematics departments do not have funds for technicians, and unless teachers see the importance of maintenance and have the skills to do it, the laptops will often gradually cease to function.

However, the most significant barrier found was the top-down and controlling culture imposed by government which percolated through school management, including governors, to heads of departments. Classroom teachers felt a lack of autonomy due to poor consultation with the end user and control exercised as accountability in the guise of performance management.

The direct involvement in schools by governments over the last 30 years has dramatically increased. In the 1980s teachers did not have to conform to a national curriculum and were able to organise how and when they taught different aspects of mathematics. There were inspections by Her Majesty's Inspectors (HMI) but these were concerned with maintaining standards through identified and targeted support rather than accountability as it is now recognised. There was no regular government testing, although certain local authorities used an 11+ examination to decide who took up places in the more academic (grammar) schools, and there were also public examinations at age 16. Teachers had the freedom to innovate and due to the system demanding less reporting and recording, there was more time to prepare resources. The advantage of the national curriculum was that it created an entitlement for all pupils, the disadvantage was that teachers found themselves having a plethora of levelled attainment targets to try and assess against and make a detailed recording of each pupil's progress. The introduction of the National Strategies for Key Stage 3 (1997), saw teaching approaches recommended and curriculum delivery become more controlled. Teachers were expected to be able to justify any deviation, such as using GeoGebra to teach that the interior angles of a triangle add up to 180^0, to those in a position of power within and outside schools, including heads of department and inspectors. Thus teachers felt more and more constrained to use methods that conformed and did not seem to pose risks.

In recent years performance management of teachers in schools has become even more judgemental. It is based on progress made and results attained by each pupil as a result of the way that Ofsted judges schools. Understandably teachers became more risk averse and less inclined to innovate. In some schools teachers reported being encouraged to use published schemes of work and texts to reduce risks. These textbooks only rarely included the use of digital technology as a supporting resource. The teachers in the study made clear that they saw using ICT as a risk. They said if there were problems with the technology they may place themselves in a situation where an observer might construe they were not in total control of their pupils. Interviewee W reported a colleague of his did not want to turn her back on her class to use the interactive whiteboard in case pupils misbehaved. Observations were negatively discussed as being designed to check up on teaching and catch out teachers not in control. This top-down management style leaves staff feeling watched and judged is contradictory to that suggested by Fullan (2008) whose 'Secret One' which was to 'Love your employees'. Fullan establishes that a judgement and pressure culture results in teachers becoming more controlling and less motivated. Within a school Fullan (2008) suggests this cycle can be broken by developing good staff relations and trust in teachers.

Where teachers are consulted with regard to what they need, rather than management imposing the latest 'must have', as described by some of the participants, there is likely to be more made use of purchases. If teachers do not feel threatened, to "use this or else" but supported by opportunities to share resources and ideas, (e.g. participants A and R), they would also be in a better position to make use of any technologies supplied. The participants in the study felt that giving teachers agency and autonomy as individuals and part of a group, to decide how they will teach and what resources they will use, without constant fear of judgement, would increase engagement and motivation to explore new resources.

More personal barriers and constraints exist such as individual teachers' beliefs about the advantages and disadvantages of using ICT or their own knowledge of resources and self-confidence with ICT. These beliefs have a marked influence on decisions about whether or not to use ICT in their lessons.

9.4 Beliefs and opportunities

Research question 3 - How do mathematics teachers' use ICT in their teaching?

The benefits of using digital technologies were recognised by participants (chapter 7). These included engaging pupils by increasing interactivity in lessons, removal of mundane tasks, improving presentation by both teachers and pupils and allowing better visualisation of concepts. Access to the internet also provides access to a wide range of resources and support. The ability to visualise and change variables was seen as a strong reason for using ICT (section 7.2.1.1) by all participants, from students to experienced teachers, but this is no longer part of the curriculum. It seems that unless the curriculum changes to include digital technology teachers in England will continue not to use ICT in their lessons. It is likely that teachers will continue to believe that ICT is distracting and provides minimal advantages in learning. It is possible that this means English pupils will be disadvantaged in the workplace. This fits with the technology acceptance model (Davis, 1989), Taylor & Todd's, (1995) decomposed theory of planned behaviour model (DTPB) and Venkatesh and Davis' (2000) TAM2 models as described in section 3.1 and the effect of external factors on perceived ease and usefulness on the intention to use.

Research question 3 requires discussion at a more personal level, making it clear that some constraints are only problematic because of what teachers believe. Teachers' beliefs can potentially be influenced although, according to Goldin (2016), beliefs are relatively stable and only change slowly. The study found that personal beliefs, attitudes and characteristics play an important part in whether a teacher embraces digital technologies when teaching mathematics.

When computers were first introduced into schools and later in the national strategies, there was a strong suggestion that teachers should change their way of teaching to a more open pedagogy to make effective use of digital technologies (Oldknow, 2000; DfEE, 2001; Glover et al., 2007) by using investigations and exploration. This proved counterproductive as it challenged teachers existing pedagogy and beliefs about working practices by requiring a change in pedagogy from the more traditional ‘chalk-and-talk’ to a more investigative and constructivist style of teaching whilst at the same time expecting them to embrace new resources. Changes in pedagogical style may best be supported when teachers receive training but despite these expectations being made clear no adequate support and training was provided for teachers. The digital environment provided by software such as GeoGebra and Grid Algebra invites the learner to investigate, explore and construct their understanding. Thus, one of the reasons digital technologies are not more widely used is because of the requirement to change away from a traditional expositional style of teaching which may feel safe in the ’accountability‘-driven atmosphere of many of today’s schools. However, such a change may lead to more lasting learning and learners willingly continuing to study mathematics later in their careers (Lee & Johnston-Wilder, 2017). The data revealed that even those who are active digital technology users when teaching state that they will, according to circumstances, sometimes also teach in a traditional way whilst traditional expositional teachers do sometimes use digital technology but not interactively. For the expositional teachers raising of awareness of the potential of the technologies to engage and interest their learners may help motivate them to use digital technologies. As the data states, they fear compromising control of the students and need to build both their confidence and competence in using digital technologies. Use of digital technologies was shown to be teacher-centred with a limited variety of software.

9.5 The teacher as a learner, from ITT to CPD

Research question 4 - What experiences of digital technology training have mathematics teachers had, and are there lessons to be learnt?

In chapter 8 the study sought to establish whether constraints can be overcome by changing the way CPD is conducted and if this would help teachers become more resilient users of ICT to teach mathematics. It appears that opportunities to have a technologically-literate workforce were missed when computers were first introduced, the machines were simpler, and there was less software with which to become familiar. If, as some of the students commented, they had not had experiences of learning with ICT as a pupil then the step to being able to teach with ICT is greater as there is nothing to build on. The whole issue of how training is presented and how more teachers can access training and support must be addressed if the number of secondary mathematics teachers using digital technologies is to increase.

The amount of time devoted to the use of ICT in teaching mathematics in initial teacher training and the amount of time classroom teachers are given for subject related digital technology CPD, is demonstrated by the data to be a major issue in the lack of take up of digital technologies for teaching mathematics. The amount of specialist subject training offered in teacher training courses, was inconsistent as was the time spent demonstrating mathematics software. Where trainees have not been exposed to mathematics software and constructivist pedagogy whilst in school, either as a pupil or on training placement, this results in a situation of 'not knowing what there is to know'.

Once newly qualified teachers' are in schools, other staff will influence the development of their knowledge and willingness to engage with using digital technology. The study identified that a great deal of time is initially needed to learn to use ICT for teaching mathematics, time for learning to use specialist software and in planning its use in lessons. The length of time recommended by B who runs the TSM training and NCETM (2010) was six hours per program, split into three sessions of two hours as any longer means there is too much information to absorb and benefits are reduced. NCETM and B also recommended that teachers would need continued support during and after training sessions, to enable participants to build up digital technology resilience. Such support is not consistent with offering ‘one-off short’ courses. It was revealing that few teachers who completed the questionnaire would opt for a two-day course suggesting they are not aware of the full potential that pieces of software can offer or that they have not experienced supportive courses.

The ability of individual teachers to engage with digital technologies was shown by the data to be variable and not necessarily considered when schools select who is to attend courses. The findings also showed that not all teachers are capable of learning how to use technology and software quickly, so the length and format of courses needs to be flexible in order to cater for people who will learn differently and at different rates. For some teachers learning how to use resources by attending short courses or experimenting by themselves is inadequate. If they are to be able to use digital technologies in teaching and ultimately to let pupils use them too, they may need on-going support.

