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AN INVESTIGATION INTO THE USE OF GRAPHICS CALCULATORS BY MATHEMATICS TEACHERS

By

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Abstract

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AN INVESTIGATION INTO THE USE OF GRAPHICS CALCULATORS BY MATHEMATICS TEACHERS

This thesis reports on the findings of four inter-related studies: a pilot study with three Post-graduate student-teachers, a longitudinal case study of a novice teacher, a cross-sectional study of novice teachers and experienced teachers, and a study of a mathematics department just beginning to use graphics calculators.

Four research tools were used in the main part of this research: a questionnaire, lesson observations, interviews and log books. The questionnaire was designed to elicit participants' responses about their beliefs and attitudes about graphics calculators. The data from the questionnaires were triangulated with data collected from lesson observations and interviews.

The questionnaire data suggested that the participants' beliefs and attitudes about graphics calculators were relatively stable and remained unchanged during the research. The interviews and observations provided much greater insight into the way teachers use graphics calculators.

The fourth strand of the research asked a group of teachers to record their use of graphics calculators in a log book. The log book data were used to identify the types of tasks and activities that teachers present to their pupils. The log book data showed that teachers make limited use of graphics calculators in their teaching.

A model to describe the way teachers use graphics calculators is proposed. The proposed model highlights the way that teachers use graphics calculators and describes four levels of use. The model also describes how teachers move from one level to the next by considering their professional development.

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AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.
A programme of advanced study was undertaken which included regular presentations at the Centre for Teaching Mathematics at the University of Plymouth.
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GLOSSARY OF TERMS

A-Level: Two year courses for post-16 students leading to high stakes public examinations, which are accepted for university entry.

GCSEs: High stakes public examinations taken by school pupils at the end of their compulsory education, normally at age 16.

Inset: In-service training offered to teachers as part of their ongoing professional development.

ITT: Initial Teacher Training. This is the training and education that is undertaken by trainee-teachers, normally over a period of one year.

NNS: National Numeracy Strategy, now known as the 'Framework for Teaching Mathematics'. This government document prescribes the content of the mathematics curriculum for school pupils aged 11-16. It recommends the use of the 'three part lesson': lesson starter, main and plenary. The lesson starter is usually a short episode at the beginning of the lesson, designed to motivate and engage pupils.

Ma1: A label used in the NNS to describe open-ended tasks, investigative tasks and problem-solving tasks that use and apply knowledge and understanding from the three other areas of the mathematics curriculum: Ma2 (number and algebra), Ma3 (shape, space and measures), and Ma4 (data handling).

NQT: Newly-Qualified Teacher.

PGCE: Post-Graduate Certificate in Education. A teaching qualification that is available to graduates after completing their initial teacher training (ITT) course.

QTS: Qualified Teacher Status: Teachers must successfully complete their ITT course and a period of probation to be considered as fully qualified teachers.

SATs: Standard Attainment Tests. High stakes examinations taken by pupils at the end of year 9 (aged 13-14) in Mathematics, English and Science.

SWIFT: South West Initiative for Training: a body accredited by the local education authorities in the south west of England to deliver in-service training (Inset) for teachers.

TTA: Teacher Training Agency. Government body responsible for administering the provision of initial teacher training (ITT). The TTA is now called the Training and Development Agency (TDA).

Chapter 1. An Introduction to the Research

1.0 Biographical Notes

Having taught for several years, I realised that I needed to re-consider my teaching style in the classroom. Although, my pupils performed well in assessments and seemed to enjoy their lessons, I felt some disquiet with my own teaching. In order to address this I decided to do some research to help me improve my teaching practices. One way to do this would be to observe best practice of other teachers. I did this initially as a piece of action research as part of my Masters Degree. I was inspired by one of the course themes of examining a situation critically so that one can give an *'account of'* the incident then give an *'account for'* (OU, 1997). Observing other teachers as part of my action research led me to conclude that giving an *'account of'* their teaching practices is relatively easy, but to *'account for'* why they taught the way they did was far more challenging.

- The first question that I wanted to investigate in this research was: why do teachers teach the way that they do?

Answering this question from my own viewpoint proved to be difficult. Ernest (1994) suggests that teachers' teaching style is a result of their philosophy about mathematics learning. For instance, he suggests that teachers with a transmissionist philosophy will tend to adopt a didactic teaching style. Teachers with a transmissionist philosophy believe that mathematical knowledge can be transmitted, and that the best way to teach mathematics is to tell pupils what they need to know. On the other hand, teachers with a constructivist philosophy will pose problems so that pupils come to construct their own meanings and understandings of the mathematical concepts. These two philosophies seem to be at odds with one another, yet I have adopted both stances on many occasions as part of my teaching. Clearly, the way that I teach is not just a result of my philosophy of learning mathematics. However, there is an underlying principle that guides the way that I teach, despite the fact that it might be a difficult construct to articulate. Ball (1988) goes as far as to suggest that teachers '*teach math just as they were taught*'. Most of the teachers that I have come into contact with would also struggle to articulate their own personal philosophy about mathematics, but each one would have a strong opinion about the right way to teach. The weight of literature suggests that they are influenced by their beliefs, and that these beliefs are a result of their prior experiences.

- The second question that I wanted to investigate was: are teachers' beliefs about mathematics, teaching and learning evident from their teaching practices?

Prior to this research I was a strong advocate of the use of technology, particularly graphics calculators. Whenever I came across a new activity that used graphics calculators I would examine the difficulty of the keystroke sequence to see if it would be suitable for my pupils. Only if I considered the keystrokes to be straightforward would I use that activity with my classes. The underlying idea was that the pupils should not be distracted from the mathematics, but as the rest of this research study shows there is more to this than meets the eye! As the research has progressed my attitude towards the use of graphics calculators in lessons has changed considerably. From being a strong advocate of using graphics calculators at every opportunity, my attitude now is that I would prefer graphics calculators not be used if they are going to be used badly.

- This leads on to the third question for investigation: When teachers do use graphics calculators, what type of tasks are they using?

1.1 An overview of the research

Alongside my role as research student, I was also a visiting tutor for trainee-teachers on a PGCE course. This involved visiting the trainee-teachers on their school placements and observing them teach. I noticed, very quickly, that none of the lessons I had observed included the use of graphics calculators. This was more surprising as the use of ICT is prescribed by the Professional Standards that the trainees are required to meet in order to qualify. This '*act of noticing*' (OU, 1997) was the springboard for the Pilot Study.

The Pilot study was an investigation into the beliefs and attitudes of PGCE students about the use of graphics calculator. A questionnaire was designed for this pilot study and based on initial results three PGCE students were chosen to participate in further research.

The structure of the pilot study was used as a basis for the main body of the research, in particular a longitudinal study of Mark, a novice teacher. The research also involved observations and interviews with a cross-section of teachers with a range of teaching experience. The findings from the observation and interview data were used to describe how teachers use technology.

A related investigation of a mathematics department just beginning to use graphics calculators, the Calculator Development Project, forms the final part of this research. The findings from that investigation were used, in conjunction with other work, to propose a model of teachers' development with respect to the use of graphics calculators.

1.2 The Research Questions

This thesis attempts to address the research questions that were raised above

- Why do teachers teach the way that they do?

  Where do they get their teaching ideas from?

  What are the influences that affect teachers' teaching styles?

- Are teachers' beliefs about mathematics, teaching and learning evident from their teaching practices?

  Do their beliefs about mathematics teaching and learning influence their use of graphics calculators in the classroom?

  What motivates teachers to use graphics calculators?

- When teachers do use graphics calculators, what type of tasks are they using?

  Are teachers making good use of graphics calculators?

  How do teachers integrate the use of graphics calculators into their lesson teaching?

  How does teachers' use of graphic calculators develop over time?

A review of the literature suggests that these questions about teachers' use of graphics calculators still need to be addressed.

In order to begin to answer these research questions a review of the relevant literature is given in Chapter 2. A discussion of the research methodology and research methods that were used in the cross-sectional study and the longitudinal study is given in Chapter 3. The pilot study is discussed in Chapter 4. Chapter 5 presents the data collected from the questionnaire and discusses the findings. The lesson observations and interviews from the cross-sectional study are presented and analysed in Chapter 6. The longitudinal study of Mark is discussed in Chapter 7. Chapter 8 describes the Calculator Development Project and how the data were used to propose a model of teachers' development. The proposed model is presented in Chapter 9. Chapter 10 presents a summary of the research and the findings.

Figure 1.1 shows a timeline of events and the participants as they became involved with the research

A Longitudinal Study of Mark: His journey from PGCE student to fully qualified teacher				
	Mark as PGCE: Completes both pre-test and post-test questionnaires & follow up interviews Non-assessed lesson observation & follow up interview	Mark as Newly Qualified Teacher: Two lesson observations and follow up interviews	Mark as fully qualified teacher: One lesson observation and follow up interview	
The Cross-Sectional Study	Pilot Study of three PGCE students: Completed pre-test and post-test questionnaires & follow up interview Non-assessed lesson observation & follow up interview	PGCE questionnaire given to new cohort of students Questionnaire given to NQTs and class teachers Lesson observations and follow up interviews with three NQTs	PGCE questionnaire given to new cohort of students Separate questionnaire given to Heads of Department Lesson observations of three classroom teachers and two HoDs	The Calculator Development Project An investigation of three teachers within the same department beginning to use graphics calculators
	Year 1	Year 2	Year 3	Year 4

Figure 1.1 **Timeline showing overview of events and participants**

Chapter 2. A Review of the Literature

2.0 Introduction

The literature review in this chapter collates the relevant work done by other researchers on the themes of beliefs and attitudes, how these beliefs and attitudes might affect the way that teachers teach, and also how they might impinge on teachers' use of graphics calculators.

As the university tutor for mathematics student-teachers I had observed several classroom lessons. In none of these lessons had the student-teachers made use of graphics calculators as part of their teaching or the pupils' learning, even though the Teaching Training Agency assessment criteria for their Post-Graduate Certificate of Education stipulated the use of computers and/or graphics calculators. I wanted to examine this situation further by investigating why teachers teach the way that they do. The earliest search of the literature (Thompson, 1992 for example) seemed to suggest that the beliefs and attitudes of these student-teachers might account for the way they conducted their lessons.

The first section of this chapter discusses some difficulties with relying solely on beliefs and attitudes to describe teachers' behaviours. Various definitions of beliefs and attitudes are given followed by a review of the literature on the theme of beliefs and attitudes.

The second section of this chapter gives a review of literature on the beliefs about the use of technology in general, and the use of graphics calculators in particular.

The third section looks at the processes involved in becoming a teacher and presents literature on student-teachers and newly qualified teachers as they become experienced teachers working in their own classrooms.

The fourth section of this chapter considers the literature on continuing professional development and teacher-change.

2.1 Beliefs and Attitudes

There is a wealth of literature (see section 2.1.2) that suggests that teachers are influenced by their beliefs and attitudes. The literature also suggests that these beliefs are formed as a result of teachers' prior experiences. However, I feel that there is an inherent difficulty in using these constructs to describe and define teachers' behaviour in the classroom. As a classroom teacher my actions are often instinctive and spontaneous and not always a reflection of any deeply held belief. As a researcher I am more aware of my teaching and this has had an impact on my teaching practice; my reflections are a result of being a researcher. I am more conscious of my beliefs and attitudes as a result of my research, whereas this is not the case for the teachers in this study. Observations and discussions with the teachers in this study suggest that they have <u>opinions</u> which influence their decisions. Although these teachers do have beliefs, they seem to be at some subconscious level. Also the teachers in this study would probably be unable to articulate what their beliefs are in a way that could account for their teaching style. It seems reasonable to assume that their subconscious (even unconscious) set of beliefs do influence the way they teach, although it may be difficult to pinpoint the cause and the effect.

Despite the difficulty of relying on teachers' beliefs and attitudes as a way of accounting for observed behaviour, the literature does provide a great deal of insight that may describe the way that teachers teach. The following literature review is presented with the premise that beliefs and attitudes influence the way that teachers teach.

2.1.1 Definitions of Beliefs and Attitudes

There have been many studies about beliefs and attitudes (see Pajares (1992) for a detailed synthesis of findings on beliefs). It is evident from Pajares' work that beliefs have been consistently difficult to define. Most often beliefs and attitudes are described and defined using metaphors and similes. For example, Pehkonen and Torner, (1996) and Thompson (1992) describe beliefs in terms of knowledge and that what one believes is '*entangled [like a] 'plate of spaghetti'*'. Similarly, Higgins and Moseley (2001) use the idea of personal experience which leads one to hold certain viewpoints. The notion of belief as being a conglomerate of knowledge and experience is put forward by Schraw and Olafson (2002) who define teachers' collective beliefs about nature and the acquisition of knowledge as '*an epistemological world view*', Thompson (1992) refers to them as '*conceptions*', and Pajares (1992) calls them '*teachers' teaching criteria, principles of practice, personal construct/theories/epistemologies, perspectives, teachers' conceptions, personal knowledge and practical knowledge*'. Ruffell et al (1998) describe attitude as '*a mental orientation*'. Something '*that is a multi-dimensional construct with three inter-woven components:*

- *Cognitive: expressions of beliefs about an attitude object*
- *Affective: expressions of feelings towards an attitude object and*

- *Conative: expressions of behavioural intention.*

They go on to say that they '*regard beliefs as part of the cognitive component of attitude*'. (Ruffell et al, 1998)

Pajares (1992) suggests that beliefs are '*the taken for granted beliefs about physical and social reality and self.... As, such they are deeply personal, rather than universal, and unaffected by persuasion. They can be formed by chance, an intense experience, or a succession of events.*' Higgins and Mosley (2001) give a very similar definition which makes a connection between belief and experience.

Clearly, it is difficult to give a precise definition of 'beliefs' that reflects the commonplace use of the term.

Trying to pinpoint a definition of a teacher's mathematical beliefs is equally elusive. Pehkonen and Torner (1996) define an individual's mathematical beliefs as '*the compound of his subjective (experience-based) implicit knowledge (and feelings) concerning mathematics and its teaching/learning*'. However, anecdotal evidence suggests that it is possible for teachers to have the same knowledge and similar experiences, yet they do not necessarily have to hold the same beliefs about mathematics.

This thesis adopts the definition of attitude put forward by Ruffell et al (1998) as being a '*mental orientation*' that leads to a '*posture*' or a stance or position. Beliefs are defined as a person's subjective and experiential or emotional response as given by Pehkonen and Torner (1996). Of the several definitions given by other researchers the definition of belief as given by Pehkonen and Torner relates mostly closely to the everyday use of the term. It refers to a person's internal and emotional reaction(s) to particular situation(s). Similarly, the definition of attitude as put forward by Ruffell et al (1998) as suggesting a person's outward appearance bears a similarity to the common understanding of the term 'attitude'.

2.1.2 The Affect of Beliefs and Attitudes on the Teaching of Mathematics

Thompson's (1992) work on teachers' beliefs and conceptions offers a thorough and detailed review of literature covering the themes of belief, knowledge and teachers' conceptions of mathematics. The research cited within Thompson's review concludes that the way teachers teach is a result of their belief system. These beliefs guide teachers into what they feel is the right way of doing mathematics and this influences the way they teach.

Similarly, Ernest (1994) suggest that '*the teacher's mental or espoused models of teaching and learning mathematics, subject to the constraints and contingencies of the school context, are transformed into classroom practices.*'

It seems as if teachers' actions in the classroom are a consequence of their beliefs. Furthermore, these same beliefs have an impact on their decision making process. On the basis of their beliefs, teachers may decide which teaching methods to use and which tasks are suitable for their pupils (Aguirre and Speer, 2000; Schoenfeld, 2002).

2.1.2.1 Formation of Beliefs and Attitudes

These beliefs begin to develop from an early stage. Picker and Berry's (2000) research into pupils' images of mathematicians showed they had developed negative views of mathematics and mathematicians. The only mathematicians these pupils had come across had been their mathematics teachers, yet they had already formed a loose image, a belief, of how mathematics teachers 'are'. Any pupils who go on to become mathematics teachers will be influenced by these early images and beliefs.

This is corroborated by Virta (2002) who writes that teachers-to-be collect impressions of what it means to be a teacher during their early school experiences. Pehkonen and Torner (1996) say that this forms a belief 'cycle' where '*beliefs and learning seem to form a circle... Thus, pupils' beliefs revealed through research reflect teaching practices in the classroom.*' So it would appear that teachers' beliefs are influenced by their experiences as a pupil, and that pupils' beliefs are influenced by their teachers and their experiences in the classroom.

Daskalogianni and Simpson (2001) suggest that university students' mathematical beliefs are shaped and influenced by '*endogenous*' factors such as their mathematical abilities, their liking for particular topics, their confidence, and intrinsic motivation. These beliefs, which are developed in school, have an impact on their transition from school to university. Daskalogianni and Simpson (2001) describe this as a *'beliefs overhang'*, and suggest that it has an effect on the students during the early part of their university course. This beliefs overhang continues to influence mathematics graduates as they begin their teacher training courses. Ball (1988) puts this succinctly:

'Prospective teachers do not arrive at formal teacher education "empty-headed"; instead they bring with them a host of ideas and ways of thinking and feeling related to math and the teaching of math, drawn largely from their personal experiences of schooling.' This adds another layer of complexity; intermingled with teachers' beliefs about teaching are their beliefs about mathematics. This '*beliefs bundle*' (Aguirre and

Speer, 2000) may explain the difficulties of understanding why teachers teach the way they teach.

Studies by Cooney (1999), Pehkonen and Torner (1996) and Higgins and Moseley (2001) add to this argument that *'teachers' actions in the classroom, their questioning and teaching approaches were influenced by their thinking and beliefs about mathematics, about how mathematics should best be taught and about what it means for pupils to be successful at mathematics.'* (Higgins and Moseley, 2001)

Beliefs about what it means to be 'successful' at mathematics vary from teacher to teacher, and are based on personal experience. During their student days, teachers may have been conditioned to seek and present quick answers by applying formulas or algorithmic steps (Grassl and Mingus, 2002), and as teachers they may encourage their students to be successful in the same way (Pehkonen and Torner, 1996; Virta, 2002). Similarly, if a teacher was successful at mathematics as a pupil because they were told how to apply algorithms, then as a teacher they may *'equate good teaching with good telling'* (Cooney, 1999). So, from the same teacher's perspective a didactic teaching style may be considered the most effective way to teach. Whereas, according to Pehkonen and Torner (1996) if a teacher thinks that mathematics learning happens at its best when pupils are doing calculations, then that teacher will provide many opportunities for practicing calculations. However, even this attitude may not be applied consistently. Schoenfeld (2002) argues that to decide how a teacher might react will depend on the context and the situation and the teacher's tendencies, '*what the teacher does depends on his or her goals for the students'*. He suggests that a question asked at the beginning of a lesson may lead to an in-depth discussion or analysis, yet the same question asked at the end of the lesson may result in a short exposition without any discussion. However, if one of the teacher's fundamental beliefs is that all pupils' questions deserve an answer, then either of the teacher's responses may be interpreted as being consistent with that belief.

'The basic argument is that teachers' decision making is a complex function of their knowledge, goals, and beliefs' (Schoenfeld, 2002). In order to understand why teachers teach the way they do, it seems important to recognise that teachers hold 'beliefs' about teaching and about mathematics, albeit at a subconscious level. In addition, these same beliefs and goals explain their moment-to-moment decisions and actions about whether to use a particular teaching strategy with a particular group of pupils or not (Aguirre and Speer, 2000).

Trainee teachers arrive at their teacher training institution with pre-formed beliefs about what it means to be a teacher;

'[they] are not "empty vessels" which can be easily filled with new "contents" in order to produce expected results. All their mathematical and pedagogical content knowledge, and their attitudes and mainly their beliefs about mathematics, its teaching and learning, mediate their behaviour' (Valero, 1997). It is important not to ignore teachers' prior experiences as mathematics students, as the way they see themselves in relation to the subject has an impact on how they teach and what they teach as teachers. Cooney (1999) notes that *'the structure of one's beliefs is an important factor in determining what gets taught and how it gets taught.'*

However, at this point, the literature seems to diverge along two lines of thought: that teachers' beliefs influence the way they teach (Aguirre and Speer, 2000; Schoenfeld, 2002; Valero, 1997); and that the way teachers teach is not always a reflection of their beliefs (Holt-Reynolds, 2000; Ruffell et al, 1998; Kynigos and Argyris, 2004; Ernest, 1994). Ruffell et al (1998) suggest that '*an alternative way to account for espoused-enacted discrepancy is to be sceptical that beliefs and attitudes generate behaviour, and to see them rather as forming part of the ethos within which behaviour is produced.*'

This apparent contradiction is given further weight by Schoenfeld (2002) who suggests that it is quite possible for a person's professed belief to be at odds with the way they behave or act '*one can think like a constructivist, while not acting like one*'.

This makes the enigma of teachers' teaching style even more difficult to decipher. If one wants to understand why teachers teach the way they teach, all one had to do was to consider their beliefs about teaching and mathematics. But apparently this in itself is insufficient because '*what teachers profess to believe and what they actually do in the classroom may or may not be consistent*' (Aguirre and Speer, 2000).

It would appear that sometimes, despite their beliefs, teachers teach in ways that contradict what is expected of them. Ernest (1994) suggests that this discrepancy may be accounted for by external factors, such as the school context. Kynigos and Argyris (2004) support this argument by saying that teachers may be expected to behave in ways that contradict their beliefs; for instance if the departmental policy is at odds with their espoused beliefs.

It seems that teachers' beliefs may be evident from their behaviour in the classroom, unless they are under the influence of external factors. Conversely, teachers' behaviours may point towards a particular belief bundle, unless outside factors are influencing their moment-to-moment decision making. Or it may be that teachers are unaware of their beliefs and are reacting spontaneously and instinctively to the situation in which they find themselves.

2.1.3 Teachers' Beliefs about Mathematics and how they might affect Teaching Practices

Thompson's (1992) review of teachers' beliefs includes a detailed and comprehensive section on the main mathematical beliefs held by teachers. She includes work by several writers. Amongst her list she includes Ernest, Lerman, and Skemp. Their ideas on mathematical beliefs are re-presented here.

Ernest (1985) describes mathematical beliefs as falling into five categories: Logicism, Formalism, Platonism, Constructivism, and Falliblism.

Having a logical viewpoint can be seen in college level mathematics lectures, which follow a cyclic pattern of definition, lemma, theorem, corollary, and is symptomatic of textbook rigour.

Formalism is the belief that mathematics is about formal rules, learnt by rote without necessarily having to understand the concepts. Ernest adds that '*there is a striking analogy between formalism and rote teaching and learning in mathematics.*'

Platonism is the viewpoint that mathematics is a static body-of-knowledge, and as such it results in the rejection of the human element within mathematics. This results in teachers treating mathematics as '*an inert body of knowledge which instruction transmits to the student.*'

Constructivism is described as being '*the opposite of Platonism*' and is about the constructive processes. These processes focus on human mathematical activities, in particular on problem-solving and modelling.

Falliblism is described as a view that '*mathematics is about what mathematicians do*'; it places '*man and history in the centre of the picture*'. This viewpoint corresponds to different types of proof at various stages in learning; these range from intuitive proof to rigorous proof. Ernest (1985) concludes that Falliblism is a viewpoint that can be transferred directly to the mathematics classroom, because it '*stresses people as creators of mathematics; the relative nature of proof; discovery as well as justification; the applications of mathematics; the role of the problem in mathematics and the importance of history.*'

Skemp's (1979) work on mathematical beliefs offers the ideas of relational understanding, instrumental understanding, and logical understanding. These ideas have similarities with the five viewpoints put forward by Ernest. Skemp defines instrumental understanding as the '*ability to apply an appropriately remembered rule to the solution of a problem without knowing why the rule works.*' Skemp says that the result of an instrumental view of mathematics is to be able to '*give right answers, as many as possible, to questions asked by a teacher (verbally or on paper).*'

Relational understanding, on the other hand, is about making conceptual connections. The goals of relational understanding are long term. Because it takes longer to form conceptual understanding than to learn rules, the educational outcome of teaching for relational understanding also supports the ability to pass examinations. '*Relational mathematics thus offers the best of both worlds.*'

Logical understanding is an addendum to relational understanding. Skemp describes this view of mathematics as being the '*difference between being convinced oneself, for which relational understanding is sufficient, and being able to convince other people.*'

In later work, Ernest (1994) writes that having an instrumental view of mathematics is more likely to be associated with an instructor model of teaching (where mastery of skills with correct performances is the intended outcome), and that in turn is linked to the strict following of a text book or scheme of work.

Lerman (1990) describes teachers' beliefs as being either absolutist or fallibilist. These are two, opposing views of mathematics. An absolutist would embed mathematics within logic, '*the construction of mathematics from basic intuition of time and the natural numbers;* whereas a fallibilist would '*focus attention on the context and meaning of mathematics for the individual, and on problem-solving processes.*'

Lerman (1990) discusses an investigation into teacher beliefs where he interviews four student-teachers. Two of these were at one extreme of the absolutist scale and the other two at the extreme of the fallibilist scale. These participants were then shown a video of a mathematics lesson and he notes that the absolutist teachers within the study felt that another teacher was not directing the students enough and was too open, yet the fallibilist teachers felt that the same teacher was not open enough and was too directed. Lerman concludes that these two views of mathematics bring '*the implication that mathematics is culture-laden and value-laden.*'

If this is the case, then it may support the ideas put forward above by Schoenfeld, Ernest, Aguirre and Speer, that the way teachers teach is influenced by more than just their beliefs.

2.1.4 The Effects of these Views on the Teaching of Mathematics

One of the effects of an instrumental belief system may be that teachers, (indeed much of society), equate mathematics with accurate computation (Walen et al, 2003; Norton et al, 2000). It is easy to see how this could lead a teacher into a style of teaching that appreciates the rote learning of algorithms (Grassl and Mingus, 2002; Pehkonen and

Torner, 1996). Similarly, *'teachers [who] saw mathematics as existing outside the human domain - a sort of Platonic view of mathematics, it was common for them to align the doing of mathematics with getting the right answers, although some teachers emphasized multiple solution methods for solving problem'* (Cooney, 1999). Thompson's own study (1984) corroborates these mathematical beliefs and viewpoints. She found that a teacher who exhibited an instrumental viewpoint, taught in such a way as to stress the importance of demonstrating rules and procedures. Another teacher saw mathematics as *'logically interrelated topics, and emphasized the mathematical meaning of concepts and the logic of mathematical procedures'*, whilst a third teacher with a problem-solving view of mathematics provided her pupils with activities aimed at engaging them in the 'generative processes' of mathematics.

Overriding these philosophical beliefs about mathematics is another layer that has politicised mathematics. Teachers have been encouraged to have a constructivist view of mathematics by such documents at 'Mathematics Counts' (Cockcroft, 1982), The National Curriculum (DES, 1994) in England and the Commission on Standards for School Mathematics (NCTM, 1989) in the USA. Yet public opinion and government policy makers hold the view that mathematics is needed for economic viability, and as such, it places an importance on rote learning in order to pass external examinations. Ahmed et al (2004) suggest that the rote learning of algorithms is not a sufficient means to an end, despite pressure from industry and government *'mathematical procedures are taught to all school pupils because they will help them in everyday life as well as in application: ninety-five percent of the population will need to use less than 5% of the procedures on the syllabus either for everyday life or for applying to sciences, industry* *or commerce. Hence, teaching mathematics is not mainly about the content but the process such as abstraction, generalisation, proof, etc.'* (Ahmed et al, 2004). The general public, industry and government have all claimed a stake in the mathematical education of young people today. However, their needs seem to be at odds with the educational reform movement. This pull from many directions may account for the discrepancy between espoused-beliefs and enacted-beliefs. So, when '*people's professions of belief don't necessarily match their description of their action'* (Schoenfeld, 2002), it may be that they are feeling the pull to behave in different ways by their beliefs, the prevailing political climate or the context of their work environment (Ernest, 1994; Schoenfeld, 2002; Aguirre and Speer, 2000). McCombs (2002) suggests that the pressures of traditional standards in teaching and external examinations mean that teachers have to be realists in the classroom, and they don't have the time to develop teaching practices that support learner-centred beliefs. Similarly, Smith (2001) suggests that teachers adopt a more conservative teaching style because they expect these established techniques to be valued by Ofsted. Even if teachers recognise that their teaching style does not support pupil learning, they may be reluctant to act on what they believe, because they are afraid to 'buck the system' (McCombs, 2002). External examinations play a large part in what happens in the classroom. Norton et al (2000) found that the teachers in their study were preoccupied with examinations and that their teaching was geared towards passing external examinations. One of the teachers comments that *"assessment is what we are about...my teaching is geared towards assessment"* (Norton et al, 2000). Teacher educators recommend exploration, investigation and open-ended tasks so that pupils will have a deeper 'relational' understanding of mathematics, yet teacher-inspectors (HMI, Ofsted and the general public) value examination results and league table positions. This might lead teachers into 'teaching-for-the-test' and having to resort to teaching in a manner that contradicts their beliefs about mathematics.

Ernest suggests that another reason for the disparity between espoused and enacted beliefs may be the culture of the school; '*The socialisation effect of the context is so powerful that despite having different beliefs about mathematics and its teaching, teachers in the same school are often observed to adopt similar classroom practices*' (Ernest, 1994). One of the reasons that many teachers adopt similar classroom practices may be the desire to conform to the accepted norms within a school or department. Thus teachers within a department often adhere to a scheme of work and use the same resources to teach a particular topic, even if it means teaching in a style which conflicts with their personal beliefs.