As teachers are adult learners, the data indicated that facilities need to be built to take into account of, and maximise, their reflective ability. Encouraging teachers to be part of a supportive network or community of practice was also shown to be beneficial for encouraging ICT use. Social networks were valued as a means of developing one’s own ideas and skills through discussion and sharing with others. Staff willing to work with others in a community of practice was seen in the data as powerful, giving all the staff a sense of belonging to a wider network of people interested in using digital technologies, whether local, national or virtual by means of social media.

The amount of, and the approach to, CPD was not always appropriate. Professional development must recognise that it takes time to become familiar with a piece of software and that being familiar with software is not the same as being able to use it confidently to teach. Training sessions also need to offer material that fits in with a teacher’s teaching activities and recognises that not every attendee is at the same stage of development. Courses need to give time to learn to use a resource, for hands on experimentation and investigation rather than simply demonstrations or instruction manuals. As with any learning, the approach by the presenters, how they organise sessions and whether they have additional knowledgeable helpers will affect the success of the sessions, as will the materials used and access to follow-up support. While teachers say they prefer ICT training to be exploratory or hands-on, this is at odds with the transmissionist style that many mathematics teachers use.

Those who were interviewed suggested that one problem with training is that teachers try and focus on learning more than one piece of software at a time and they recommend learning one in depth rather than attempting to use too many. A cascade model is evidenced as ineffective as each time the ideas are disseminated the effect is diminished to a point the recipient is unable to use the information. For short courses focussing on only one element, such as a piece of software, and starting with a small activity, allows knowledge and understanding to grow rather than giving too much to absorb.

For teachers to become proficient with digital technologies there were wider issues considered. Apart from the innovators and early adopters others, including those in a position of power, did not necessarily see advantages in using digital technologies and therefore were not advocates themselves. Where an accountability culture exists, as in England, the school management's focus must be on whether or not the digital technologies have the power to raise attainment, rather than being persuaded by increased engagement and understanding. The expectation that subscribing to initiatives and teachers attending professional development courses to learn how to integrate digital technology will instantly raise standards is unrealistic, as there are too many other factors involved, including teacher relationships with pupils and their response to change.

The absence of digital technology as statutory in the mathematics curriculum and examination syllabi has given it low status amongst school management, teachers, pupils and textbook publishers. Much of the more powerful software learning environments require a change in teachers' pedagogy to be more constructivist. This has constrained their widespread use as mathematics has traditionally been taught using a transmissionist style. The interviewees said that they used a mix of pedagogies according to the situation they were in and would adapt for different classes. Sharing experiences of using technology including software and files in school, through internal or external communities of practice or via social media is likely to reduce the isolation individuals can feel and, by sharing resources, reduce workload and planning time. Participants who were using ICT in their teaching mentioned the importance being in a community of practice in supporting them, with the availability of email, wikis, blogs and social media, such as LinkedIn, Facebook and Twitter, the advantage being that these communities can be virtual with worldwide members.

Since the initial introduction of computers into schools, professional development has been insufficiently funded to give all teachers a thorough grounding in the use of software to teach mathematics. The reasons given for this lack of appropriate CPD included lack of consultation about what was wanted and needed, and that it was offered by consortia who were not school facing. There was also no money to pay teachers to be released from class or as 'over-time' which made any training of limited appeal. The lack of technical support for teachers, unreliable equipment and the imposition of new technology such as interactive whiteboards and virtual leaning platforms without suitable training has left teachers feeling unsupported by those in positions of authority.

The over-arching question was 'How might more English secondary school mathematics be encouraged to use digital technologies in their teaching?

The first key element restricting teachers in their use of digital technologies seems to be the lack of encouragement. The difficulties presented by inadequate equipment, problems with software and the internet are a major hurdle which only the most tenacious will strive to overcome. Teachers are not technicians, so sufficient technical support to solve problems swiftly would be necessary if teachers are to routinely make use of digital technologies. In secondary schools, technical support could be sourced from students who are intending to take, or taking, a qualification such as the City and Guilds Level 3 Advanced Certificate and Level 3 Advanced Extended Diploma in Digital Technologies through the school or a local college.

Digital technologies need to be treated in the same way as any other resource and be made available when needed. The provision of sets of up-to-date portable devices, such as laptops, loaded with specialist mathematics programs would enable their use within a lesson in the normal classroom, even if they have to be shared within the department.

Sharing with others within the department may help build teacher confidence by developing a community of practice within school or with other local schools where experiences, ideas and resources can be shared. Encouragement to share lessons, where one teacher supports a colleague, would enable both to become more proficient with a particular piece of software and would also help a less confident teacher.

To learn a piece of software beyond a basic level requires time. Within a community there are lead people who have training and expertise on a piece of software, for example spreadsheet, dynamic geometry and interactive whiteboard software. These lead people would then act as the 'knowledgeable point of contact' who can support and guide others. This provides an opportunity to hold a number of short sessions related to the area of study at that point in time. Further opportunities to feed back to other participants about how the activities were received in the classrooms would provide effective learning in a department and reduce the cost of commercial courses whilst enabling more people to receive training. The rise in social media does not confine groups to one locality and there are many teacher forums, blogs and resources such as Facebook and Twitter where ideas are shared and advice given. These present an alternative to face-to face discussion and allow anonymity with regards to one's own school.

When organised training is provided the presenter needs to be chosen carefully to suit the audience. Many presenters are enthusiastic and wish to share as much knowledge as possible in a short space of time, while an overview can be useful, too much information can be daunting to those who lack confidence. Presenters also need to have patience, encouraging small steps, rather than trying to rush participants. Where training is given to a group of people there needs to be recognition that it has to have a purpose appropriate for all participants and that people will be starting with different knowledge bases.

As it is difficult to listen, absorb and write, notes should be available for later study along with a copy of the tasks and the solutions. A short one-of course is not sufficient and steps should be made to have a series (possibly with a task to try in-between) with an expectation that the participants will have tried out the software with a class and be prepared to share experiences, including how it was relevant to the curriculum. A way of contacting the presenter following the session enables people to email questions.

There are some teachers who are not likely to engage without a clear purpose and these are the group of teachers who Rodgers (1983) called the late adopters or laggards. They will be reluctant to change and they will need to be persuaded. If digital technology was mandated in the national curriculum, or in examination syllabi, either through a skill to be taught or by content needing more than that possible though paper methods, many more teachers would feel the need to learn to teach with digital technologies. Hand-held technology is becoming less costly and therefore it is conceivable that examinations could include questions that would take too long to complete without technological assistance, enabling the study of more challenging mathematics.

More problematic is the reluctance of government ministers to approve a curriculum that is not based on a traditional pre-calculator and computer age. To include use of technology as a requirement, for example enabling pupils to explore 'real' problems, would require in a major shift in thinking by a group of people who would not have experienced the possibilities afforded by digital technology themselves when at school. Teachers currently do not have an incentive to integrate digital technology into their teaching practice.

In order to engage more teachers there needs to be a culture change at all levels and recognition that although digital technology does not raise standards by itself, improvement in pupil’s motivation, commitment and engagement with the subject will. Having a curriculum that young people feel is relevant to their lives and not embedded in historic ideologies, with interesting subject matter that develops recognisable skills for life, including problem solving, giving pupils ownership of their learning through challenges and use of technology will support more engagement. For some teachers this will mean a change in pedagogy, and a sense of being de-skilled. However, working in a supportive, caring less judgemental environment and using ’step change’ rather than changing quickly will enable such teachers to develop confidence as well as competence in using technologies. For teachers access to technical support, reliable equipment and internet services could provide a curriculum that pupils are interested in and enhance their lessons and make it easier to plan lesson knowing that the technology will work. Consultation about what would enhance their work would help teachers to feel valued by management and encourage them to investigate possibilities and resources. Recognition of the benefits of subject personal development by the school accompanied with funding for release from class or to attend courses is motivational, especially when the teacher is able to choose the course. Where teachers are given the opportunity to learn how to become a trainer and run courses for colleagues this can benefit the whole department. If teachers are encouraged to work on using digital technology towards accreditation via SDL or SRL this provides an end goal and adds value to their work. This will need to take place over time which gives opportunities to reflect on practice and develop knowledge, especially if this takes place in a community of practice.

Chapter 10 Conclusions

10.1 What this study has added to knowledge and where it might lead

There are many benefits to using ICT to teach mathematics, dynamic geometry programs offer environments where pupils can experiment and come to know, connect and understand concepts in mathematics. These programs allow complex ideas to be visualised, simplify the accurate drawing of graphs so that the properties of graphs can be explicated, as well as allowing rotations and other transformations to be understood. This was mentioned by many of the participants in this study. So why are so few teachers using ICT to teach mathematics?