So, it would appear that the relationship between beliefs about mathematics and classroom practice is further complicated by external influences such as the examination system (McCombs, 2002; Norton et al, 2000), teachers' own perceptions of what is considered valuable by Ofsted (Smith, 2001), and the current political climate (Povey, 1997) and the school environment (Ernest, 1994)

2.1.5 Stability of Beliefs and Attitudes

There appear to be two opposing arguments about the stability of teachers' beliefs and attitudes. On the one hand, there is a suggestion that teachers' beliefs are fairly static and unlikely to change over time. This was found to be the case by Cheung and Wong (2002) who also noticed that '*teacher beliefs are usually rigid and highly resistant to change*'. This is further supported by Virta (2002), who comments that '*prior beliefs or* *implicit theories may be negative or positive, but they are generally highly stable'.* Virta goes on to suggest that the reason for this apparent stability in beliefs may be because entrants to teaching were usually good students in traditional schools which employed traditional teaching styles, and '*therefore less willing to change their beliefs'*. However, Pehkonen and Torner (1999) add to this by saying that teachers' beliefs about mathematics '*function as an inertia force for change.'* This seems to imply change in beliefs is possible, but that it is slow and laborious.

Tharp et al (1997) found that teachers in their study changed the way they behaved in their lessons when beginning to use graphics calculators, but they noted that their fundamental beliefs remained static. Similarly, Senger (1999) found that '*teachers' deep values (the good of the child, the value of education, the intrinsic rewards of teaching, etc) do not change so easily. ... What seemed to have changed in this study were the teachers' instrumental or secondary beliefs about what constitutes "good" mathematics teaching'*. This seems to suggest that the basic, fundamental beliefs of teachers remain stable and consistent, but it is their attitudes that may be less static. Their emotional responses (their beliefs) are difficult to change, and are less open to outside influences. However, their attitude (their stance or position) is not so static. Teachers can be encouraged to adopt new postures (behaviours) if they can accommodate new ideas into their existing beliefs systems.

2.1.6 Mathematics for Pleasure and Attitudes in the Classroom

One adjunct to the studies on the effects of beliefs is the idea of mathematics for pleasure: unlike teachers of other subjects, for instance English (Holt-Reynolds, 2000), there is little evidence within the literature to suggest that mathematics teachers indulge in recreational mathematics outside of their teaching. Stipek et al (2001) note that if teachers do not enjoy mathematics and lack self-confidence as mathematicians, it is highly likely that they will have difficulty in fostering and developing enquiry-orientated beliefs and attitudes in their students. Stipek et al go on to say that *'It is not obvious why teachers who held the more traditional beliefs claimed to enjoy mathematics less and exhibited relatively less enthusiasm in their classrooms.'* They account for this by suggesting that teachers who do not engage in mathematics for pleasure were extrinsically motivated and assumed that their pupils would be also. This implies that both teacher and pupils engaged in mathematics because they were required to do so, and not because they saw a value in the process of learning mathematics.

In this section an overview of different definitions of beliefs and attitudes was presented, and how these beliefs affect the way teachers teach. The literature suggests that teachers' beliefs about teaching and mathematics are formed from their personal experiences and these may go back to when they were pupils themselves. These beliefs and attitudes influence the moment-to-moment decisions that teachers make about teaching strategies and activities. However, teachers' behaviour is not always consistent with their beliefs. They maybe influenced by external factors, such as the school environment, Ofsted or external examinations. Research suggests that teachers' beliefs are relatively stable, but that their teaching practices maybe more flexible.

2.2 Teachers' Beliefs and Attitudes towards Technology and the use of Graphics Calculators

This section presents a review of the literature about teachers' beliefs and attitudes towards technology in general, and graphics calculators in particular. It has already been discussed that teachers' beliefs and attitudes may have an impact on the decisions and choices they make in the classroom. If, as my observations of trainee-teachers showed, teachers are making little use of graphics calculators, then it seems that their beliefs about graphics calculators and the use of technology may be influencing their classroom practice.

2.2.1 The Purpose of Information and Communications Technology (ICT) within Mathematics Education

Information and Communication Technology (ICT) within mathematics has been charged with providing pupils with an 'entitlement' to: learn from feedback, observe patterns, see connections, explore data, work with dynamic images, and 'teach' the computer (Becta, 2000). With the exception of the last two entitlements it could be argued that mathematics education has always provided these opportunities. The push to include technology in mathematics classrooms comes from all sections of society. Successive governments have provided funding for the inclusion of technology in all schools. This funding has included providing 'laptops-for-teachers', teacher-training through the New Opportunities Fund, and computers/internet access with the National Grid for Learning, to name but some of the incentives over the last decade. The main drive behind this has been the belief that '*technology has revolutionised the way we* *work and is now set to transform education. Children cannot be effective in tomorrow's world if they are trained in yesterday's skills'* (DfEE, 1997). This belief is questioned by Wellington (2005) who asks '*'can and should the use of ICT in education be driven by the vocational imperative, that is, the preparation for employment?'* He goes on to say that behind this 'vocational imperative' the pedagogical argument for including IT is to make teachers and pupils more productive by helping them to perform better. This is reiterated by Yildirim (2000) '*It is obvious that in the 21st century, almost all jobs will involve computers in some way. It is, therefore, crucial for teachers to have appropriate technology training... if they are to meet their students' needs for the next century.'* However, Olson (2000) warns against being overwhelmed by the '*Trojan Horse in our midst'*. He suggests that computer-assisted learning will bring about more than teachers have bargained for, by changing the purpose of education. He cites the case of geography education which has become a training ground for general skills rather than for the learning of geographical knowledge which is valuable in its own right. Furthermore, he voices concern for those teachers who have not yet embraced ICT being '*berated as Luddites'* (Olson 2000).

Educators argue that this idea of making teachers and pupils 'perform better' is the reason for using ICT in classrooms. The general consensus is that ICT is more than just a 'productivity tool' (van den Dool and Kirschner, 2003; Goos et al, 2003; Wellington, 2005). ICT can act as a '*cognitive amplifier'* [Grassl and Mingus, 2002; Goos et al, 2003] or a '*mind tool'* (van den Dool and Kirschner, 2003; Kirschner and Davis, 2003). Goos et al (2003) claim that '*technology can foster conjecturing, justification, and generalisation by enabling fast accurate computation, collection and analysis of data,* *and exploration of multiple representational forms. ...technology is one of several types of cultural tools that not only amplify, but also re-organise cognitive processes through their integration into social and discursive practices of a knowledge community.'* However, this comes with the caveat that '*it is one thing to use a tool, but quite another thing to use it effectively*' (Penglase and Arnold, 1996).

This is corroborated by Gibson's (2001) assertion that '*the value of any technology for education is proportional to the need for that technology in realizing educational objectives*' (Gibson, 2001). He goes on to discuss whether all technology-use is good-use by citing the example of two different schools. The first is a difficult school where '*drugs and violence are a recurrent problem [yet] the computer lab is a relative haven*'. In this computer lab these same difficult and troublesome students work well and in silence. The second school is a private school and is in complete contrast to the first. Here the students '*are active and noisy*', they take on their role of amateur archaeologists and they get into a '*heated debate*'. Gibson says that the two groups of students were shown distinctly different visions of teaching and learning with '*vastly different sets of expectations for life outcomes*'.

Teachers' motivations for using graphics calculators need to be examined quite closely, because using technology for the sake of using technology does not add to the quality of learning from the pupils' point of view. Ahmed et al (2004) point out that *the effective use of didactical materials used in the classroom will depend on the nature of the tasks, the role of the teacher and the climate and social culture of the classroom'*. Accordingly, it may be better to teach mathematics well without using graphics calculators than to teach it badly with technology.

2.2.2 Teachers' Beliefs about ICT

Despite the overwhelming number of studies that espouse the use of technology within the classroom, only Gibson (2001), Penglase and Arnold (1996), Olson (2000) and Wellington (2005) caution teachers to be wary of using technology for the wrong reasons, or of using technology with no reason at all.

However, the predominant feature of mathematics classrooms is not of poor or ineffective use of technology, but of no use of technology. Several recent studies (Becta, 2003; Conlon, 2004; Demetriadis et al, 2003; Norton et al, 2000; Yildirim, 2000) show '*despite the availability [of technology] the mathematics teachers rarely used computers in their teaching*' (Norton, et al 2000). Conlon (2004) suggests that this may be due to a failure of New Opportunities Fund (NOF) and that '*was due to multiple factors, including lack of readiness of the technical resources, failure to motivate teachers, inattention to the context in which teachers work and an underestimation of what is involved in developing appropriate knowledge and skills*'. Failure to understand teachers' beliefs and attitudes about ICT seems to have hindered the uptake of ICT in the classroom. One of the teachers in Norton et al (2000) believed '*that using computers in mathematics teaching was less effective than traditional methods in developing higher-order thinking*'. Another teacher in the same study says that she believes '*that technology would be best used following traditional teaching, if time permitted*'. (Norton et al, 2000). Hennessy et al (2005) make a similar point that '*teachers did not automatically assume that because technology is being used, learning is being facilitated.*'

If these beliefs about technology are prevalent, then it is understandable why teachers make little or no use of ICT in their lessons. Teachers are motivated to do the best for their pupils; they would be remiss if they used teaching methods they believed would hinder pupil progress. Norton et al (2000) add that teachers' resistance to using ICT was in part due to their beliefs about teaching and learning mathematics, but also about constraints from external examinations, lack of time and a preference for a particular textbook.

If teachers are to be encouraged to include the use of technology in their classrooms then:

1. *teachers must believe that technology can more effectively achieve or maintain a higher-level goal than what has been used ("effectiveness")*
2. *teachers must believe that using technology will not cause disturbances to other higher-level goals that they evaluate as more important than the one being maintained ("disturbances")*
3. *teachers must believe that they have the ability and the resources to use technology ("control")* (Demetriadis et al, 2003)

This change in beliefs and attitudes can be brought about by professional development that is localised and long term (Williams et al, 2000a). The literature on professional development and teacher-change is considered in section 4 of this chapter.

In a survey of Scottish teachers Williams et al (2000b) found that generally, when teachers did use ICT in their lessons, the picture was a positive one. Teachers reported a great deal of interest and motivation to learn more about the potential of ICT. However, on closer inspection they note that '*the teachers who tend to display more negative* *attitudes and make lower use of ICT are those in mathematics and science'* with business studies teachers having the highest use scores. The reason for this may be partly due to the areas investigated by Williams et al only included: internet, email, networking, video conferencing, fax, digital cameras, scanners, CD-ROM, word-processing, databases, and spreadsheets. If these were the only options listed on the questionnaire it may explain the low-use score by mathematics teachers. It is possible that spreadsheets were the only listed item that they use with their pupils. Williams et al (2000b) also found that teachers '*displayed some preoccupation with teaching ICT rather than teaching with ICT'*. Tondeur et al (2007) note similar findings in Flemish schools; the teachers in their study also focused on '*technical ICT skills to a large extent'* rather than teaching with ICT.

One other major trend that has been observed in the literature on ICT use in mathematics lessons is the way that ICT is treated as a 'bolt-on' to the curriculum. One reason suggested by Crisan et al (2007) is the fact that ICT use within mathematics is not assessed in external examinations. Crisan et al (2007) go on to say that the pressure of completing the examination syllabus does not leave teachers enough time to use ICT with pupils for exploring concepts in mathematics. Although, according to Hennessy et al (2005) teachers are resistant to the idea of 'bolting-on' ICT to the curriculum, treating the use of technology as an addition to the curriculum is partly down to inappropriate planning (Hennessy, 2005; Leach and Moon, 2000; Norton et al, 2000). Integrating ICT is a 'low priority' (Norton et al, 2000), so topics using ICT are planned for in an ad hoc and 'random' way (Leach and Moon, 2000).

2.2.3 Teachers' Beliefs about Graphics Calculators

Graphics calculators are *'arguably the only form of technology developed particularly for school mathematics education'* (Kissane, 2003). Yet despite this, my observations suggest that, very little use is being made of them in mathematics classrooms. Literature and research has consistently shown that graphics calculators enhance and support pupils' learning (for example Drijvers and Doorman, 1996; Harskamp et al, 2000; Merriweather and Tharp, 1999; Ruthven, 1990). Studies such as these show how *'the graphics calculator proved to be an essential participant, serving catalytic, facilitating and checking roles, all important in deepening understanding of graphing.'* (Hennessy et al, 2001). However, teachers are making little use of graphics calculators in their lessons.

Just as beliefs and attitudes about the use of ICT, and technology in general, hinder teachers' use of computers as part of their mathematics lessons, the same may be true of their use of graphics calculators. It would appear as if teachers' beliefs and attitudes about graphics calculators do not coincide with their beliefs about mathematics and mathematics education (Doerr and Zangor, 2000).

In order to examine teachers' beliefs and attitudes towards graphics calculators it is pertinent to also consider their views about four-function and scientific calculators as.

One of the main beliefs about calculators is that they will cause a decline in basic skills. Teachers, parents and students have a fear that the use of the calculator will *'adversely affect computational skills'* (Dunham, 2000). Abboud-Blanchard and Lagrange (2006) found that teachers still rarely consider using calculators because they believe that by-hand numerical calculations have a crucial role. Quinn (1998) cites a teacher who believes that '*when a person constantly uses a calculator there is a tendency to become unsure of yourself. Basic math skills tend to deteriorate when not used'*. The belief that pupils can become over-dependent on calculators was also suggested by a teacher in Edward's (2000) study. This teacher believed that all her pupils should learn to use the calculator, but she did not want them to become too dependent on them, so she restricted when the pupils could use them. Similarly, Simonsen and Dick (1997) found that teachers showed a correlation between their fears of calculator dependency and their reluctance to use graphics calculators in the classroom too often.

A survey of 200 primary school teachers in England found that teachers had strong reservations about using calculators with their pupils (Warren and King, 1995). The reasons they gave in Warren and King's survey (1995) were: *misuse (cheating, unnecessary use, and over-dependency), reduces mental agility, basics first, discourages learning of tables*, amongst several other reasons. Warren and King (1995) note though that these teachers '*are **genuinely** worried that inappropriate use of calculators will hinder children's written and mental calculation facility' [my emphasis].* As with the use of computers and other technology, if teachers believe that the calculator will hinder pupils' progress and learning, then those beliefs act as a filter as to whether calculators are appropriate or not (Bright, 1994). More recently it was shown that '*calculators are not seen as tools to be used in doing mathematics but as replacements for memorizing arithmetic facts and procedures, the very stuff of which school mathematics seems to be made.'* (Walen et al, 2003). In the same way that teachers are concerned that basic numeracy will be compromised by over-use of calculators, so teachers fear that algebraic skills will decline if students use the graphics calculator (Milou, 1999).

These somewhat negative beliefs about calculators are offset by several positive beliefs about using calculators. Fleener's (1995) study into teachers' attitudes showed that they recognised the motivational effects of calculators (although they remained sceptical about the cognitive effects). Teachers often used the graphics calculator as a motivational tool (Simmt, 1997), and as '*special treats*' (Smeets and Mooij, 2001) or as '*recreational pastimes*' (Crisan et al, 2007). This influences the way they incorporate graphics calculators into their teaching. Although the graphics calculator is not being used as a learning tool in these circumstances, it does give pupils a positive exposure to the technology.