The study particularly noted several important aspects that were not seen in the literature but which have seriously hindered the take up and use of digital technologies in teaching mathematics. These were:

- how "top-down" the introduction of digital technologies has been since the 1980s. The digital technologies that have been introduced into schools have in almost every case in the data been purchased either because they were recommended of funded by governments or because the technology company offered a “good deal” to the leadership team. In no case did participants indicate that the end users in the school had been consulted about what technologies they felt to be appropriate or most useful for their teaching
- the increased government control of schools, the curriculum, examinations and the advent of greater accountability has made teachers more risk averse. Technology is reported as having many and various risks associated with it, such as the machines not working, other classes unexpectedly taking over a computer room and software not being accessible. All of these mean that teachers using ICT may appear not to be in control of their classes as a result of malfunctions in technology

- the lack of support in repairing, trouble-shooting and loading software onto machines even when dedicated laptops are available for use within mathematics departments
- the lack of encouragement from schools for teachers to access courses which would allow them to learn how to use technology and know what there is available. Even where there is enthusiasm to use ICT, developing knowledge of what is available and how it could support pupils learning is difficult
- teachers do not know what they do not know. They may not have used ICT as student themselves or whilst they trained as a teacher. Consequently they have no idea what benefits there might be in using ICT
- textbooks are widely used especially by less confident teachers and departments and textbooks only rarely offer ideas for using ICT and where they do it is as an add-on extra.

Over many years Government-led initiatives have supported schools to purchase equipment including computers and projectors, whiteboards and software. As the goods were offered on a “take them or leave them” basis, management teams had little encouragement or reason to consult the teachers, who would use them. A custom was thus inadvertently established of senior management teams not giving the end users a chance to voice their opinions. By being listed as an 'approved supplier' through Becta, and more recently directly by government (Crown Commercial Service, 2015), companies, manufacturers and businesses have benefited by promotion of their goods and services, although training that might routinely be offered to commercial customers has not been provided to educational purchasers to keep costs down. This situation could be improved by management having a two-way dialogue with teachers about what ICT they felt they needed and being open to implementing suggestions.

Technical support is vital as digital technology development is ongoing and hardware and software specifications are constantly upgraded. Where equipment is ageing then, a reserve equipment pool would provide a replacement if there is a breakdown. In school technological support to maintain and trouble shoot the systems is vital, teachers cannot be expected to have either the expertise or time to do this. A way forward would be to offer students a chance of gaining a recognised award if they learned to deal with less complicated problems.

There has been insufficient depth of instruction and training in digital technology available for teachers for as long as computers have been in schools. The study highlighted how little CPD in-service training, funded by the school, teachers received. Several teachers in the study paid for their training themselves. It might be expected that teachers would wish for longer rather than short periods of training, but this was not the case. This is an example of teachers not knowing what they do not know as they neither realised the potential of using digital technology nor how long it takes to become a competent user. A solution might be to use 'knowledgeable people' within the school who receive training and specialise in an aspect of software or technology with a view sharing their understanding with others in the department. Building communities of practice between schools was also discussed as a solution to helping teachers know more about and become competent users of technologies. Such communities could be user groups, either real or virtual, enabling the sharing of ideas and building confidence in their participants. Some such communities already exist, but the problem remains of how to interest those who are averse to digital technology.

The constant monitoring of teachers discourages risk-taking by introducing the kinds of pedagogical change associated with using ICT. Teachers report concerns about how pupils will react to change, whether they will focus on their work or 'will take advantage' and that this is will be observed by management which would cause problems for the teacher. This is particularly true for the use of 'open' software where pupils have a level of autonomy to which they are not accustomed. A possible solution may be the use of wireless keyboard and mouse which allows teachers to move in the room and pupils to input from their seat. Teachers could also demonstrate ideas using a large display before involving the pupils by asking them to add their contributions with the wireless keyboard and mouse. Once pupils understand how to use the software they are more likely to complete set tasks on computers which would also reduce the risk of off-task behaviour.

There are many benefits for pupils in their teachers using ICT to teach mathematics however teachers have rarely experienced learning in technology rich environments themselves and therefore have no vision of how ICT can be used or belief that it should. Overcoming this barrier would take a real push either from government, which is unlikely in the current climate, from schools who could encourage rather than discourage risk taking and who should see education using ICT as important to their pupils, or from individual teachers who see the benefits and share their expertise with colleagues. Perhaps the most hopeful message in this study are the number of teachers who overcome the barriers of insufficient training, poor hardware and software and use ICT to the benefit of their pupils.

10.2 Limitations of the study

There are many limitations to this study, some small and relatively insignificant whilst others had more effect on the outcomes. Some of the limitations which I will detail here had to be considered as I set out the findings of the study and considered how trustworthy the information that I was presenting would be.

The sample sizes are smaller than I would have desired and I would have preferred a more structured data collection method with participants drawn from only one or two areas of England. However, access to teachers and trainees willing to take part was difficult, especially at a time when school re-structuring was taking place and the mathematics curriculum and examination syllabi were undergoing reform. My option was to take small opportunistic samples for the questionnaires, using teachers and trainees attending different courses.

By asking those attending national courses to complete the questionnaires, the wider geographic location of the teachers gives some strength to the outcomes. I had intended to introduce a control factor, however, this was not possible. I therefore made the decision to question people who were voluntarily attending mathematics courses and were interested in professional development.

I also wanted to use the views of teacher trainees as I felt that they would use more ICT naturally in their lives and this might incline them to use ICT in teaching. I also felt they would tell me about the way that new teachers received training in ICT. I had hoped to revisit one of the groups after they had completed a school placement to hear what had happened in reality but this could not be arranged. These limitations, whilst being taken account of in the outcomes of this study also presents opportunities for further research as suggested in 10.4.

Although interviewees were asked about their beliefs and approaches to teaching, in-depth profiling was not explored and it was while transcribing the interviews that similarities became apparent, so taking another larger sample could support or reject the idea of similarities in personality being associated with ICT use. Similarities included their experiences of programming and their interest in music, both of which require an ability to take certain risks and cope when success is not instant.

While researching into the timeline of ICT in schools I developed a better insight into the history of ICT in schools which put government initiatives into context. The interviewees through their reminiscing highlighted how far digital technologies have progressed in 30 years, and it would have been interesting to investigate how teachers were using ICT in the 1980s and compare it with today. As I used an interview sample drawn from those who feel confident when using ICT, I knew that I was not hearing the voices of those who are not confident with ICT in the classroom, exploring those voices would be useful further research. It would have been interesting to gather views of exponents of the use of digital technologies in school such as Dame Celia Hoyles or John Monaghan as people involved in related research projects rather than in classrooms to ascertain what their vision for the future could be if the constraints were removed.

10.3 Recommendations

As many teachers have been taught mathematics at school and university with little exposure to digital technology resources and may have only experienced its use a limited amount within their professional training, raising awareness of the potential of digital technologies will be a priority if there is to be greater uptake of digital technology by those teaching mathematics. If people are to be encouraged to become engaged they need support and encouragement to move out of their existing comfortable but less productive teaching and to develop resilience to overcome the constraints and barriers they face. Teachers who are able to access quality CPD led by knowledgeable people, whether in-house or externally are better placed to develop the competence and confidence to use digital technologies effectively than those expected to self-train. Access to training should available to all mathematics teachers as all their students would benefit from its use. Currently just a few access training and support through locally based, possibly in-house training or through national conferences. Very few teachers are given either time to train or are funded by their school or college to attend courses. Courses could be timed so that teachers do not have to have school or department permission to attend. This would enable interested teachers to take personal responsibility for their own professional development. Communities of practice, real and virtual, could also encourage teachers as they allow the sharing of good practice and ideas and give support to those who are less confident.

Localised networks, open to all which meet face-to-face for regular discussion and sharing of ideas, are known to be particularly effective. Using conferencing systems such as Skype would broaden participation to those whose circumstances make attending out-of-school activities difficult. Where training is offered there must be recognition that not all participants will be at the same stage, differentiated activities provided with a stepped approach ensure participants do not feel overwhelmed and feel confident in having progressed their understanding before leaving the session.

All the participants in this study were educated in England and were teaching were in the English education system, so ideas and experiences may be different in other countries. This study involved people who were prepared to develop their own thinking and be proactive in taking training opportunities and does not address the issue of those who do not volunteer. In some countries teachers are motivated to undertake professional development by offering Master's level awards linked with a financial incentive for completion. Currently gaining a Master's qualification in England gives no financial reward, although it might be taken into account for promotion purposes. Giving an option for CPD to be certificated towards an award at Masters Level or an opportunity to use this to progress to a higher salary is likely to give some motivation to develop further skills. Any such qualification should include subject specific pedagogy which incorporates demonstrating knowledge of the use of digital technology in teaching and also enables teachers to apply for entry to one of the chartered institutes for teachers.