Walen et al (2003) showed that calculators were often seen to be '*tools for speeding up arithmetic computations, or for ascertaining the accuracy of those computations.*'

Other studies (Edwards, 2000; Fleener, 1995; Warren and King, 1995) have shown that teachers tend to use calculators as an efficiency tool, rather than as a learning tool in the same way as they view the use of ICT as a productivity tool. The belief that the graphics calculator is mostly an efficiency tool may be because teachers seem unaware of the use of the graphics calculator as a cognitive tool. Teachers seem unsure of ways to use technology so that it extends pupils' learning (Watson, 2001).

Even when the research discusses graphics calculators the beliefs and attitudes seem to be very similar to those attributed to scientific and basic calculators. Simmt (1997) found that teachers used graphics calculators to verify and check work. They suggested that the graphics calculator *saved time* by generating many graphs quickly. The graphics calculator was also seen as a *motivational device.* Simmt concludes that the way the teachers used the graphics calculators was a reflection of their beliefs about mathematics and mathematics education.

In Simonsen and Dick (1997) the teachers reported that the graphics calculator removed the drudgery of graphing, '*It allows them to do a lot of functions quickly that would take a long time with pencil and paper'*. 'Immediate feedback' and 'enhancement of visualization' were also considered to be major trends in the way that these teachers used graphics calculators.

Many of these teachers (Simmt, 1997; Simonsen and Dick, 1997) seem to be using the graphics calculator as an efficiency aid, that is, as a 'productivity tool' rather than as a 'cognitive amplifier'. They appear to be restricting the use of the graphics calculator so that it fits in with their beliefs about how students learn mathematics. This is confirmed by Tharp et al (1997) who found a high correlation between teachers' views of mathematics and their views on the use of graphics calculators. The teachers in their study that demonstrated a rule-based view of mathematics were more likely to believe that graphics calculators do not enhance learning, and may even hinder it. On the other hand, teachers with a less rule-based view of mathematics are more likely to use graphics calculators as an integral part of their lessons. This was confirmed in a later study by Kendal et al, (2005) where they found that teachers adopted teaching practices using technology that complemented and supported their beliefs about mathematics and mathematics teaching.

Another common belief about mathematics that influences the use of calculators and graphics calculators is the concept of 'mastery'. Fleener (1995) found that over half of the teachers in her study believed that pupils should master a concept before they use the calculator, whilst the remaining teachers disagreed or had mixed feelings. Fleener goes on to say that the teachers who insisted on mastery before calculators were influenced by their belief that calculators will cause a decline in computational skills. This result is supported by Walen et al (2003) who found that '*nearly half...mentioned that students should wait until they have mastered the basics*'.

It seems as if some teachers believe in leaving the use of graphics calculators till the students have learnt the topic using traditional pen-and-paper methods, at which point the graphics calculator can be used for checking or for generating many examples more quickly (Smeets and Mooij, 2001).

Teachers' beliefs about examinations and assessments also affected whether they used graphics calculators in their lessons. Until quite recently, the UK examination regulations prohibited the use of graphics calculators in many examination papers, and this influenced whether the graphics calculators were used in lessons (Graham et al, 2003; Kastberg and Leatham, 2007; Rodd and Monaghan, 2002). Simonsen and Dick (1997) also found similar beliefs amongst the teachers in their study. They note that teachers felt that '*if graphing calculators are not allowed in the AP [Advanced Placement] exam they should be used only minimally in the classroom*'. It seems as if teachers' beliefs about the role of the graphics calculator and how it can support students' learning of mathematics are at odds with their beliefs about how students prepare for examinations (Hennessy et al, 2005; Monaghan, 2000; Olson, 2000)

This is aptly summarised by Kendal and Stacey (1999). They asked three teachers to present a task to their pupils, and noted the teachers' style. Kendal and Stacey also discuss the notion of '*teacher privileging*' as being teachers' personal preferences in the way they teach and how that influences pupils' learning outcomes. They found that two of the teachers (teacher A and teacher C) in their study were enthusiastic about using graphics calculators in their classroom, but their teaching styles were quite different. The teachers privileged the way they used the graphics calculator. They noted that teacher A did not take advantage of the graphical functions and rarely made connections between algebraic and graphical ideas. However, teacher C encouraged a more exploratory approach, and used graphical and algebraic methods often. Kendal and Stacey note that the *'implementation of the lesson guidelines varied significantly and the differences translated into substantial differences in how their students solved problems and what they understood'.*

So, even when teachers are "doing the same thing, they are doing something different"; two teachers seemingly teaching the same lesson, both using graphics calculators, but the learning outcomes for the pupils are quite different.

Dunham (2000) writes that there is a consensus amongst researchers that students who use graphics calculators show a better understanding of graphs and that they are better at problem-solving. Yet the fact that this is not being translated into regular classroom use suggests that this research is not reaching the classroom teacher.

Thus far the literature has shown that beliefs and attitudes about ICT, calculators and graphics calculators are complex and entwined with beliefs about mathematics and mathematics education. Teachers' beliefs that ICT is less effective than traditional methods, and that pupils should master techniques before using ICT, mean that ICT and graphics calculators in particular, are rarely used in classrooms. Furthermore, teachers' beliefs that calculators might hinder number skills and that graphics calculators might hinder algebraic concepts also act as a barrier to the inclusion of technology in lessons. When teachers do use graphics calculators in their classrooms, they tend to use it as an efficiency tool, rather than as a cognitive tool that extends pupils' learning. They also tend to use the graphics calculator as a motivational tool.

Teachers' teaching style results in them privileging the way they use the graphics calculator, and their teaching style is a consequence of their beliefs about mathematics and mathematics education.

2.2.4 Bogs, Barriers and Affordances

Alongside teachers' beliefs which hinder the use of graphics calculators, teachers are also affected by barriers which prevent or slow down the integration of graphics calculators into their teaching. Conversely, there are systems in place which encourage the use of ICT and graphics calculators. The literature on these barriers and affordances is discussed in this section.

Rodd and Monaghan (2002) suggest that the metaphor of a 'barrier' does not always adequately convey the way teachers respond to ICT and graphics calculators. They suggest that teachers more often than not felt *'bogged down'* by environmental factors which restricted teachers' energy.

In this thesis factors which stop teachers using ICT and graphics calculators are described as 'barriers', whilst factors which slow down progress are considered as being 'bogs'. Affordances (Webb, 2005) are used to describe systems or factors which provide opportunities and encourage the take-up of ICT and graphics calculators.

2.2.4.1 Barriers

The 'highest' barrier that prevents teachers from using ICT and graphic calculators within their teaching seems to be the one created by their beliefs. Dunham (2000) suggests that *'a complex web of beliefs about the nature of mathematics and the goals of mathematics education work against the full inclusion of technology.* We have already seen that if teachers believe that the best way to teach is using the traditional pen-and-paper method, then they are unlikely to include ICT into their lessons. In fact, Hennessy et al (2005) note that *'teachers are considered to be reluctant to adopt a technology which seems incompatible with the norms of an antecedent sub-culture.'*

Being unaware of how to use the graphics calculator as a tool for teaching and learning also acts as a barrier (Demetriadis et al, 2003; Penglase and Arnold, 1996; Rodd and Monaghan, 2002). If teachers are unsure how to use or include technology, they will prefer not to plan for it in their lessons (Dunham, 2000). Fear of embarrassment, lack of self-confidence, classroom management difficulties, lack of knowledge to resolve technical problems (Becta, 2003) alongside teachers feeling that they are *'subservient to the technology'* (Goos et al, 2003) combine together to create an attitude of uncertainty and this acts as a barrier against teachers' use of graphics calculators in their teaching. Another barrier is lack of access or availability. If teachers do not have access to ICT or graphics calculators, then no matter how positively they feel about them they cannot use them in their classroom. However, over the last decade there has been a strong push to make all schools and classrooms technology rich. In the UK, this push has come in the form of equipment via the National Grid for Learning (NGfL), training via the New Opportunities Fund (NOF) and curriculum requirement from the DfEE (Crisan et al, 2007). Hennessy et al (2005) suggests that teachers' resistance to use ICT was '*attributed to factors beyond their control*'. Teachers often feel that initiatives are forced upon them from outside agencies (Harskamp et al, 1998; McNamara and Corbin, 2001), and that they are expected to react to new curricula without being given the opportunities to reflect on how they can integrate these new ideas into their existing teaching practices. The '*power-coercive*' (Cheung and Wong, 2002) model of teacher change often acts as a barrier when new ideas are introduced into teachers' existing practices.

2.2.4.2 Bogs

Rodd and Monaghan's (2002) study into the use of graphics calculators by secondary school teachers in Leeds reveals a comprehensive list of the 'bogs' that slow down teachers' uptake of graphics calculator use in their teaching. This list includes: '*accepting the status quo; money; time; people; curriculum; modes of working*'. The idea of teachers maintaining the status quo (Rodd and Monaghan describe this as teachers believing that they are already doing the right thing) has also been noted by Stanulis et al (2002). They found that newly-qualified teachers '*adopted ways of thinking and acting that placed them in harmony with the existing occupational culture*'. Pehkonen and Torner (1999) noted that '*teachers' choices seem to be affected more often by pressure from their colleagues...than by educational considerations*'. It seems that breaking from tradition is difficult to do, especially if teachers believe that what they already do is the right thing. Wellington (2005) describes this as the '*grammar of schooling*', the way that schools and departments straitjacket teaching and learning, as being '*remarkably difficult to shift*'.

One result of accepting the status quo is that graphics calculators are not regularly used in mathematics classrooms and teachers find themselves 'bogged down' by doing things the way they have always done.

Money, or rather lack of money, also hinders the take up of graphics calculators within mathematics classrooms. As early as 1990, Ruthven pointed out that reliable access to graphics calculators encourages both students and teachers to make more use of graphics calculators, this means having the money to provide pupils with graphics calculators. Later, Simonsen and Dick (1997) note that '*many teachers suggested that for successful implementation each student must have his or her own calculator for use on homework as well as in the classroom.*' Clearly, this level of access has financial implications for schools.

Sam and Kee (2004) found that take up of graphics calculators was low with Malaysian teachers because the price of equipment was considered to be quite high. However, according to several other studies the price of graphics calculators, relative to other IT equipment, remains cheap and they suggest that cost is not really an effective barrier (Doerr and Zangor, 2000; Grassl and Mingus, 2002; Kissane, 2003; Simonsen and Dick, 1997). Despite the relative cost of graphics calculators there still exists a great discrepancy between the 'haves' and the 'have nots'.

Even when teachers have access to graphics calculators, this access can be restricted. Restricted access is not strictly a barrier, more of a bog, as it hinders teachers' use of graphics calculators. The equipment is needed to be kept securely locked away. The additional time to collect the equipment, including projection panels and over-head projectors would make the teachers consider whether the additional effort was justified. Occasionally, teachers would plan to use the graphics calculators, but would not be able to access the equipment because another teacher was using it. This sort of restriction to ready access is trivial yet hinders teachers' use so that they get bogged down.

However, having '*no money to improve expertise*' (Rodd and Monaghan, 2002) does create problems for teachers who may wish to use graphics calculators in their lessons, but feel they do not have the necessary skills. Several studies and surveys into teachers' use of graphics calculators and ICT have noted that lack of (quality) training is an area for concern (Becta, 2003; Demetriadis et al, 2003; Kirschner and Davis, 2003; Selwood and Pilkington, 2005). Furthermore, Tondeur et al, (2007) found that *'only half of the [Flemish] teachers have followed at least one ICT training course during the last 5 years. Moreover, for the majority of the teachers, ICT training has only contributed 'to a lesser extent' to ICT integration in the classroom'.*

Hennessy et al (2005) found that the teachers they interviewed were open to change rather than being resistant to it and that they wanted to include ICT into their teaching. This, they say, will only come about if teachers are given the opportunities to develop and share pedagogic expertise. For schools to provide such opportunities means spending money on 'improving expertise'.

Researchers suggest that training courses should emphasise the pedagogical aspects of graphical calculators (Hennessy et al, 2005; van Dool and Kirschner, 2003; Kirschner and Davis, 2003) rather than continue to present teachers with technical workshops which focus on keystrokes. However, technical difficulties are often cited as a factor that hinders teachers' use of ICT in the classroom (Becta, 2003; Demetriadis et al, 2003; Wellington, 2005). The 'fear of embarrassment' (Becta, 2003) that may be caused when teachers are faced with technical difficulties when using graphics calculators could be overcome by providing training that meets teachers' needs.

The literature on in-service training and professional development is considered separately in section 4 of this literature review.

Time seems to be the one of the most frequently mentioned bogs. Time constraints mean that planning and preparing to use graphics calculators with classes is often relegated to the bottom of a list of priorities. Monaghan (2004) noted that teachers using ICT tended to produce their own worksheets and resource materials for pupils to use, whereas for non-technology lessons they seemed to be content to use the set textbook for exercises and examples, which would require less preparation.

Alongside the time needed to plan and prepare lessons, Niemi (2003) found that teachers needed opportunities to practice using ICT for themselves. Leat and Higgins (2002) describe this as 'tinkering'; the process of experimentation that teachers go through in order to improve their teaching repertoire.

Experimenting with ICT to improve one's own confidence, planning how to include the use of technology into the lesson, and preparing suitable resources all takes up additional time that teachers would not need to allocate if they used their current teaching approaches.

Sam and Kee (2004) said that the teachers in their study reported that they had limited time to work with graphics calculators because they ended up repeating keystrokes for pupils and pointing out where certain functions were located. Alongside the time taken up with the technical aspects of using the graphics calculator, the teachers also commented on the time it takes to organise and set up the equipment. Teaching pupils how to use the graphics calculator takes time, which Mitchelmore and Cavanagh (2000) say needs to be done explicitly.

Crisan et al (2007) also found that part of this time constraint came from the pressure to complete the syllabus in time for examinations. They reported that '*most of the teachers felt that the mathematics syllabus did not allow room or time for pupils' exploration with ICT.*'' The use of ICT as a bolt-on has been discussed above, but this study gives another reason why teachers tend to leave graphics calculator lessons till the end of term, and use them for *'special treats'* (Smeets and Mooij, 2001).
However, there are other issues related to examinations and curriculum that feature strongly in the list of things that create bogs. Teachers' reliance on textbooks is one of them, combined with the fact that schemes of work tend to follow these textbooks quite closely (Hennessy et al, 2005; Olson, 2000; Rodd and Monaghan, 2002; Sam and Kee, 2004). If teachers are to be encouraged to use graphics calculators then *'changes will need to be made to student worksheets and textbooks to accommodate changes in the curriculum and teaching practices'* (Kendal et al, 2005). Unfortunately, according to Hennessy et al (2005) '*teachers have not started re-writing schemes of work to incorporate ICT*'. The scheme of work is seen as a valuable tool in informing teachers' classroom practice. Donnelly (2000) suggests that '*on the surface, schemes of work constrain and codify practice, but it is clear that they have other possible functions and impacts. An optimistic account might suggest that they facilitate change and reflection, by providing a formal vehicle for making public and available what would otherwise be*

ephemeral'. Teachers, especially novice teachers, feel compelled to follow the scheme of work, and often they make great efforts to work at the same pace as other teachers (Ensor, 2001). Crisan et al (2007) point out that teachers say they are more likely to use ICT if they had access to a pool of ready-to-use resources, which were clearly mapped to the mathematics objectives in their scheme of work.