While the group known as 'laggards' or 'luddites' (Rogers, 1983, Glover and & Miller, 2001) may be difficult to convince of the merits of using digital technologies, the early and late adopters offer a target audience but even they would need convincing and access to support. By making both the curriculum and examination syllabi include explicit references to and expectation that digital technologies will be used, there would be a greater chance of including these groups. Any intimation that using ICT will improve standards just by its use are justifiably treated sceptically. Encouragement to use ICT in teaching is most likely to be effective if digital technologies are seen as a tool to motivate pupils to develop skills necessary for future careers and skills such as visualisation, problem solving and modelling using large data sets and which will enable them to appreciate the context of mathematics in the real world.

10.4 Implications for future research

From this study there are a number of further research possibilities, some of which were indicated in 10.2 and include researching the views of teachers who are not engaged at all with using digital technologies in teaching mathematics. Any such research would need to establish ideas that would support non-users to use digital technologies in order to suggest a way to encourage greater engagement.

It is likely that the current 'top-down' culture prevents the voices of classroom teachers being heard and therefore research is needed to establish what is really needed by teachers.

An international comparison of the beliefs and attitudes of teachers to digital technology and the barriers and constraints experienced within other countries would also be revealing, especially in those with a lesser top-down control mechanism.

The similarities in the interviewees approach to risk, motivation to self-teach and attitude to teaching methods suggests that people have similar personality profiles when they are early adopters. Those who are later adopters may also demonstrate some similarities. A larger sample using a mix of innovators, early and late adopters and laggards would reveal the extent of these similarities and whether training approaches may be adapted in the light of this knowledge.

A further investigation that arises from the findings is the idea of working with teachers to try different training methods as mentioned in chapter 8 using the same software to see which have the most beneficial outcomes. Undertaking research to investigate how apps and other digital technologies can be developed to provide support for mathematics teachers learning to use digital technologies in the classroom by working with groups of teachers who are not confident users could engage those who currently do not know how to use digital technologies for teaching.

10.5 Impact on my thinking and career

Having worked as a teacher in English schools since the 1970s when the first computers were introduced I was surprised at the amount and depth of the top-down culture that existed. I was fortunate in that I received training in the early days as I was working in a large primary school that promoted a constructivist pedagogy, innovation and consultation with teachers. We had frequent contact with R who was an advisory teacher at that time who advised and trained staff in the use of hardware and software available. I now realise I was in a privileged position.

As a result of this study I have changed my approach when giving training sessions to teachers on software by covering less and relating examples to use in classrooms. As part of doing a PhD we were expected to build an e-portfolio and this encouraged me to try and build my own website. I uploaded my presentations and files onto this site for revisiting and sharing with others which allowed files to be personalised by those accessing the site. I have worked as an Adult Education tutor for groups studying for a level 1 or 2 Key Skills award who had not responded to a GCSE approach while at school. While researching 'adults as learners' I improved my presentation by adapting my style to accommodate hands-on learning which was well received and helped these learners with their understanding of mathematics.

This study has also encouraged me to improve my writing for academic purposes and given me the confidence and knowledge to submit abstracts for conferences in the future. My next career goal is to present my research at conferences and write articles for journals.

10.6 Dissemination of research

My main route for dissemination is planned to be through articles in professional journals including Research in Mathematics Education and those for teachers such as Mathematics in Schools (MA) and Mathematics Teaching (ATM). I have disseminated part of my research in person at the June 2013 meeting of BSRLM titled 'Mathematics Teachers and use of ICT' in Sheffield UK and at 6th International Conference on Education, Research and Innovation ICERI2013 in Seville, Spain where I presented a paper titled 'Developing Teachers' Resilience with Using Digital Technologies in the Classroom'. Further presentations are envisaged at future UK conferences including British Congress of Mathematics Education (BCME), British Society for Research into Learning Mathematics (BSRLM) and international conferences such as ICERI (International Conference on Education, Research and Innovation) INTED (International Technology, Education and Development) conferences, orally or by poster.

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Appendices

A1 Ethics Approval

THE UNIVERSITY OF WARWICK
Institute of
EDUCATION

Application for Ethical Approval for Research Degrees
(MA by research, MPHIL/PhD, EdD)

Name of student Alison J Parish	MA By research	EdD	PhD ✓

Project title
ICT in KS3 Mathematics. (How and When is ICT Incorporated into Mathematics Lessons?)

Supervisor P J Johnston-Wilder and A.M Pritchard

Funding Body (if relevant)

Please ensure you have read the Guidance for the Ethical Conduct of Research available in the handbook.

Methodology
Please outline the methodology e.g. observation, individual interviews, focus groups, group testing etc.

I will be using both interviews and questionnaires to gain an insight into how teachers (including trainees) are using ICT in lessons. This will give me an idea of the types of resources being used (including hardware and software) and the respondents' experience of how effective this is in teaching and learning. I will also include questions as to the styles of ICT training they have personally experienced and their preferred learning style. I will also interview training providers. An audio record will be made of each of the interviews with the permission of the participants. In addition to the interviews, I will to do classroom observations in Suffolk County Council schools. (I hold a current CRB for Suffolk County Council, which is my employer).

Participants
Please specify all participants in the research including ages of children and young people where appropriate. Also specify if any participants are vulnerable e.g. children; as a result of learning disability.

The participants will be teachers working in schools (including trainee teachers) and training providers.

Respect for participants' rights and dignity
How will the fundamental rights and dignity of participants be respected, e.g. confidentiality, respect of cultural and religious values?

The interviews, questionnaires and reports of the lesson observations will be anonymous and non-invasive. The schools will not be identified by name. Interviews will only be recorded with permission of the participants. ✓

Privacy and confidentiality
How will confidentiality be assured? Please address all aspects of research including protection of data records, thesis, reports/papers that might arise from the study.

The design of the interviews and questionnaires will be so that no individual may be identified. (1)

Consent - will prior informed consent be obtained?

- from participants? Yes from others? Yes ✓

- explain how this will be obtained. If prior informed consent is not to be obtained, give reason:

I will explain to the potential participants the nature and purpose of my research. I will also explain that the interview and questionnaire is to establish some general facts. Participants may choose whether to complete the questionnaires, and how many questions, interviewees will be able to refuse to answer questions if they wish. Permission for interviews to be recorded will be obtained from the interview participants before the interview is recorded. ✓

- will participants be explicitly informed of the student's status? Yes ✓

Competence

How will you ensure that all methods used are undertaken with the necessary competence?

I have completed training in research methods (Open and Cambridge Universities where my studies involved action research, and ARM at Warwick) and I will follow the guidance provided there. I will discuss all research methods fully with my supervisors prior to implementing. I will discuss the proposed interview questions and questionnaires with my supervisors before the event. ✓ ✓

Protection of participants

How will participants' safety and well-being be safeguarded?

The completion of the interviews and questionnaires is voluntary and participants will not be personally identified. Lesson observations will be only carried with the agreement of the management of the school and the teacher involved. ✓

Child protection

Will a CRB check be needed? Yes (If yes, please attach a copy.)

Addressing dilemmas

Even well planned research can produce ethical dilemmas. How will you address any ethical dilemmas that may arise in your research?

Discuss a possible approach with my supervisors as to the best way to deal with this.

Misuse of research

How will you seek to ensure that the research and the evidence resulting from it are not misused?

This work is to investigate channels for further enquiry as part of my inquiry and as such will not be published apart from being part of my thesis.

Support for research participants

What action is proposed if sensitive issues are raised or a participant becomes upset?

Questions (which are non-intrusive) may be left unanswered should the participant wish.

Integrity

How will you ensure that your research and its reporting are honest, fair and respectful to others?

This work is about systems rather than people and is to inform the further development of my inquiry. 2

What agreement has been made for the attribution of authorship by yourself and your supervisor(s) of any reports or publications?

No report or publication of this data is intended apart from my thesis. If the occasion should arise where a report is to be forthcoming, authorship will be discussed with my supervisors before it occurs. 3

Other issues?

Please specify other issues not discussed above, if any, and how you will address them.

Signed

Research student | A Parish. | Date 07/01/10.