Seen from this point of view it is important that heads of department begin to incorporate the use of graphics calculators into the programme of study for each year group if they want to develop and support the use of graphics calculators within their department.

Equally as important as the curriculum, there exists the bog that is created by the present examination system.

Until quite recently graphics calculators were not allowed in many of the A-level examinations and examinations questions were written in such a way that students with graphics calculators are not advantaged (Graham et al, 2003, Monaghan, 2000). Sam and Kee (2004) note that because graphics calculators were not allowed in the examinations, students were not encouraged to purchase their own. This in turn meant that they did not use them in lessons and teachers did not plan to teach with them. Similarly, Kastberg and Leatham (2005) found that '*teachers feel restricted by their curriculum- in particular, by high-stakes testing. If teachers perceive that these tests value by-hand procedures, then they feel obligated to prepare their students...this often means limiting the use of graphing calculators.*' In Graham et al's (2003) study of a group of A-level students, it was noted that students 'privileged' the methods used in their text books. These students relied on the worked examples within the textbook and used them as templates for answering questions in the examinations, and these worked examples did not make use of graphics calculators. So it seems that both teachers and students rely on the textbook for examination teaching and revision.

Several studies (Graham et al, 2003; Hennessy et al, 2005; Kendal et al, 2005; Monaghan, 2000; Olson, 2000) suggest that teachers are not using graphics calculators with their students because their use is not included in the text book, and their use is prohibited in many of the examinations. Monaghan (2000) suggests that this may be because it is easier to write examination questions which 'bypass' the use of technology, rather than to write questions that embrace it. However, writing questions in examinations that embrace graphics calculators raises a dilemma: the examinations taken by students in Britain are often taken by students overseas, and many of them may not have access to graphics calculators (as may be the case with poorer communities in Britain). Sam and Kee's (2004) work raises the issue of equity of access because of cost. This may mean that students may be disadvantaged by their lack of access to graphics calculators. Another option may be to write separate examinations questions for students that have graphics calculators, yet this raises serious moral questions about two-tier examinations based on affluence.

2.2.4.3 Affordances

The list of affordances, unlike hindrances, is rather small. However, this list includes some strong motivators to encourage teachers to use graphics calculators in their classroom.

By far the greatest affordance has to be the relative accessibility of graphics calculators compared to other forms of technology. Doerr and Zangor (2000) found that the low cost of graphics calculators, their portability and ease of use has encouraged teachers in the United States to use them for teaching about graphs and functions. Similarly, Kissane (2003) notes that '*the significance of graphics calculators for mathematics education rests in no small part on their accessibility, a function of their physical size, price relative to other technologies and ready portability*'. It is quite feasible for a teacher to have access to a set of graphics calculators such that there is one for each pupil. There is no need to relocate to a computer room to use graphics calculators, and unlike using computers or laptops, there is no need to log-in which can be fraught with complications. Under these conditions, Olson (2000) asks;

'*What is likely to happen if teachers regularly take their students out of the classroom to a computer laboratory? Why take students to such a place?.... why would a teacher want to abandon the complex and sustaining resources of the classroom for a computer laboratory'?* Often the response is that teachers do not want to abandon their classroom for an environment in which they feel uncomfortable. The fact that the graphics calculator can be integrated into the normal classroom environment is one of its main advantages; '*portable ICT devices do not dominate in the same way desktop computers can, and may be more readily integrated into classroom use, with the minimum of disruption to existing practices*' (Becta, 2003). Studies into teacher behaviour have commented that teachers have a preference for their existing practices and are reluctant to change (Hennessy et al, 2005; Yildirim, 2000). If this is the case, then the fact that graphics calculators are easier to use in the classroom, helps to alleviate the need to use dedicated computer suites.

One aspect of using graphics calculators that often goes unrecognised is that the *'learning experience with the graphics calculator is sufficiently different from the learning experience in the computer environment'* (Berger, 1998). Often teachers privileged the computer, preferring to use software such as 'Autograph' or 'Omnigraph' for graphing and 'Excel' for spreadsheets. Teachers seem to be unaware that the graphics calculators have other potential benefits, such as allowing pupils to write small programs for themselves. Teachers need to consider using the graphics calculator as well as the computer as part of their teaching. *'The important difference between the graphics calculator and the computer is that the calculator belongs to the student. It is accessible and portable'* (Adie, 1998). This difference, if recognised, could act as an incentive for teachers to make more use of the graphics calculator in their lessons. Basit (2003) writing about the recent National Numeracy Strategy (NNS) says that *'despite some scepticism, surprisingly, we have a top-down policy that is being viewed positively by many in a group of future professionals who are among those on whom it has the maximum impact'*. This suggests that the take up of graphics calculators may improve as their use is recommended within the NNS. It has already been suggested that teachers rely quite heavily on schemes of work. These schemes of work are based on statutory documents from the Education Department. Combined together with the NNS, the scheme of work and teachers' willingness to follow guidance (McNamara and Corbin, 2001), it is possible to encourage teachers to make regular use of graphics calculators.

One final aspect that could encourage much greater take up is to provide convincing evidence that graphics calculators support, enhance and transform pupils' learning. Much of the research literature on students' use of graphics calculators has suggested that the technology enhances their understanding of mathematics (Graham and Thomas, 2000; Harskamp et al, 1998; Quesada and Maxwell, 1994; Ruthven, 1990). However, most teachers are unaware of this research. Kastberg and Leatham (2005) suggest that all '*teachers should be exposed to the research on the effects of access to graphing calculators*'. This suggestion was also made by Dunham (2000) who wrote that lack of knowledge about research findings was part of the reason why teachers avoid using technology. There is a shift within education towards 'evidence based practice' (Guskey, 2002; McNamara and Corbin, 2001) which suggests that teachers are motivated to follow new initiatives if they can be shown to work better than the current teaching methods.

This section of the literature review has considered the Barriers, Bogs and Affordances that either hinder or help teachers' use of graphics calculators.

Barriers are created when

- teachers believe that graphics calculators have limited place on the curriculum
- teachers have no access to the technology at all.

There are several aspects that hinder teachers' use of graphics calculators and these are described as bogs. Bogs are created when:

- teachers believe in the status quo
- there is insufficient money to purchase equipment and/or training
- the teachers do not have enough time for planning/preparation/experimenting
- graphics calculators are not included in the scheme or work/textbook
- graphics calculators are not allowed in certain examinations

Affordances that encourage teachers to use graphics calculators:

- The portability and accessibility of graphics calculators
- The different type of learning experience offered to students
- The evidence of research that suggests students' learning can be enhanced using graphics calculators

2.3 The Journey from PGCE to Qualified Teacher

Post-graduate students follow a one-year course at a teacher education institute, which usually includes two school-based teaching practices. Having completed their PGCE course, they start working as newly-qualified teachers; this first year of teaching is a probationary year, during which they complete their training. After this probationary period they are recognised as fully qualified teachers. This section of the literature review considers the journey taken from PGCE to qualified teacher.

2.3.1 Student-Teacher: The First Step

The literature on beliefs shows that teachers' attitudes and classroom practice are affected by their previous experiences. The same is true for student-teachers. Although student-teachers may not be able to articulate their beliefs, they are influenced by their subconscious ideas about mathematics and education.

Ball (1988) suggests that prospective teachers arrive at teacher-training with pre-conceived ideas about mathematics, mathematics education and mathematics teaching. She writes that student-teachers '*do not arrive at formal teacher education 'empty-headed'; instead they bring with them a host of ideas and ways of thinking and feeling related to math and the teaching of math, drawn largely from their personal experiences of schooling*'. This is reiterated by Virta (2002), who writes that *'there is rich literature showing the importance of the early school experiences and the beliefs of student-teachers at the beginning of their studies as the basis of their development as teachers. During this apprenticeship of observation, teachers-to-be collect impressions and tacit knowledge about their future profession'* (Virta, 2002). Both Ball (1988) and

Virta (2002) recognise the importance of pupils' school experience in shaping beliefs. These beliefs go on to influence whether, as teachers, these PGCE students will use graphics calculators in their classroom. During the intervening years between Ball's (1988) work and Virta's (2002) study, research (see literature on ICT) suggests very little has changed with regard to the use of graphics calculators, and technology in general. It would appear that the 'apprenticeship of observation' points to one reason why the PGCE students in this study were not making use of graphics calculators on their teaching practice. The literature above suggests that the trainees' teachers have not made much use of graphics calculators; as A-level students themselves they have preferred to use scientific calculators because they were prohibited from using graphics calculators in their examinations, hénce their apprenticeship of observation has provided very little experience of graphics calculators. Goulding et al, (2003) conducted a study of over one hundred PGCE mathematics graduates. In that study they examined the student-teachers' experiences of their undergraduate mathematics courses and how their undergraduate course prepared them for the mathematical content of the PGCE course. Graphics calculators, or ICT, are not mentioned at all in their results. This suggests that technology had almost no influence on their undergraduate study. This is supported by Ragupathi et al (2007) and Lavicza, (2005); both works suggest that ICT use at undergraduate level is very limited, whilst graphics calculators are not specifically mentioned at all.

For these PGCE students, the apprenticeship of observation has given them very little experience of graphics calculators. Added to their personal lack of experience with graphics calculators are their beliefs and attitudes about mathematics and mathematics teaching.

In their study into attitudes towards mathematics Ruffell et al (1998) asked 26 PGCE secondary students to describe positive and negative experiences of mathematics. They found that the majority of positive experiences were related to 'the self', (*'clicking into place', 'seeing the light'*) whereas the negative experiences were related to teachers (*'giving wrong answers on the board and hence confusing pupils'*). In a study of young pupils' images of mathematicians, Picker and Berry (2000) found that the pupils had stereotypical, negative impressions of their mathematics teachers and that these formed part of a cycle that perpetuates the myths of mathematics and mathematics teachers. Pupils saw their teachers as being coercive, foolish, overwrought, unable to teach, and disparaging. Contrast this with Jaworski's *'teaching triad'* (1992) which includes *'student sensitivity'* as one of the three elements of mathematics teaching. In her study Jaworski (1992) describes Clare's *'intense interest in and caring for the student'*. Mathematics teachers' perception of themselves as caring professionals seems at odds with the pupils' perceptions of their teachers. In a similar study, Fung and Chow, (2002) noted that PE trainees had perceptions of themselves as having a 'nurturing' role, yet their actual practice was at odds with their beliefs and they displayed transmission and apprenticeship approaches. It seems that often trainees think they are behaving in a sensitive way, but their actions are perceived differently.

Despite being perceived by pupils as being 'overwrought' it has been suggested that *'the most striking finding arising from this analysis of the student-teachers' accounts of their practice is the seriousness with which they appeared to regard pupil learning'* (Burn et al, 2000). Clearly, student-teachers take their teaching role more seriously than has been realised.

The student-teachers in Virta's (2002) study described good and bad models of teachers; they saw bad teachers as being inefficient, using boring methodologies, having poor communication skills and classroom management, whilst good teachers encouraged critical thinking, were creative and well informed. One of the students in this study described how his school experience shaped his image of a good teacher: '*There was a teacher who was an absolute authority for me, he kept his classes silent and interested during the whole lesson. He transmitted his knowledge...and will certainly remain in the minds of all his students for the rest of our lives*' (Virta, 2002).

Geoffrey's comment, in Ensor's (2001) study, that '*tell and drill is a sure way to get results*' may be a reflection of his own personal experiences as a student. It may be that he believes that getting good grades ('results') is important, and consequently values teaching styles and methods that produce good results.

The four mathematics PGCE students in Smith (2001) viewed teaching as either '*transmission orientated*' or '*learning by discovery*'. One particular trainee believed that teachers '*should explain to their classes rather than provide learning opportunities*' because that was his preferred learning style. Goulding et al (2003) point out that many trainees see their school experience as a '*golden time*' as compared to the experience they had at university as undergraduates. *There is clearly a danger then that poor school practice will be recycled, and that the one-year PGCE course will have difficulty in interrupting this process*' (Goulding et al, 2003).

However, trainees sometimes recognised that what worked for them as students may not work for them as teachers. One of the students in Virta's (2002) study praised his

[History] teacher but added that '*in these days his methodology would certainly be out of date*'.

Flores (2001) found that, even when trainee-teachers reported negative episodes from their own school days, they stressed the impact of those experiences in shaping their current practice. One student-teacher comments that she avoids interacting the same way as her teachers, another student-teacher says that she behaves in exactly the same way; yet both are influenced by their past experience which shapes their current practice as a consequence.

On the whole, trainee-teachers are successful school-students and it would seem that they appreciate the teaching methodologies they encountered at school. However, as Virta (2002) notes '*the model of the apprenticeship of observation seems to function as a source of contradictory messages, possibly supporting conservative or indifferent attitudes on teaching*'.

Hill (2000) comments that trainee-teachers rely on familiar teaching methods, methods which can be '*implemented without much conscious effort and thought*' and instead of teaching the way they were encouraged at teacher-training college they '*revert to teaching the way they were taught at school*'. She suggests that one reason for this reversion may be that '*the former [school] experience lasted longer and took place during their formative years*'.

It would appear that trainee-teachers may be trapped in a self-perpetuating cycle that begins at school; they teach the way they were taught at school, and their pupils, who later become trainee-teachers, repeat the process.

Despite these entrenched beliefs and attitudes at the beginning of a teacher training course, student-teachers are in a period of transition. McNamara et al (2002) describe teacher training as a '*ritual ceremony*', a '*rite of passage*' from a trainee towards a novice teacher. In the study by McNamara et al (2002) the student-teachers comment that they perform '*symbolic rituals*' such as wearing smarter clothes, adopting a new title (Sir/Miss), and acquiring the new knowledge of the professional community; but they also recognise that teaching practice is a 'performance'; that they need to '*demonstrate to tutors, class teachers, parents and pupils their ability to behave in a 'teacherly' way*' (McNamara et al, 2002). In order to be accepted as a teacher, trainees feel they have to convince their university tutor and their school mentor of their suitability. Trainees' performance is measured against criteria set by the Teacher Training Agency (TTA), and is checked by the school mentor, with occasional visits and observations from the university. This desire to meet the standards set in the assessment document often leads student-teachers to 'play it safe' when it comes to using graphics calculators. It is easier not to use them and to demonstrate safer lessons when they are being assessed. It seems that the assessed observation is one of the '*hoops to jump through*' (McNamara et al, 2002). Jones (2001) notes that '*it is conceivable that the ubiquitous threat of assessment inevitably discourages less confident trainees from exploring alternative, slightly more risky strategies, thereby promoting an uninspired, "play-it-safe" attitude*'.

Another concern for student-teachers is that they exist between two worlds; the real world and the ideal world. McNamara et al (2002) note that '*many of the students valued and privileged the 'real' world of the classroom in preference to the 'idealised'*' *world of university'*, whilst realising at the same time that their performance was being measured against an ideal. The difficulty, they say, with this notion of 'ideal' is that different institutions (school, university, government, colleagues and so on) have different expectations and views of what this 'ideal' entails.

Several studies (Chuene et al, 1999; Ensor, 2001; Halbach, 2000; Taylor, 2003) suggest that the school based teaching practice has more influence over the student-teachers than the college based activities. In fact, trainees in Chuene et al (1999) actually found that ' *'the theory learned during these classes was found to be irrelevant to real classroom situations'*. These student-teachers suggested that their university tutors should spend time in real classrooms, so that what they are taught at university would more closely match the practices they observed in schools.

Ensor (2001) notes that often it was easy to agree with the teacher educators, but rather more difficult to put their ideas into practice. Mary, one of the teachers in Ensor's study (2001) found that she identified more closely with the classroom teachers than she did with the idealised world presented by the university tutor. However, Mary '*drew on the teacher education course insofar as it provided useful orientations to, and resources for, teaching'* (Ensor, 2001). This was also true of the trainees in Halbach (2000). They also tended to value the world of the classroom over the world of the university, and the issues that were raised as a result of classroom observations left a deeper trace on their beliefs than those issues discussed in college. Chuene et al (1999) note that the experience gained during actual teaching practice helps the trainees make sense of the theory learnt during the college based course. Halbach (2000) found that *'in all cases the trainees' responses seem to indicate that their perception of the teachers' role was modified as a consequence of the teacher they were observing most directly in the* *context of their training.* This implies that if classroom teachers can become positive role models using graphics calculators in their teaching then the likelihood of PGCE students emulating the same teaching methods is greater. Similar findings by Fung and Chow (2002) suggest that the classroom teacher, as well as the pupils that are being observed, could have an influence on the way that students teach. They suggest that class size, age group and the topic being taught are all considerations. Trainees sometimes feel that having teaching methods that differ from the class teacher confuses the pupils, so they abandon their own methods and adopt the same style as the class teacher (Boz and Boz, 2006).

O'Reilly (2006) suggests that all of these factors have a greater impact when PGCE students are considering the use of graphics calculators. In his survey O'Reilly found that planning and differentiating work for pupils was raised as an issue by the student-teachers, and often they linked these issues to classroom management. Virta (2002) found that careful planning was part of student-teachers' survival strategy. Abboud-Blanchard and Lagrange (2006) note that because the trainees are concerned about '*mistakes and wasting time*' they are '*more dependent on their preparation than 'older' ones, and to be on the safe side, trainees comply with the dominant models of the professions*'. They go on to say that this has the effect of encouraging student-teachers to behave in a '*traditional way, which is a central feature of teachers' professionalism*'. Quentin, a PGCE student in Smith's (2001) study comments that he liked many of the teaching activities he had been shown at college, but '*he felt unclear how they might fit into the department's scheme of work and how he might justify the place of these in his teaching.*' Without support from the class teacher Quentin resorts to using the scheme of work. Resorting to traditional and familiar teaching styles seems to be survival strategy often used by novice teachers (Virta, 2002).

The student-teachers in Flores' (2001) study refer to the '*gap between theory and practice and to the inadequate preparation for coping with the daily problems of the school and classroom*'. The gap between theory and practice has also been noted by Boz and Boz (2006). The students in that study point out that they did not have the chance to make the links between school and university because '*they could not observe teachers apply teaching methods learnt in university courses due to the fact that the classes they observed were always delivered by traditional teaching*' (Boz and Boz, 2006). The other reason why student-teachers prefer the practices of the school above those recommended by the university may be that the trainees feel that they are inadequately prepared for dealing with the moment-to-moment problems that arise in the classroom situation (Flores, 2001). However, Hill (2000) suggests that one of the tasks of the university is to help the trainees '*accept that doubt and uncertainty are constant companions on the journey of truly reflective teaching*'. The student-teachers in Hill's study had quite rigid views about teaching; they preferred didactic, controlling methods. They believed that '*the curriculum exists, the teacher follows it and the children learn it*'. The only problem that stopped this from happening naturally was maintaining discipline and order. Student-teachers find that problems with developing pupil-centred learning arise mostly when they have difficulties with discipline and class size (Chuene et al, 1999). Capel's (2001) study of PGCE students found that '*maintaining the appropriate degree of class control*' was their greatest concern, closely followed by '*getting a favourable evaluation of my teaching*'. Boz and Boz (2006) found that not being able to observe the teaching theories and strategies they learnt on their education course in the context of the classroom caused confusion and discouraged student-teachers.

The literature points out that teachers' personal history plays an important role: if they have had no experience of graphics calculators as pupils, undergraduates or as trainees, they are unlikely to use them in their teaching. If they do not use graphics calculators in their teaching they are unable to model practice for the next generation of trainee-teachers. Ball (1988) comments that '*teacher education is often a weak intervention*' and that teachers '*in spite of courses and workshops, are most likely to teach math just as they were taught*'. There is a strong need to break this cycle and it may be that the most accessible period is during Initial Teacher Training.

One way to overcome these prejudices, according to Lin (in press), is to make the use of technology integral to the PGCE course. Lin's study found that integrating the use of web-based instruction into the teacher-training course resulted in the student-teachers having greater self-confidence, which in turn encouraged them to use technology in their teaching. Da Ponte et al (2002) used a similar strategy. They too integrated the use of the internet into pre-service mathematics course, by asking the trainees to produce an interactive web page using dynamic geometry software. At the end of the course, the student-teachers felt that they had a better awareness of the potential of ICT for mathematics teaching. They felt that they were better prepared. Their perceptions that ICT was useful had also increased. One of the students commented that '*Using GSP showed me that when pupils use it [GSP] they understand geometry better*'. This seems to suggest that integrating the use of graphics calculators into the university course can help trainees become more confident.

O'Reilly's (2006) study into mathematics PGCE students found that when trainees did use graphics calculators in their lessons, it was mostly with younger pupils. The suggestion is that this may be because the PGCE students '*feel that they can risk using the calculators with these classes*'. Related to this was the fact that 14 out of the 18 PGCE students in O'Reilly's study said that they rated their knowledge as 'none at all' or 'a little'.

Abboud-Blanchard and Lagrange (2006) found that the trainees in their study rarely used calculators with the 11-14 age range, and they suggest that this may be because teachers consider by-hand calculations to be crucial for younger pupils. Student-teachers, like many qualified teachers, have pre-formed beliefs about using calculators as part of teaching and learning. These same trainees did use graphics calculators with older pupils for quite specific topics such as functions, whilst retaining the scientific calculators for statistical or numerical calculations (Abboud-Blanchard and Lagrange, 2006).

Walen et al (2003) found that there was a seeming contradiction between trainees using calculators to do an arithmetic calculation and their pupils using calculators. The trainees felt it was acceptable for them to use calculators because '*their task is not to learn, but to do*' but it was not acceptable for their pupils because '*their task is not to do, but to learn*' (Walen et al, 2003). One of the student-teachers goes so far as to say '*I never needed a calculator and my students won't either. If you give them a calculator, they will just punch buttons and won't learn the math*' (Walen et al, 2003). It is easy to understand how these types of beliefs would make trainees reluctant to use graphics calculators in their teaching practice.

Even when trainees are prepared to use graphics calculators they do not always get the support they need. Tony, a PGCE student in Smith's (2001) study planned to teach a lesson with a difficult group, the lesson required a substantial amount of preparation and included worksheets and visual aids. However, Smith reports that '*there was encouragement from the school staff to try this, but little guidance with the planning.*' Often the class teachers are not any more proficient than the trainees when it comes to using technology.

Just as lack of time for planning is a bog for experienced teachers the same is true for PGCE students. Van der Valk and Broekman (1999) asked student-teachers to prepare a lesson without resorting to a mathematics textbook. It took the students an hour to collect ideas on prior knowledge, put relevant concepts into an order they felt was appropriate and to produce a worksheet. Students on teaching practice tend to produce elaborate resources and this takes time. In the early stages lesson preparation for using graphic calculators can be time-consuming, so they may be a hindrance if speed is important. Abboud-Blanchard and Lagrange's (2006) study of pre-service teachers using ICT found that the trainees preferred to download ready-made resources or photocopy from a text book rather than design and create their own worksheets using the word processor.

Using graphics calculators in lessons required that the trainee spends time rehearsing the keystrokes but Taylor (2003) notes that lack of time to practice was seen as a constraining factor to students' development.

Another constraining factor that may hinder PGCE students using graphics calculators is that their subject knowledge is not as secure as experienced teachers (Prestage and

Perks, 2001). PGCE students tend to merge their subject knowledge with TTA requirements and the traditional teaching methods. Prestage and Perks go on to say that these students are just as heavily influenced by text books and departmental policy documents as the experienced teachers. Yet the literature above suggests that the use of graphics calculators is not addressed in either textbooks or the scheme of work. Burgess (2000) notes that the '*separation of subject and pedagogy*' is of concern to initial teacher training (ITT) providers because the trainees (and their subject mentors) are more worried about meeting the qualified teacher status (QTS) standards. On the one hand the trainees have to teach a particular topic area and on the other they have to meet the ITT assessment criteria.

However, as the students progress through their training year they begin to move beyond concerns with the self and begin to consider pupils' learning. When planning lessons the trainees rate pupil achievement as the main aim of their lesson (Burn et al, 2000). Burn et al also note that the trainee-teachers use three different subcategories when discussing 'pupil achievement': cognitive (learning a new skill or concept), coverage (getting through the syllabus) and product (producing a finished piece of work). Using graphics calculators does not fit neatly into this model of pupil achievement. Graphics calculator lessons are often seen as an addition to an already overcrowded syllabus, neither do they produce a print-out, so there is no record of the work the pupils have done.
Despite these constraints, Da Ponte et al (2002) found that pre-service teachers wanted to use ICT in their teaching. The pre-service teachers in their study tended to agree that using technology would have a '*very strong role in the school of the future*' but that

they were concerned about the lack of resources. They also perceived a '*dominant opinion in teachers against the use of technology*' (Da Ponte et al, 2002).

Although one of the greatest influences on student-teachers is the classroom teacher with whom they are paired, they are also influenced to a degree by their university tutor. Whilst the student-teachers are on their teaching practice, the university tutor takes on the twin roles of mentor and assessor, and this can cause confusion in the minds of the students (Jones, 2001). On the one hand the university tutors are there to guide and support the students, and on the other hand they also need to assess the student's performance against the TTA criteria. This creates problems for both the PGCE student and the university supervisor (Jones, 2001).

The other difficulty with the mentor/assessor role is that there may be an unintentional discrepancy with the way that advice is perceived by student-teachers. '*I have tried to show how "what I say" is frustrated by "the way I say it": I speak of new and exciting teaching methods but involve students in a discursive regime that is regulatory*' (Klein, 1997). Often the advice given by mentors is loaded by their own preferred teaching style and beliefs.

In her study of mathematics trainees, Klein notices that they begin to use the language of constructivist practices, yet the behaviour of these student-teachers demonstrated that they still believed that mathematics was a subject to be '*conveyed*'. One reason for this discrepancy, according to Klein (1997) is that her mentoring style was '*coercive*', in as much as students that disagreed with her way of thinking were considered as '*unmotivated*'. However, the mentor role eventually gives way to the assessor role, and because the students need to pass their training year, they take on the language of constructivist practices, even if they cannot take on the teaching methods (Klein, 1997). One other possible reason for the discrepancy noted by Klein (1997) is suggested by Ensor (2001). Ensor discusses the notion of a '*professional argot*' and how individuals construct their understanding of particular concepts and ideas. She says that a professional teaching argot provides student-teachers with access to a vocabulary and modes of argument to describe 'best practice' (Ensor, 2001). Using this idea of professional argot *'the apparent inconsistency between what is offered in teacher education courses, and the manner in which beginning teachers perform in classrooms…only emerged if the professional argot was taken to embody a fixed meaning for both teacher educators and student-teachers. Once it was perceived to mean something different from Mary's [a student-teacher] perspective, she could be seen to be acting consistently'* (Ensor, 2001). This also helps to explain why often teachers behave in ways that seem to contradict their professed beliefs (Ernest, 1994). This dual-role of the university tutor, acting both as mentor and assessor, can create confusions for the student-teachers; they may be unsure whether to take onboard advice about best practices or to follow the assessment criteria. In particular this affects student-teachers' use of graphics calculators. Edwards and Protheroe (2003) noted similar findings from their study of primary school trainees. They note that the PGCE students were caught between the accountability-led system and classroom pedagogy. This results in the student-teachers '*presenting effective performances of teaching rather than risky attempts at interactively supporting pupil learning*'. Flores (2001) points out that trainees '*adopt a strategic compliance*' and they follow their supervisor's behaviours even if they don't agree with them. It would appear that a different strategy is needed if PGCE students are to be encouraged to use graphics calculators in their teaching.

Humphreys and Hyland (2002) suggest that '*a critical dialogue between mentor and student in an environment of demonstration, rehearsal and practice is the cornerstone of effective teacher education*'. It would seem as if a closer, more collaborative approach is needed if PGCE students are to be encouraged to use graphics calculators. If the use of graphics calculators is not being modelled by the teachers at their placement school, then best practice modelled by the university mentor may have a positive influence. Edwards and Protheroe (2003) recommend extending the role of the school-based mentor, so that the class teacher who is best placed to team-teach, guides the student-teacher. They go on to say that the school mentor needs to have closer links with the university mentor, and trainees should not be left to develop in isolation. However, as shown by the literature, these same classroom teachers are making little or no use of technology, so for them to act as mentors they will need to develop their skills at using graphics calculators as well as at mentoring and collaborative teaching. This may be too large a task to be attended to simultaneously. Interestingly, the teachers in Davies and Ferguson's study (1997) commented that they had not had enough observation of 'good' teaching when they were trainees, yet the vast majority thought the school-based experience was better than the college based work. When these teachers were asked whether they felt they could take on the role of being subject-mentor for PGCE students, Davies and Ferguson (1997) report that over four-fifths said that they didn't think they could. Several reasons were given, amongst them the idea that '*bad habits can be passed on*', '*there is no time for theory: need to know how children learn; need a rationale behind what you are doing*', '*no academic rigour in* *schools, teachers haven't time to keep abreast of all the changes'* (Davies and Ferguson, 1997). These teachers seem to be implying they do not have the skills to train PGCE students, yet that is exactly what universities expect of them.

Flores (2001) suggests that initial teacher education has a '*weak impact in determining beginning teachers' professional behaviour'*. Most of the student-teachers in Quinn's (1998) study seemed to imply that the training period had little effect on their beliefs about using technology. This raises questions about how best to encourage the use of graphics calculators and at which point in their journey to becoming a fully qualified teacher. Holt-Reynolds (2000) found that the student-teachers at her university '*expected teacher education courses to be practical, to model pedagogies and provide opportunities to practice strategies and techniques.'* Trainees wanted their PGCE course to be rooted in the real world that they wish to emulate. This creates an inconsistency when this argument is used about using graphics calculators. Graphics calculators are not really evident in the real world as the trainees see it, but to exclude the technology from the training course means that they will not have the training they all say they need.