Supervisor | | Date 8/1/10

Action

Please submit to the Research Office (Louisa Hopkins, room WE132)

Action taken

- [x] Approved
- [ ] Approved with modification or conditions – see below
- [ ] Action deferred. Please supply additional information or clarification – see below

Name G LINDSAY Date 28.1.10

Signature

Stamped

Notes of Action

I have approved but please note + think about the following as annotated

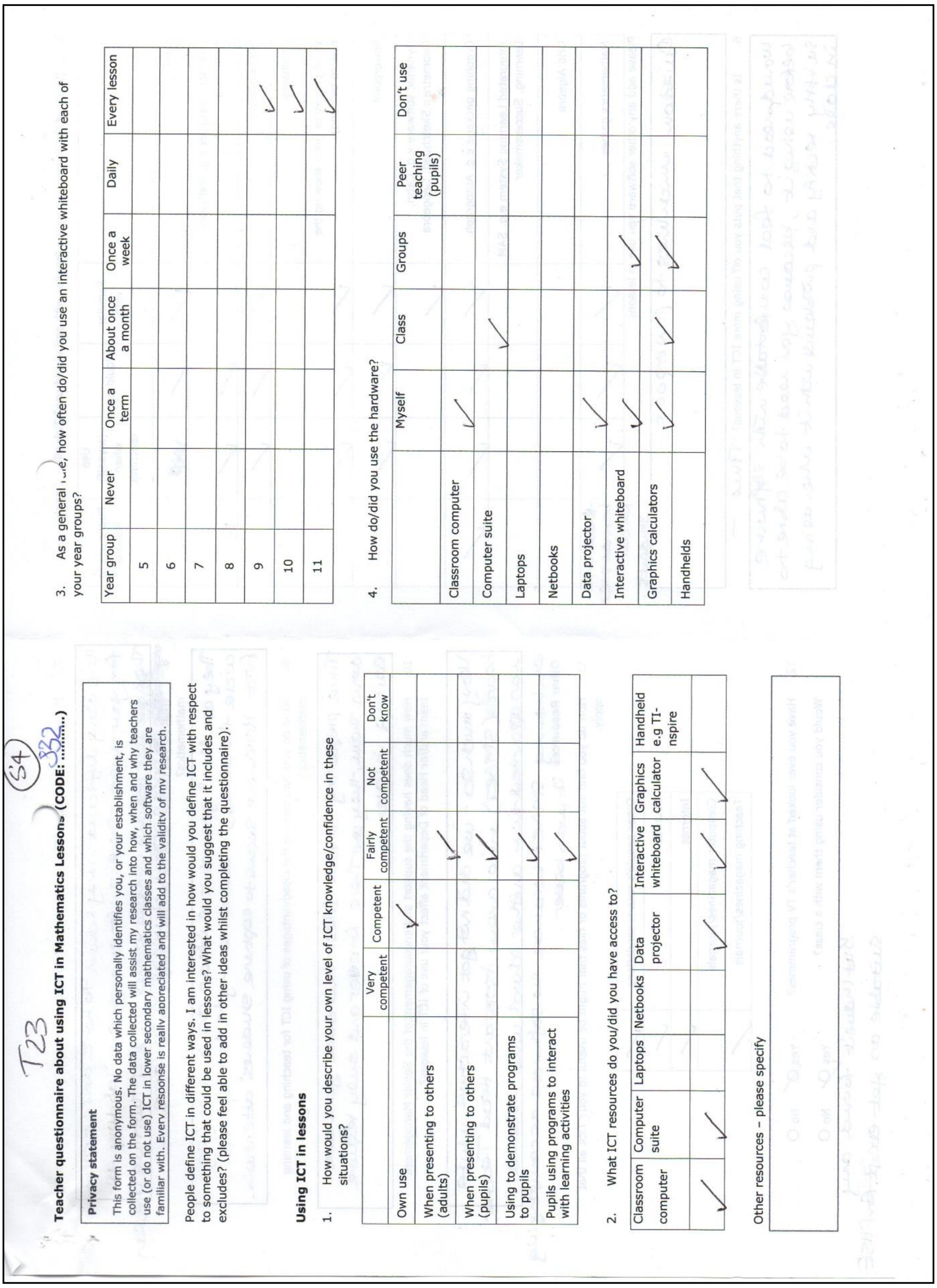
(1) Consider also the school(s)

(2) These apply even if systems – eg fairness of reporting –

(3) As a PhD is intended in principle to be publishable I urge you to keep this in mind + discuss with supervisor(s)

A2 Sample questionnaire

Similar questions were presented to undergraduate students and trainee teachers.



T23 S4 S32

Teacher questionnaire about using ICT in Mathematics Lessons (CODE: ....)

Privacy statement

This form is anonymous. No data which personally identifies you, or your establishment, is collected on the form. The data collected will assist my research into how, when and why teachers use (or do not use) ICT in lower secondary mathematics classes and which software they are familiar with. Every response is really appreciated and will add to the validity of my research.

People define ICT in different ways. I am interested in how would you define ICT with respect to something that could be used in lessons? What would you suggest that it includes and excludes? (please feel able to add in other ideas whilst completing the questionnaire).

Using ICT in lessons

1. How would you describe your own level of ICT knowledge/confidence in these situations?

	Very competent	Competent	Fairly competent	Not competent	Don't know
Own use		✓			
When presenting to others (adults)			✓		
When presenting to others (pupils)			✓		
Using to demonstrate programs to pupils			✓		
Pupils using programs to interact with learning activities			✓		

2. What ICT resources do you/did you have access to?

Classroom computer	Computer suite	Laptops	Netbooks	Data projector	Interactive whiteboard	Graphics calculator	Handheld e.g TI-nspire
✓	✓			✓	✓	✓	

Other resources – please specify

3. As a general rule, how often do/did you use an interactive whiteboard with each of your year groups?

Year group	Never	Once a term	About once a month	Once a week	Daily	Every lesson
5						
6						
7						
8						
9						✓
10						✓
11						✓

4. How do/did you use the hardware?

	Myself	Class	Groups	Peer teaching (pupils)	Don't use
Classroom computer	✓				
Computer suite		✓			
Laptops					
Netbooks					
Data projector	✓				
Interactive whiteboard	✓		✓		
Graphics calculators	✓	✓	✓		
Handhelds					

5. Which of the following are you familiar with and would use? Tick all that apply.

	Familiar with	Would use	Use (myself) when teaching	Pupils use in lessons
Internet	✓	✓	~~✓~~	✓
Internet resources e.g. Mathsnet, Mathletics	✓	✓	✓	✓
Spreadsheets	✓	✓	✓	
Databases				
Word processor (incl. showing the task to be done)	✓	✓	✓	
Powerpoint	✓	✓	✓	
Dynamic software e.g. Cabri, Geometre's Sketchpad, Geogebra	✓			
Graphing package e.g. Autograph	✓	✓	✓	✓
Integrated Learning System e.g. SAM Learning, Successmaker				
Grid Algebra				
Mathematics games	✓	✓	✓	these are banned sites from students.

Please add any other software you use in lessons

Quizdom which links to powerpoint.

6. Is there anything that puts you off using more ICT in lessons? Time –

Would need to feel comfortable with software before using it, because you need to be able to swiftly rectify and problems with it when using in class.

7. If you were able to use ICT in a different way to now, what would you choose to do?

It is very difficult in my school to book an ICT room for your class - there is not enough availability as there are ICT lessons in those rooms most of the time. We can only book a room 2 weeks in advance.

8. What do you consider to be the benefits of using ICT for teaching and learning mathematics?

They can "see" geometrical ideas are correct (eg. circle theorems) without having to do the proofs first. Movement seems to capture students' attention.

9. What do you consider are the disadvantages of using ICT for teaching and learning mathematics?

Time preparing SMART files - but once you have done them, they are there forever and only require editing in later use.

10. How much does having the support and encouragement of the Senior Management team and/or Head of Department affect your use of ICT in lessons?

Very much so - we did not get interactive white boards (SMART) until a new Assistant Head Teacher was appointed from another school who insisted on having SMART because the software accompanying it was better.

Other Resources

11. How do you find out about programs or files that might be useful to you? Tick all that apply.

Other people's recommendations	✓
Courses	✓
Internet	✓
Computer magazines/journals	
Teaching magazines/journals	✓

12. Have you ever looked at teacher's TV programmes? Yes ✓ No

Would you consider using them with a class? Yes ✓ No

But I haven't found any suitable as yet except for PHSE

13. Have you, or would you, consider using a camera, video, or sound recording in your lessons? Yes O No O

If so how did you/would you use them?

14. Apart from initial teacher training, have you received any formal ICT training? Yes O No O

No initial teacher training (Good old !!)
Informal trainings plus NOF.

15. How do these forms of ICT INSET work for you?

	Excellent, able to use program easily afterwards	Good – able to use afterwards with a little more help	Poor - needed to use another method afterwards before I could use it	Ineffective – lost interest easily, not able to use program/software	No experience of this method
Exploration (experiment with program by yourself)			✓		
Demonstration (just watch a presentation)			✓		
Hands on session (shown program by someone familiar with it and then trying it under their guidance)		✓			
Following a sheet of printed instructions or manual		✓			
One to one tuition (peer or teacher)		✓			
Video clips and help files available whist trying out program		✓			
On-line tuition					✓

Other methods you have met

16. Generally speaking, what would be your ideal training session (Please order with 8 being the best choice)

Whole day 8

Half day (morning) 34

Half day (afternoon) 3

Twilight 1

Two whole days 6

Two half days (mornings) 7

Two half days (afternoons) 5

Two twilights 2

About you

This helps me to group the data to see if some groups use ICT differently to others. This is the only information that will be recorded – no names/places of employment other than county or country are required.

I am looking to see if there is a gender difference so it would be helpful to have this information.

17. Please tick options that describe you?

- Male ☐
- Female ☑
- 21-30 ☐
- 31-40 ☐
- Over 41 ☑

18. Which type of school are you working in/was your last post (please circle)?

primary/middle/high (or upper)/FE
urban: privileged / mixed / deprived area
rural: privileged / mixed / deprived area

19. Number of years teaching

- 0-10 ☐
- 11-20 ☐
- 21-30 ☑
- 31-40 ☐
- 41-50 ☐

20. In which country/county do you normally teach? Bedfordshire

Thank you very much for your help, it is greatly appreciated.

Alison

A3 Sample interview questions

A3.1 Interview questions for mathematics teachers who are engaged in using ICT in their mathematics lessons.

Introduction and recording check

Background

6. When was your first experience in using of IT?
7. What were your early experiences, for instance was it, at home, school, university, teacher training, workplace?
8. In your own school experience, did you study IT as a subject?
9. Did you use IT in mathematics lessons at school or in your university course?
10. What programs did you come across?
11. Have you been given (i.e. paid for by someone else) IT training in your role as a teacher?
12. How have you found out about possibilities of various programs?
13. How have you learnt to use new resources, do you teach yourself and/or have colleagues/courses played a part?

Teaching with IT

14. What encourages you to use ICT? Are you a competent user in other situations?
15. What do you see as the contribution of ICT to mathematics lessons? (Teaching/presentation/pupil experience).
16. Are you able to give some examples of where use of ICT has been beneficial?
17. What software/hardware do you have access to?
18. Do you tend to use it mostly yourself or with students?
19. What is your favourite a) hardware b) software and why?
20. Is there anything you would like to have?

21. How supportive is your college of the use of ICT in lessons and do you think this makes a difference?

Teaching approaches

22. What views do you hold on the importance of mathematics as a subject?
23. What views do you hold on the role of pedagogy in teaching of mathematics? Would you say that you lean more to the constructivist or transmissionist end of the spectrum? Would you say that you are creative, a connectionist ... how do you view your teaching style and is it the same for all groups? What influences you?
24. Do you use examples from other subjects?
25. Do you think that teaching with ICT is the same as teaching it without? If yes, what do you think is different and can you give examples?
26. Have your views changed over time e.g. at different career stages?
27. What influence do you think exams have on using ICT in lessons?
28. Do you use textbooks? Do you think that they have influence on teacher's use of ICT?
29. Are you and innovator or prepared to take risks?
30. What happens when you have a very IT savvy person in your class who likes to correct teachers?
31. Some researchers have found that teachers say that they are discouraged from using ICT by lack of resources, support from other staff, not enough time to find out/learn programs or in the allocated lesson time to work with classes, it is not examined, training. Could you give them tips/advice on overcoming any of these constraints?

Other bits

Are you interested in music – playing, singing or listening?

A3.2 Interview questions for advisors/trainers:

These are a guide and you are completely free to ignore any of them, change the order or add some extra information.

PERSONAL BACKGROUND -

32. What was your background, for example was it through mathematics, computer science or another discipline?
33. Prior to this where you classroom based and in which phase?
34. How would you describe your teaching approaches? Would you say that you were prepared to be innovative/take risks?
35. Was digital technology an important resource for your own teaching?
36. Did you experience any barriers in being able to use technology? Such as the technology itself/situation
37. How did you become interested in using computers (this can include non-work situations)?
38. Do you have any 'stories' of early experiences? Especially from the 'early days' such as successes and frustrations.
39. How were you initially trained and what was included/biased towards (admin, generic programs, specific programs, teaching and learning)?
40. Were you expected to do much 'self-training' or have you made a choice to teach yourself?
41. Where and when did you first run courses/become a teacher trainer?
42. How did you become interested in that role?
43. Has this changed over time?
44. How did you become interested in developing software and for which machines?

HISTORY OF THE COMPUTERS

45. Which computers did you first come across and do you know through what funding stream/method they arrived in schools?
46. I understand that your county chose BBC rather than the RM or Sinclair, can you enlighten me about this choice?

47. What did the first bundles comprise of – did they have monitors/ disc drives /printers?

48. Was the operating system included on the computer or did this have to be loaded?

49. What software was included?

50. There were several initiatives and funding streams such as MEP, MSU, ESG, NOF, NCET portable computers project, NGfL, National Curriculum. Can you tell me anything about these, - such as influence on hardware/software/training provision?

51. After the original BBC computers, what was the development line in your county and what was the provision of subject software like – commercial and in-house ...?

52. What software were you involved in writing – was it just for the BBC computers and just your county?

53. Thinking about the software – Logo + BBC, why did it seem to fade away (move to IT subject area / training of teachers to use it / only in support are of NC not in 'must do'?)

54. Graphics calculators were available from 1985 were maths teachers trained to use them (as in CAN schools) properly? Or the data logging for 'real maths'? Do you have any stories about them?

55. Were PDAs used in maths as part of the NCET pilot around 1997?

THE SCHOOLS

56. How much did the attitudes of schools themselves – heads/governors – play in the introduction of IT into their schools? E.g. adding more from their funds/ allowing extra teachers to be trained?

57. What factors did you see play an important part in whether ICT is well developed in schools/colleges?

58. What is your take on how computers have been used in maths lessons? Was there a sudden demise or has the use never really taken off to give Ofsted reason to say they were not being used enough pre 2000?

COURSES – 1980-2000

59. How would you describe a typical group who came to be trained?

60. Has there been change over time?

61. Have the courses change over time? (i.e. who attend, numbers attending, types of training offered, including different software packages generic v. subject specific)

62. Did you notice any differences in participation levels from different sub-groups, i.e. a) those who have been sent v. those who volunteer and come in their own time (and all 'shades' in-between), b) complete novices v. competent users of IT?

63. Are any types of courses more successful than others? (e.g. lecture v. workshop, conference, school/college INSET, one day/part of day)

64. How did you structure your courses to cater for people with different levels of expertise/knowledge?

65. Have you had to deal with a 'know-it-all' and how did you manage that?

66. Was there any follow-up/support available for people who have attended courses?

A4 Sample agreement

A4.1 Information given to participants

THE UNIVERSITY OF WARWICK

Information Sheet

Project Title: Mathematics Teachers who use ICT in lessons

Date: 12/05/2012

You are invited to take part in a research study which is being conducted as part of a PhD degree at the Institute of Education, the University of Warwick. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please feel free to contact us if you would like more information or you have any concern regarding this research. Take time to decide whether or not you wish to take part.

What is the purpose of this study?

This study aims to explore how and when teachers use ICT as part of their lessons, the programs used, the training they have received and the problems they encounter.

Why is the study being done?

Ofsted reports have highlighted that there is a less than desirable amount of ICT being used in mathematics lessons and whilst there have been studies on the effect of teaching there has been less found out about why teachers use it, or not. They study aims to look at whether and how more people might be encouraged to use ICT within their lessons.

Why have I been invited to participate?

You have been invited to take part in this study because this study intends to collect your views as a practitioner.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part, you have to sign a consent form for this study. You will be free to withdraw at any time and without giving a reason. This decision will not affect you or your rights in any way.

What do I have to do?

You will be asked to sign a consent form and take part in an interview and' or complete a questionnaire. The interview questions are open-ended in nature and there are no right or wrong answers. The interview session would take about 20 to 25 minutes.

What are the possible benefits of taking part?

There are no direct benefits to you from taking part in this study. We are hoping that the data collected will produce information about and contribute to an understanding of the real situation in schools and whether there are ways to encourage teachers to include more ICT.

What are the possible disadvantages of taking part?

The interview will take some of your time. Every effort has been made to keep any inconvenience to a minimum.

Will my taking part in the study be kept confidential?

The use of any information that identifies you during the course of the research will be kept strictly confidential. This information will be kept in a secure place and only people involved in the study or authorised individuals will have access to it.

What happens when the research stops?

The data obtained will be used for internal publication for a PhD Project and submitted for assessment with a view to being published in academic journals/ conferences. We can also send participants a summary of the study results on request.

Contact details

If you would like any further information please contact:

Alison Parish

Institute of Education

University of Warwick

Coventry, CV4 7AL

Tel: +447961502211

Email: a.j.parish@warwick.ac.uk

Web: http://go.warwick.ac.uk/ep/pg/edrfbo

Thank you for taking the time to read this information.