Holt-Reynolds (2000) suggests rather than provide the type of course the trainees want, teacher educators ought to re-examine the way they educate the student-teachers. One way forward suggested by Hart is the use of log-books and journals. Hart (2002) found that using reflective journals with PGCE students helped them to change beliefs and attitudes consistent with reforms in mathematics education. Although Hart does add the caveat that it was difficult to assess how *'resilient their change will be to the culture of the school and pressures of being a practicing teacher'*. In a similar study which de

Jager et al (2002) conducted with experienced teachers, the use of reflective journals was used again to encourage a change in teaching style, but de Jager et al recognise that not all the characteristics of their chosen method were consistently adopted.

A similar exercise during teacher-training was conducted by Taylor (2003). Taylor's (2003) work with geography PGCE students and their use of ICT made use of '*learning histories*'. Through these personal learning histories Taylor was able to identify '*previous experience, method of learning and featurès of the software*' as factors involved in the process of learning new software. The trainees also put forward learning strategies with ICT which worked for them:

- *'Just tell me what I need to know for the task' – the trainee wanted basic instructions, which they would repeat in future*
- *'Let me play with it' – the trainee approached the software in an unstructured way*
- *'Tell me then let me try' – the trainee wanted someone else to introduce them to the software'*

If teacher educators want to encourage new mathematics recruits to have more positive attitudes towards the use of graphics calculators, then the use of log books and personal histories may provide a valuable strategy.

According to Maynard and Furlong's (1993) five stages of development, student-teachers move sequentially through a period of '*early idealism*' to '*survival*' '*recognising difficulties*' '*hitting the plateau*' and '*moving on*'. It is only in the final stage that student-teachers are able to experiment with their teaching, and this is most likely to occur during their first year as a newly-qualified teacher. The next section considers the literature on newly-qualified teachers.

The literature on PGCE students suggests that:

- Like experienced teachers their practice is influenced by their beliefs and attitudes, even if it is difficult to pinpoint the nature of those beliefs
- Their beliefs and attitudes are formed by their previous experiences as school pupils and university undergraduates and that these experiences form an 'apprenticeship of observation'
- Their training year is a year of 'symbolic acts' and 'ritual ordeals', and passing their teaching practice assessment is one of the 'hoops' they have to jump through in order to become recognised as teachers
- The trainees 'privilege' the 'real world' as represented by the school placement above the 'ideal world' as represented by the university

All of these points suggest some of the reasons why student-teachers are making very little use of graphics calculators in their teaching.

2.3.2 Newly-Qualified Teacher: The Next Step

There is very little in the literature that refers specifically to the beliefs and attitudes of newly-qualified teachers, or their attitudes about technology and graphics calculators. Newly-qualified teachers are subsumed into the research on teachers in general. This section reviews the literature specifically relevant to newly-qualified teachers (NQTs), and their development over their probationary year.

One of the first things that NQTs say is different from being a trainee is the sudden shock of being a full time teacher (Flores, 2001; Farrell, 2003; Stanulis et al, 2002). Wee-Jin, in Farrell's study (2003) of an English language NQT in Singapore, notes that his '*first reality shock was that his teaching load had greatly increased'*. Combined with concerns about discipline and class size, this has implications for planning and preparation. NQTs are also expected to take on other professional roles, for which they may not have been prepared, such as counselling pupils in his tutor group or taking on extra-curricular activities. Despite being told by others in the department that his administrative load was lighter than theirs, Wee-Jin still felt overwhelmed (Farrell, 2003). This may explain why mathematics NQTs do not use graphics calculators, because they are already feeling overwhelmed and they do not want to make matters worse by adding the use of technology to their agenda.

In Stanulis et al, (2002) Jennifer often uses the word 'frustration' to describe how she feels about her early experiences as a novice. These frustrations are borne out of a sense of loneliness and isolation (Davies and Ferguson, 1997; Ensor, 2001; Farrell, 2003; Stanulis et al, 2002). For Jennifer (in Stanulis et al, 2002) this isolation comes from a loss of support from her university mentors. As a student-teacher she felt able to turn to her mentors for help and guidance, as a novice, she felt that that support was no longer available. *'Novice teachers used to the constant interaction and feedback from their mentor teacher and university supervisor are left alone to make the daily decisions of teaching'* (Stanulis et al, 2002). On top of that her school mentor was not supportive, and this exacerbated difficulties '*leaving her isolated and disenchanted'*. Similar feelings are echoed by the NQTs in Ensor's study (2001). Mary says, '*I have felt very* *alone in the department, like I don't really know what's going on. I don't know if I'm doing the right thing'* (Ensor, 2001).

This isolation can be physical as well as emotional. Wee-Jin (Farrell, 2003) was located in a separate block from the main staff room, and this limited his opportunities to discuss difficulties with his colleagues. '*Lack of communication*' was the main dilemma he faced in his first year. '*I didn't talk much with the other teachers because they were always busy*' (Wee-Jin, in Farrell, 2003). This NQT is physically and professionally isolated. This isolation leads NQTs to rely on their own recollections of solutions to problems they had as student-teachers (Davies and Ferguson, 1997). Stanulis et al (2002) suggest that '*their engaging "new, research-based" ways of teaching are quickly overshadowed by overwhelming feelings of isolation and loneliness, the tendency to sacrifice ideals for more traditional practices and the complexity of decision-making in the moment*' (Stanulis et al, 2002). Their first steps into teaching end up following the well worn path of teaching the way they were taught (Ball, 1988). Chuene et al (1999) note that there is a contrast between the teaching strategies used by student-teachers and those used by NQTs. They found that almost all of the trainees used student-centred teaching strategies, and had little difficulty in implementing this. However, *novice teachers seem to encounter problems using student-centred strategies. Almost half of them prefer the "chalk and talk" method to teach mathematics'* (Chuene et al, 1999). Flores (2001) comments that teacher training has '*weak impact on determining beginning teachers' professional behaviour'*. The teachers in their study refer to the '*gap between theory and practice*' and how there was a difference between what they expected and the reality of teaching.

Chuene et al (1999) suggest that exposure to the school environment affects NQTs' views of mathematics teaching. Ensor (2001) comments that NQTs are often ring-fenced by the departmental scheme of work. Mary, one of the NQTs in Ensor's study, found that there was a departmental requirement that all the teachers adhered to the scheme of work, and that they all moved through it at the same pace '*there was little or no scope for individual repertoire development.*' Mary feels she has to justify her transmission-style of teaching. She thinks of herself as having no autonomy and '*obliged to adopt a monitorial style of transmitting mathematical rules and procedures.*' It seems as if NQTs often feel unable to continue to develop the ideas and theories from their university courses. Terrika (in Stanulis et al, 2002) struggles to create a learning environment that suits her teaching style '*it's kind of hard to be the way I want to be and to teach the way I want to teach because that's not what they [pupils] are used to, because the students don't respond to that*'. Flores (2001) notes that NQTs miss the opportunity to observe colleagues, as they did when they were trainees. These NQTs say that '*as time goes on teachers forget what they have learned*'. Bubb and Earley (2006) accuse schools of '*educational vandalism*' by not supporting NQTs with adequate or appropriate in-service training. Often NQTs need training in specific areas, but instead the school or department have prioritised alternative courses. This means that whole school development is prioritised and individual training requirements are not adequately funded. Bubb and Earley suggest that the budget allocated to be spent on NQTs is often not used appropriately; this leaves NQTs feeling as if their professional development needs are unimportant.

Other reasons given for adopting traditional teaching methods are pupil behaviour (Davies and Ferguson, 1997; Donnelly, 2000), along with pressures to complete the syllabus and meet deadlines (Ensor, 2001).

The literature seems to imply that NQTs would find it difficult to include the use of graphics calculators into their teaching unless the technology was already integrated into the scheme of work. However, they are often not in a position to make amendments or additions to the existing schemes of work. Findings reported by Flores (2001) suggest that the NQTs in her study *'felt that they were not encouraged to plan and implement curriculum projects and to develop professionally'*. These new teachers were not involved in any of the curriculum planning and development, yet they were expected to work with schemes of work written by others in the department (Ensor, 2001; Flores, 2001). Farrell (2003) points out the *'survival, as opposed to professional development, is the description of a new teacher working in a highly individualistic culture within a school.'* This means that often NQTs are aware of their training needs but these needs are put aside until they feel more confident about their teaching.

Using the case of Wee-Jin, Farrell (2003) uses Maynard and Furlong's (1993) five stages of development to describe the stages that an NQT goes through during their probationary year:

- *'early idealism...he really wanted to make a difference*
- *realism...shock, survival, seeking quick fixes*
- *plateau stage...coping better, establishing routines*
- *moving on...more attention to quality of pupils' learning'*

The use of graphics calculators fits in best with the first and last of these stages. This would suggest that graphics calculators needed to be embedded into the departmental policy from the beginning. NQTs need to arrive at their new school already confident and proficient users of the technology. They need to be encouraged to use the technology within their lessons by supportive colleagues.
It would appear that NQTs find it difficult to adopt the teaching practices encouraged by their university mentors, and as with PGCE students, the 'real' world of the classroom takes precedence over the 'ideal' world of educational theory. In order to be accepted by their new colleagues, NQTs adopt the predominant teaching methods within the department. They feel bound to follow the scheme of work quite rigidly. Unable to share ideas or to discuss difficulties, the NQTs 'survive' their early teaching experiences (Farrell, 2003; Flores, 2001).

The journey from PGCE student to NQT is complex and multi-faceted. The literature has suggested that there are many reasons why trainees and novices do not use graphics calculators and why they continue to teach using traditional methods during their first year:

- They feel overwhelmed by the workload and do not want to add to this by planning lessons with graphics calculators
- They feel isolated. They no longer have the support of their university mentor to offer advice on how to include graphics calculators into their teaching
- They feel they have to follow the departmental schemes of work and the use of graphics calculators is not integrated into the documentation
- Their graphics calculator training needs are not always supported by the school

The last section of this literature review considers models of professional development and how they affect teachers' classroom practice.

2.4 Continuing Professional Development and Teacher Change

The literature on beliefs and attitudes suggests that teachers are not using graphics calculators in their teaching, because *past experience can often act as obstacles'* to development (Ball, 1996). Several other studies (Ball, 1988; Kirschner and Davies, 2003; Valero, 1997) point out that teachers are not '*empty vessels'* and that these prior experiences not only affect their beliefs and attitudes about technology, but also affect their responses to training and professional development. Pehkonen and Torner (1999) suggest that teachers *'try to cope mechanically, since they want to develop themselves'*, and this may be one of the reasons why teachers end up using traditional teaching methods when using technology (Hennessy et al, 2005). Improving pupils' learning and '*seeing students' interests in, and success with, the mathematics and new teaching approaches, teachers [are] motivated to proceed with their efforts to reconstruct their teaching'* (Spillane, 1999). It is generally recognised that professional development and improving pupils' learning are two strong motivators for teachers to make changes in their teaching (Demetriadis et al, 2003; Hennessy et al, 2005; Selwood and Pilkington, 2005), although it has been pointed out that change is sometimes forced on teachers (Scott and Dinham, 2002; McNamara and Corbin, 2001). There is a variety of reasons why and when teachers take up the challenge of a new initiative; *'we identified a spectrum of warranting practices that extended from the personal legitimisation, "it* *works for me", to the public authorisation, "it's in black and white".'* (McNamara and Corbin, 2001)

The literature on technology and graphics calculators, above, has shown that teachers who make regular and effective use of graphics calculators have been able to enhance pupils' learning. Hennessy et al (2005) and Tharp et al (1997) imply that it is worthwhile encouraging more teachers to follow suit, as the use of graphics calculators also encourages teachers to employ more pupil-centred teaching methods. However Guskey (2002) notes that '*If a new program or innovation is to be implemented well, it must become a natural part of teachers' repertoire of teaching skills... teachers must come to use the new practices almost out of habit*'. Yet it is also recognised that teacher training as it stands at present is ineffective and poorly delivered (Ball, 1988; Battista, 1994; Guskey, 2002; Kirschner and Davis, 2003), and this is particularly so when the training is about graphics calculators, and technology in general (Williams et al, 2000a).

Some studies find teacher training to be particularly ineffective; '*Teacher training institutions are going in the right direction, but lack the necessary quality, expertise, intensity, attention and momentum.*' (van den Dool and Kirschner, 2003)
MacNab (2003) adds to this by saying that curriculum change is '*piecemeal*' and that it does not really address questions about purpose and motivation. Writing about the New Opportunities Fund, Kirschner and Davis (2003) suggest that it was a failure because it had failed to motivate teachers and take their work context into account. Battista (1994) makes a similar remark about the poor quality of in-service training available to teachers. He comments that '*these "make-and-take workshops" fail to cause the changes called for, because they do not address teachers' underlying pedagogical*

philosophies, their knowledge and beliefs about mathematics, or their knowledge of the processes by which students come to understand mathematical ideas'. (Battista, 1994) Fullan (2000, p106) makes several recommendations for successful development and teacher change, one recommendation that is particularly relevant to this thesis is the idea that '*effective change takes time*'. Fullan goes on to suggest that this timescale could easily be in the order of two to three years, and institutional change can take even longer. The most effective programme needs to include opportunities for teachers to learn new skills, and then share ideas, discuss and reflect (Estebaranz et al, 2000; Fullan, 2000; West-Burnham, 2000). Although training in technology often has these key elements, there is no opportunity to repeat the cycle of development. Having used the new technology teachers need to come together again to follow up their experiences in a collaborative environment (Swafford, 2000) particularly as most of the in-service training on graphics calculators takes place over a short period of time (typically a day). In order to be successful, professional development needs to be long term and localised (Williams et al, 2000a). This implies that teacher training should be more than just an afternoon workshop, or one day's attendance at an Inset course. When it comes to training about technology Tharp et al (1997) suggest that '*teachers need opportunities to experience both procedural, conceptual and inquiry-based learning and to reflect on the nature of their experience as well as that of their students'*.

Another aspect often not addressed by in-service training is recognising that teachers are also learners. Certainly teachers-as-learners appear to be lacking in most professional training courses on graphics calculators (Crisan, 2001). Pehkonen and Torner (1999) noted that teachers often do not see themselves as learners, preferring to think of themselves as teachers. This will have an effect on how they react to tasks and activities that are presented to them on a training course. (Demetriadis et al, 2003) suggest that teachers will put themselves in learner mode if they want to improve their expertise so that they can improve their professional standing.