A4.2 Information about the project

Dear

Thank you for offering to help me in my research on maths teaching with ICT. I am funding this work myself and so have no particular theories that I am trying to prove, or disprove, for a third party. My research is thematic, and all participants and establishments will remain anonymous.

The interview is semi-structured in that I have a list of topics I would like to investigate. However in the ones I have already conducted we, the participants and I, have found it beneficial to treat it more as a conversation, allowing the participant to develop thoughts at their own pace, checking at the end to see if everything is covered. Some people like to have the questions in advance and I am happy to email them. There is no obligation to answer the questions and information will remain anonymous in the thesis.

Three main themes are evolving, the history of the introduction of IT including people's early experiences at home, school and university, the 'modern' use of hardware and software, and teaching and learning. Within these there are also some common personal attributes and experiences that are emerging (not contentious) which is quite interesting so I would like to talk (via Skype or face-to face) to some more people to see if the patterns continue or whether I have just, by chance, found an isolated group.

Thanks again for your offer of help

Alison

A4.3 Consent form

THE UNIVERSITY OF WARWICK

CONSENT FORM

Project Title: Mathematics Teachers who use ICT in Lessons

Name of Researcher: Alison Parish

I confirm that I have read and understood the information sheet dated 12/05/2012 for the above project which I may keep for my records and have had the opportunity to ask any questions I may have.

I agree to take part in the above study and am willing to have my involvement in the interview recorded.

I understand that my information will be held and processed for the following purposes:

- To be used anonymously for internal publication for a PhD project and submitted for assessment with a view to being published in academic journals / conferences.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason without being penalised or disadvantaged in any way.

Name of Participant		Date		Signature
Researcher		Date		Signature

A5 Sample coded transcript

Edited transcript of my interview with P (Secondary Teacher) –

This was subsequently coded again in NVivo and with highlight pens.

Who		Notes/code
A	So have you been, paid by someone else to come on this course – or is it all on your own?	
P	I was quite lucky, I managed to somehow get some money from the staff development. They, they've paid for this entirely which was a bit of a surprise, fully anticipating paying some or all of it myself. But I was encouraged to go … for it and somehow got approved. I think the previous staff development manager had been very frugal with the staff development budget, so I just got lucky really.	CPD paid for TSM finance encouraged school approval finance
A	So that generally is not a sort of part of your package at work?	
P	We've had sometimes people come in like to do Autograph training, I think we had Adam – Alan Catley in, and Martin Willington.	In-house CPD People into school
P	I remember Alan coming in, but mostly 95% of the IT I've taught myself, really.	Self taught 95%
A	Ok, how do you find out about possibilities of programmes?	

Who		Notes/code
P	I'd always been aware that you could add functionality and customise things using programmes, exactly what you want, I actually first sort of got into it when I sort of exhausted other things and I just learned, pretty much mastered, just about everything in word and then in PowerPoint, and then I'd sort of gotten into using Excel, and I was aware you could write macros which could add a new level of sophistication and somebody brought back from some training this little thing that sort of got you started on macros, literally just a couple of sides, just getting a start with a very, very simple macro explaining the first stages. I grabbed that as soon as I could then just basically went from there and just gradually got more and more ambitious, writing more and more complicated programs. I just liked pushing boundaries and seeing if I could do something that, that seems a bit insane.	Possibilities Functionality Generic Word PowerPoint Excel Personal development Goal setting Write macros Customisation Sharing colleague Support Motivation Experimental Writing programs Pushing boundaries Self taught Progression

Who		Notes/code
P	I mean first of all, the feeling that it's giving the students a better experience, and also a great deal is the challenge of it, really. You know, I can do something that, you know, somebody else has never done before. I've written a program to do, for example, that, that correlation program that you saw, I don't think anybody else has thought of doing that,	Better experience Student focus Challenge Creative Innovator Divergent thinker Program writing Self taught
P	… just the challenge and the, the fact that, you know, I can be proud of something, I can be proud of doing something that, that can be used for the students really.	Instant feedback Excel Visual Basic Application Pride Student use
P	yeah, I've written programs for all sorts of things, so I've done lots of - GC I've done, for example, shows you how to construct a stem and leaf diagram, one that does place value and significant figures. It gives a demo of how you can round things to different numbers of significant figures, sort of the GCSE end, and then I've done stuff with pure maths, I've a random graph generator which then can then be used interactively as a rich activity with the students. They can guess what the equation is, you can also press a button to see what the actual equation is.	Program writing GC Stem and Leaf Place value significant figures demonstration random graph generator interactivity fitting syllabus equation feedback

Who		Notes/code
P	And then I've done quite a lot in decision maths, because a lot, decision maths is quite a lot of work to actually set up with problems. there – so for example if you wanted to do Prim's algorithm then you've got to create all these matrices and it's a nightmare, actually thinking all the numbers up, and you know cutting and pasting them, with a computer program I just programmed it to generate a suitable set of numbers and then just put it on the board so it would work and then you know what you're focussing on is actually the problem.	Decision , maths Problem setting Matrices Prim's algorithm Creativity Time Computer generated numbers Suitability Demonstration Focus on problem Time
P	If I do want to make a worksheet I can just copy the question off Excel, into a Word table and also even better, have the answers already done. Once you've done the work it's like something that's gonna repay you for as long as you need to teach the topic.	Worksheet Cut and paste Computer generated numbers Preparation Answers pre-prepared Instant feedback Re-use time
A	So do you also have access to something like dynamic geometry?	

Who		Notes/code
P	We have Autograph in college, so I've used that to generate graphs, especially for things like PowerPoint presentations. A lot better than using the built-in PowerPoint graphs and things. You can get an exact normal distribution curve, for example,	Dynamic geometry Autograph Embedding Discerning Quality More accurate
P	My favourite piece of hardware or software? Oh, probably Excel. I just use it so much. It's not absolutely perfect – it doesn't do everything – but it's just, you can do so much with it.	Excel Usage Limitations
A	Is there anything you would like to have?	
P	Maybe a bit more time and energy to do this sort of things, you know. Also, to some extent I've had that here, is just, you know, ideas of how to use it more, how to use it better in the classroom, how to handle it so you get a better learning, a richer activity, experience.	Enthusiasm Developmental Learning Time and energy Ideas Learning Rich activities experience
A	Would you say your college is supportive of you using IT in lessons?	

Who		Notes/code
P	I would say, I mean the fact that they've paid for me to come here is testament to that but they do, they do expect us to use IT. Although, to be honest, there's no actual pressure to use IT. I, I could, if I wished I could use zero IT apart from, you know, the administrative tasks we have to do like fill in Excel sheets and things with, with marks and stuff like that.	Establishment supportive ICT use expected Not pressured to use IT Admin
P	Before I started teaching I would have been, sort of transmissionist, but I've sort of gradually got my head round more the sort of constructivist side of things. Although it is a bit tricky then because students often express, expect a transmissionist approach, especially at A-level. They want you just to tell them the techniques and the answers. Um so sometimes can take a bit of persuading to get them to get really, on-board with that. I do prefer the constructivist method, that's how I used to learn as a child by just sort of working everything out for myself, you know, and seeing how things went.	Change in pedagogy Transmissionist Constructivist Student expectation Students at A level Student expectation Student insecurity Lack of thinking effort Personal learning style Constructivist Self evaluating Adaptable

Who		Notes/code
P	My views change all the time; it depends what people tell me, you know I'm always looking for new ideas and new perspectives and things. As I say, I used to be more sort of transmissionist and so I've sort of gradually changed that.	Views changed Seek new ideas New perspectives Accepts new ideas Transmissionist
A	Do you think exams have an influence on how people use ICT in their lessons?	
P	I suppose to a certain extent a lot of the stuff I do is actually geared towards exams, I do quite a lot of stuff that gives them direct practise in what they would do in the exam but just makes it a lot easier than if they were going to be doing it on paper, although I like to have things that are not necessarily directly connected to the exams but do enhance their learning if I can. I mean if, if it makes learning more efficient or more effective in, in any way then, then that's the reason for using it.	Exam influence Geared to exams Syllabus Practice Enhance learning Learning Efficiency Effectiveness Reason
P	What would life be without risks? Being able to try new things and some of the things I've tried haven't worked or there've been mistakes in them and I've had to gone back and correct them or improve them, whatever. You know, it'd be a pretty boring life if you couldn't innovate or take risks.	Innovation Risk taking Evaluation Revise

A6 Sample of curriculum links from KS3 Numeracy strategy, (DfES, 2004)

A6.1 KS3 Plans

The pages listed are those were specific mention is made of dynamic software. There are other situations where it could be beneficial. The timing relates to the sample plans and core programme. Key Objectives are in bold.

Page	**Objective**	**Task – dynamic geometry software**	**Year**	**Timing**
14-15	Solve word problems and investigate in a range of contexts	Draw a circle inside a square & vice versa	9	SSM 1 Autumn
18-19	Solve word problems and investigate in a range of contexts	Draw a square ¼ of an original	7	SSM 1 Autumn
180-1	Identify properties of angles and parallel and perpendicular lines, and use these properties to solve problems.	Parallel and perpendicular lines Identify alternate and corresponding angles	7 8	SSM 2 Autumn SSM 1 Autumn

Page	Objective	Task – dynamic geometry software	Year	Timing
182-3	Identify properties of angles and parallel and perpendicular lines, and use these properties to solve problems.	Angles at a point, on a straight line Proof of angles in a triangle, quadrilateral, exterior angles of a triangle. Interior and exterior angles of polygons	7 8 9	SSM 2 Autumn SSM 1 Autumn SSM 1 Autumn
184-5	Identify and use the geometric properties of triangles, quadrilaterals and other polygons to solve problems; explain and justify inferences and deductions using mathematical reasoning.	Visualise and sketch 2-D shapes Visualise and sketch 2-D shapes Visualise and sketch 2-D shapes	7 8 9	SSM 2 Autumn SSM 1 Autumn SSM 1 Autumn

Page	Objective	Task – dynamic geometry software	Year	Timing
186-7	Identify and use the geometric properties of triangles, quadrilaterals and other polygons to solve problems; explain and justify inferences and deductions using mathematical reasoning.	Triangles, quadrilaterals and other polygons Know and use side, angle and symmetry properties of equilateral, isosceles and right angle triangles. Classify quadrilaterals Know and use angle and symmetry properties of polygons, and angle properties of parallel and intersecting lines, to solve problems and explain reasoning. Know and use properties of triangles, including Pythagoras' theorem. Understand and recall Pythagoras' theorem.	7 8 9	SSM 2 Autumn SSM 1 Autumn SSM 1 Autumn

Page	Objective	Task – dynamic geometry software	Year	Timing
188-9	Identify and use the geometric properties of triangles, quadrilaterals and other polygons to solve problems; explain and justify inferences and deductions using mathematical reasoning.	Solving problems Solving problems Understand and recall Pythagoras' theorem.	7 8 9	SSM 2 Autumn SSM 1 Autumn SSM 1 Autumn
190-1	Understand congruence and similarity	Congruence Congruence	8 9	SSM 3 Spring SSM 3 Spring
192-3	Understand congruence and similarity	Similarity	9	
194-7	Understand and use the properties of circles	Circles	9	SSM 1 Autumn

Page	Objective	Task – dynamic geometry software	Year	Timing
202-5	Understand and use the language and notation associated with reflections, translations and rotations Recognise and visualise transformations and symmetries of shapes	Reflections Combinations of two transformations Combinations of transformations	7 8 9	SSM 4 Summer SSM 3 Spring SSM 3 Spring
206-7	Recognise and visualise transformations and symmetries of shapes	Reflection symmetry	7	SSM 4 Summer
208-9	Recognise and visualise transformations and symmetries of shapes	Rotation Rotation	7 8	SSM 4 Summer SSM 3 Spring
210-1	Recognise and visualise transformations and symmetries of shapes	Rotation symmetry Reflection symmetry and rotation symmetry	7 8	SSM 4 Summer SSM 3 Spring

Page	Objective	Task – dynamic geometry software	Year	Timing
212-3	Recognise and visualise transformations and symmetries of shapes	Translation Enlargement Enlargement	7 8 9	SSM 4 Summer SSM 3 Spring SSM 3 Spring
214-5	Recognise and visualise transformations and symmetries of shapes	Practical use of software	8	SSM 3 Spring
226-7	Find simple loci, both by reasoning and by using ICT	Use ICT to investigate paths	9	SSM 1 Autumn

A6.2 KS3 Sample Y8 plans for the spring term with potential ICT links

Page numbers refer to the supplement of examples for the core teaching programme

	SUPPORT From the Y7 teaching programme	CORE From the Y8 teaching programme	EXTENSION From the Y9 teaching programme
Handling data 2 (6 hours) Handling data (248–273)	• Given a problem that can be addressed by statistical methods, suggest possible answers.	• Discuss a problem that can be addressed by statistical methods and identify related questions to explore.	
		• Decide which data to collect to answer a question, and the degree of accuracy needed; identify possible sources.	• Discuss how data relate to a problem; identify possible sources, including primary and secondary sources.
GC will produce lines of best fit, histograms, box and whisker and some new ones will even draw a pie chart.	• Design a data collection sheet or questionnaire to use in a simple survey; construct frequency tables for discrete data.	• Plan how to collect the data, including sample size; design and use two-way tables for discrete data.	
The WEB can be a excellent source of data		• Collect data using a suitable method, such as observation, controlled experiment using ICT, or questionnaire.	• Gather data from specified secondary sources, including printed tables and lists from ICT-based sources.
SS are the perfect tool for analysing and presenting data	• Calculate statistics for small sets of discrete data: - find the mode, median and range; - calculate the mean, including from a simple frequency table, using a calculator for a larger number of items.	• Calculate statistics, including with a calculator; recognise when it is appropriate to use the range, mean, median and mode; construct and use stem-and-leaf diagrams.	
Access is good at designing a database, but it is extremely difficult to use for beginners.	• Construct, on paper and using ICT, graphs and diagrams to represent data, including: - bar-line graphs; use ICT to generate pie charts.	• **Construct, on paper and using ICT:** **- pie charts for categorical data;** **- bar charts and frequency diagrams for discrete data;** **- simple scatter graphs;** **identify which are most useful in the context of the problem.**	
		• Interpret tables, graphs and diagrams for discrete data and draw inferences that relate to the problem being discussed; relate summarised data to the questions being explored.	• Interpret graphs and diagrams and draw inferences to support or cast doubt on initial conjectures; have a basic understanding of correlation.
PP can be an excellent way to make a presentation.	• Write a short report of a statistical enquiry and illustrate with appropriate diagrams, graphs and charts, using ICT as appropriate; justify choice of what is presented.	• Communicate orally and on paper the results of a statistical enquiry and the methods used, using ICT as appropriate; justify the choice of what is presented.	
Solving problems (28–29)		• Solve more complex problems by breaking them into smaller steps or tasks, choosing and using resources, including ICT.	

A7 Mathematics Software for Use in Schools

Unlike many subjects taught in schools, mathematics, by its nature, inspired the development of ostensibly curriculum enhancing software. Apart from generic software such as word processing, presentation, spreadsheet and databases, teachers have access to programs written for dealing with mathematical concepts such as dynamic geometry, graphing and computer algebra. Additionally some programming software can be appropriate to the mathematics curriculum. Some of the software is also present on graphics calculators and handhelds, often in a reduced form making it possible to have access to the programs without computers. Some software is available as apps for other operating platforms such as iOS and Android for use on ipads and tablets.

This list is only a sample of the available software and new resources are constantly being added.

- Generic. Includes productivity suites Microsoft and Open Office suites, with word processing and desktop publishing, presentation software and data handling in the form of spreadsheets.

- Mathematics applications. Includes dynamic geometry, graphing packages and computer algebra systems. Some of these are freely available such as GeoGebra whilst others need to be purchased including Autograph.

- Integrated learning systems and exercise programs. Integrated learning systems and programs used to provide 'exercises' make up the third category. These tend to be subscription based or a 'one-off' purchase for a school site.' This includes MyMath and Mangahigh to which many schools subscribe and SAM learning as both provide feedback on performance to teachers and refer to this group as learning systems.

- Mathematics support. includes applets written for classrooms, of which many are available free from the internet, as well as resources to provide specific content includes simulations and games (such as Bowland Maths, 10Ticks and Nubble).

- Graphics calculators and hand-helds. These range from those able to carry out just calculations to the more complex hand-helds, which provide some of the features of the specialist mathematics software packages.

Examples of some available software:

Generic - Presentation	Word	Publisher	PowerPoint		
Spreadsheet/ statistics	Excel	GeoGebra	Autograph		
Dynamic Geometry	Cabri II, 3D	GeoGebra	Geometer's Sketchpad	C.a.R.	Cinderella
Graphing Package	Autograph	GeoGebra	Mathematica	Maple	MathsCad
Computer Algebra	Derive	GeoGebra	Mathematica	Maple	MathsCad
Programming	MSW Logo	Scratch	NetLogo	StarLogo	
Learning Systems	SAM Learning	Success-maker	MyMath	Mangahigh	

Additionally there are resources such as Bowland Maths (www.bowlandmaths.org.uk/) and websites that provide links such as Times Educational Supplement (TES) www.tes.com/teaching-resources.