Watson (2001) writes that professional development '*intends to augment the existing curriculum by providing specific skills and competencies focused on specific types of applications*'. However, some researchers argue that training seems to focus too much on technical skills development so that teachers 'can teach'. (Selwood and Pilkington, 2005) found that teachers wanted to address pedagogy so that they could plan '*interactive and engaging lessons*'. Similarly, Leat and Higgins (2002) found that teachers '*need activities, and advice on how to use them and routines*'. This is supported by Williams et al (2000a) who recommend that in-service training should:

- *Be appropriate to classroom use*
- *Have a hands-on practical element*
- *Provide on-the-spot help*
- *Provide opportunities to work and share ideas with other teachers.*

However, Watson (2001) points out that to be effective '*professional development [needs to include] time for reflection, the acquisition of basic skills, provide specific training, discussion, the consideration of alternative practices and the redesign of adopted practices.*' Kirschner and Davis (2003) argue that in service training should help teachers to use technology as a mind tool and to extend their educational paradigms. They suggest that mind tools '*help users represent what they know as they transform information into knowledge; they are used to engage in, and facilitate, critical thinking and higher-order learning*'. (Kirschner and Davis, 2003)

Despite the fact that in-service training often meets these needs, it continues to have little impact on teachers' classroom practices. Basit (2003) questions at which point teacher training is most effective; '*one is confronted with a chicken and egg situation: whether to reform the way teachers are taught or to change the practice of experienced teachers'*. The literature so far has suggested that graphics calculator training is a low priority for PGCE students and NQTs.

Several studies have shown that professional development programmes need to take teachers' ideas about teaching and learning into account, as well as their attitudes towards the use of ICT (Cheung and Wong, 2002; Schraw and Olafson, 2002; Higgins and Moseley, 2001) yet too many Inset courses work on a 'one-size-fits-all' model. Cooney (1999) asserts '*that what teachers learn is framed in the context in which that knowledge is required'* and this argument is supported by several other researchers (Kirschner and Davis, 2003; Kynigos and Argyris, 2004; Schoenfeld, 2002; Vrasidas and McIssac, 2000). West-Burnham (2000, pg 15) suggests that one way to make staff development more appropriate to teachers' situation is to '*ground teachers' learning experiences in their own practice by conducting activities at school sites, with a large component taking place in individual teachers' classrooms.'*

Sometimes the same training course can have differing effects on teachers' practice. Edwards (2000) reports that two teachers used calculators more extensively after attending a training course, but the way they used the technology was influenced by their beliefs about how calculators should be used. In Kendal et al (2005) one of the teachers changed her teaching style, from teacher-centred to more pupil-centred, once she started using graphics calculators, whilst another teacher reverted to using former methods. So, some teachers begin to change the way they teach once they begin using technology in their lessons, but as Quinn (1998) and Simonsen and Dick (1997) found *'most respondents indicated that their beliefs concerning the use of technological aids had remained relatively unchanged'* (Quinn, 1998).

Exposure to graphics calculators does not seem to change teachers' beliefs to any great extent, but does seem to change the classroom environment. Teachers seem to use more pupil-centred teaching styles; they move from being the 'sage-on-the-stage' to being the 'guide-on-the-side' (Gobbo and Girardi, 2001; Hennessy et al, 2005; Watson, 2001). *'In order to effect a successful and positive change, teachers need first to be 'perturbed' in their thinking and actions, and secondly, they need to commit themselves to doing something about that 'perturbance'* (Pehkonen and Torner, 1999). One way to create a 'perturbance' of this type is to use pre-images, which are then shared and discussed with colleagues and present a vision of 'what could be' (Senger, 1999).

Whatever strategy is used to cause a perturbation in teachers' thinking, they need time to reflect (Prestage and Perks, 2001; Senger, 1999; Tharp et al, 1997) and this is generally missing from in-service training on graphics calculators. Teachers are sent away with ideas and resources that they can use in lessons. There is no opportunity for them to try out ideas and then feedback on their new experiences once they have returned to the classroom. This could be addressed by building a culture of mentoring and collaboration within and across schools (Craft, 2000 p21).

One of the reasons that effective professional development takes many years is that it involves *'cycles of practice, reflection, and revision'* (Wiske et al, 2001) and this might give the outward appearance of slow or limited teacher change. Watson (2001) writes that teachers' personalities also play a part in how they react to change; there are the *'innovators, early adopters, early majority, late majority, laggards'* and the change process might not seem complete until the 'laggards' have caught up with the 'innovators'.

Quite often it seems as if schools are involved in change for the sake of change (Olson, 2000; Scott and Dinham, 2002). Basit (2003) reminds us that '*change should not be imposed for the sake of it, but should have an inherent moral imperative. It should aim to improve, not just the practice of teachers and the learning of pupils, but also the life chances of our children.*' It is important to question the motives behind encouraging teachers to use graphics calculators; is it in the best interest of pupils' learning that teachers should use graphics calculators in lessons?

The literature in this section suggests that:

- Teachers' professional development is often of a poor quality because is fails to take into account teachers' prior beliefs and the context in which they work.
- Teachers need to be perturbed into considering new ideas and practices.
- Teacher change is a slow process and taking time to reflect needs to be built into any in-service programme.

2.4.1 Models of Teacher Change

As a consequence of the data collected for this research it was noted that teachers' professional development was an important factor in their use of graphics calculators in the classroom. Based on this data, a model of teacher development with respect to the use of graphics calculators is proposed.

This section reviews the literature on teachers' use of ICT and also reviews models of teacher development for comparison.

2.4.2 Models that Describe Teachers' Use of ICT

Becta (2000) suggest that pupils at Key Stages 3 and 4 are 'entitled' to use ICT so that they can '*learn from feedback, observe patterns, see connections, work with dynamic images, explore data and teach the computer*'. In short, this is the governmental vision of working with ICT and as the literature has shown this is not always the experience of pupils in school. However, another model, which describes the way that teachers integrate ICT into their teaching, is presented by McCormick and Scrimshaw (2001) and suggests a broader view of ICT use in classrooms.

McCormick and Scrimshaw (2001) propose three levels in the integration of ICT. Their work is presented as a general model for ICT across the curriculum and with computers in particular.

Any implementation of ICT in schools requires a level of change in practice. We examine three such levels – namely, where existing practice is made more efficient or effective, where it is extended in some new way, and where it is transformed.

McCormick and Scrimshaw describe the first level as one where the teacher '*aspires to provide a more effective means of doing what is already being done*'. The ICT is used to replace a traditional resource, but the lesson is essentially unchanged from previous practice.

The second level of change is described as one where the ICT is used '*to provide a major extension to what can be achieved, one goes well beyond the efficiency level. In this case the ICT extends the reach of the teacher, the learners, or both.*'

The third level goes beyond extending, and is described as transforming. At this level '*the technologies may transform the nature of a subject at the most fundamental level*'. The transformative level is described as having the most impact on teachers' knowledge and pedagogy.

These three levels (efficiency, extending, transforming) can be used to describe the way that teachers use ICT in their lessons, and evidence at two of the three levels has been recorded in studies of teachers and ICT. For instance, Simmt (1997) notes that teachers used the graphics calculator as an efficiency tool; Doerr and Zangor (2000) found that teachers were encouraging pupils to use the graphics calculators to '*explore, confirm or check mathematical ideas.*' However, '*ICT was perceived as enhancing current practice, rather than transforming it.*' (Hennessy et al, 2005) and no literature was found that reported on teachers using ICT to transform pupils' learning. In fact, Hennessy et al (2005) suggest that their findings show teachers are using technology to teach the way they have always done, and that in essence nothing has really changed. McCormick and Scrimshaw's (2001) model describes how teachers use technology to be efficient and to extend, and it suggests ways that ICT could be used to transform. However, it seems as if the transformation level is rarely achieved, nor does the model describe how teachers can move from one level to the next. Furthermore, there are some studies which report on teachers' use of technology yet it is difficult to match their use with a corresponding level. For instance, Fleener (1995) found that teachers recognised the motivational aspects of using calculators, but were unsure about the cognitive aspects. Using ICT as a motivational tool is one aspect not recognised within McCormick and Scrimshaw's three level model.

Ruthven and Hennessy (2002) investigated successful use of computers by teachers and developed a 'practitioner model' to describe what mathematics teachers were doing when they used computers in their lessons. They describe the following themes within their model which 'exploit affordances':

1. *Ambience Enhanced*, changing the general form and feel of classroom activity
2. *Tinkering Assisted*, helping to correct errors and helping to experiment
3. *Routine Facilitated*, enabling tasks to be carried out easily, rapidly, reliably
4. *Features Accentuated*, provides vivid images to highlight properties and features. Within these four themes they include the following sub-themes
5. *Restraints Alleviated*, removing the need for laborious pen-and-paper presentations
6. *Motivation improved*, generating student enjoyment and building confidence
7. *Attention Raised*, helping to focus on the important issues
8. *Engagement Intensified*, helping students' commitment to the activity
9. *Activity Effected*, maintaining pace and productivity
10. *Ideas Established*, supporting student understanding.

Ruthven and Hennessy suggest that the last three themes (8, 9, 10) occur as a result of the three previous (5, 6, 7), and all of these are based on the first four main themes. These four main themes are very similar to the levels in McCormick and Scrimshaw (2001) suggesting that computers can be used for efficiency, to extend or transform pupils' understanding. Unlike McCormick and Scrimshaw's model, Ruthven and Hennessy's model does not propose a hierarchy within their themes, suggesting only differing outcomes in pupils' behaviour or understanding. They say that their model is not *'deterministic'* but rather that it highlights critical states which require active planning and management for teaching and learning. Ruthven and Hennessy (2002) conclude that their study suggests a gradual process where teachers initially *'view ICT through the lens of established practice'*.

Another model similar to the McCormick and Scrimshaw (2001) model is proposed by van den Dool and Kirschner (2003). They put forward the idea of 'benchmarks'. These benchmarks include *'ICT as a mind tool'*, *'Educational/pedagogical use of ICT'* and *'ICT as a tool for teaching'*. They go on to say that these benchmarks guide teachers through *'three worlds of learning'*. The first world of learning describes traditional, guided learning which takes place *'within the frame of reference'*, the second describes collaborative, inquiry and reflective learning and *'extends the frame of reference'*, and the third world of learning is *'expansion learning, critical learning'* and *'builds a new frame of reference'*. This resonates strongly with the three levels in McCormick and Scrimshaw (2001). It also suggests a hierarchy within the three worlds of learning, with the third being the optimum level. Van den Dool and Kirschner go some way to addressing the progression from one world to the next. They suggest that there need to be closer links between research and practice. They present this as a 'loop' that starts with having a gallery of ideas for teaching and learning with mind tools, and then building, designing, testing, evaluating and reflecting to produce more ideas for teaching and learning with mind tools. However, when it comes to teachers' use of graphics calculators there seems to be a problem with the initial part of the loop, in as much as teachers are not using graphics calculators as a mind tool and do not use many of the resources that are available within their 'gallery of ideas'.

Goos et al (2003) also put forward four metaphors to describe the way teachers use ICT in their lessons. These are labelled as; *'Technology as master' 'Technology as servant' 'Technology as partner'* and *'Technology as extension of self'*.

When the technology is master the teachers and students are subservient; their knowledge and use of the technology are limited to the narrow set of operations over which they have technical competence. When technology is being used to speed up processes and replaces pen and paper calculations, it is being used as a servant. Goos et al suggest this type of use of technology leaves the classroom tasks unchanged. The technology is a servant as it supports teachers' preferred teaching methods. Similarly, when the technology is being used as a partner it '*mediates mathematical discussions in the classroom*', and the most sophisticated mode of functioning is when technology is an extension of self. At this level teachers '*incorporate technological expertise as a natural part of their mathematical and/or pedagogical repertoire.*' These four descriptions suggest a hierarchy of use.

The literature on ICT has shown that teachers using graphics calculators tend to be working at the two lower levels. Whilst the model presented by Goos et al can be used to address the issue of teachers using graphics calculators only as a motivational tool, it does not describe the process by which teachers progress from one level to the next.

A model which specifically considers the use of graphics calculators is presented by Kissane (2003). Like the other models considered here, it describes four hierarchical stages of development; '*Where's the on button?*', '*Black line mastery*', '*Routine use*', and '*What's in the curriculum?*'

A teacher working at the first stage is able to use the graphics calculator confidently and independently for the mathematical topics that they teach. '*Work at this stage is concerned with finding out what kinds of things calculators are capable of doing'*.

For the second stage the teacher uses the graphics calculators with pupils, teaching topics already existing within the curriculum. The main focus at this stage is on the teacher '*making effective use of activities and materials developed and trialled by others.'*

Routine use at the third stage involves the teacher considering possible uses of the graphics calculator for pupils' learning. At this stage the graphics calculator has lost its novelty status, and teachers are beginning to develop their own resources.

The final stage describes teachers '*pushing curriculum boundaries, adding and deleting curriculum topics*'. For teachers at this stage the graphics calculator is seen as '*an instrument for curriculum development and even school change'*.

The model captures many of the features of teachers using graphics calculators, and it connects teachers' professional development needs at each stage. Kissane highlights the fact that at the first stage many teachers rely heavily on the graphing functions only. He goes on to suggest that this changes as teachers gain more experience. Yet the literature suggests that teachers continue to rely on the graphics calculators for plotting graphs and are often unaware of other functions that are available. They certainly do not appear to be using matrix manipulation with confidence, even for personal use. This model also suggests that teachers will progress from one stage to the next and eventually reach the fourth stage. Given the status of the 'ordinary' classroom teacher it seems unlikely that they will be in a position to add or delete topics from the school curriculum.

The models of teachers' use of technology and/or graphics calculators presented in this section have suggested levels of hierarchy of expertise. These levels vary from describing teachers as beginners up to experts. The route from one level to the next is not necessarily discussed, but the descriptions could imply that the path is a smooth progression. These levels also seem to suggest that progression from one level to the next is 'equal' in time and effort. Some of the levels do not describe the early stages of graphics calculator use sufficiently to capture teachers' practices, yet they all assign a highest level which the model implies is attainable. These models do not seem to recognise that the majority of teachers are working at the lowest levels, and many are not even on the lowest level of the model. This contradicts much of the literature on graphics calculators which shows that teachers are not using ICT effectively in their teaching.

2.4.3 Models that Describe Teachers' Development

In this section the literature on how teachers change and develop their practice is considered. This connects work on how teachers use ICT and graphics calculators from the previous section and tries to describe how they might progress from the beginning stages towards the expert stages of those models.

Berliner's (1988) five-stage model of teacher development considers the stages that teachers go through during their career. His model recognises that there are two levels for beginning teachers and he labels these as '*Novice*' and '*Advanced Beginner*'. During the novice stage teachers are inflexible and need rules and instructions to carry out their practice. This stage lasts about a year and is typical of someone during their teacher training year. The advanced beginner is more flexible and able to react to situations using prior experience. Berliner suggests that this stage can take two or three years. The third stage when teachers become '*Competent*' *is* reached around their fourth year. At this stage teachers are able to make conscious decisions about their practice, monitor their own progress. As teachers reach the fifth year of their teaching they may become '*Proficient*'. At this point they have a holistic view of their teaching, they are more intuitive. The final stage, '*Expert*' is a stage often not reached by many teachers. At this stage teachers operate and react automatically to situations.

Although this five stage model refers to the development of teachers' practice, it might also be used to describe teachers' development as they begin to use graphics calculators. The PGCE students and NQTs in the literature display the characteristics of novices and advanced beginners in the way they use graphics calculators in their classroom. Berliner's model also recognises that although there is an expert level, that not all teachers will reach that stage.

Guskey (2002) presents a model of professional development and teacher change that suggests teachers' beliefs and attitudes can be changed if they have evidence of improvements in their pupils' learning.

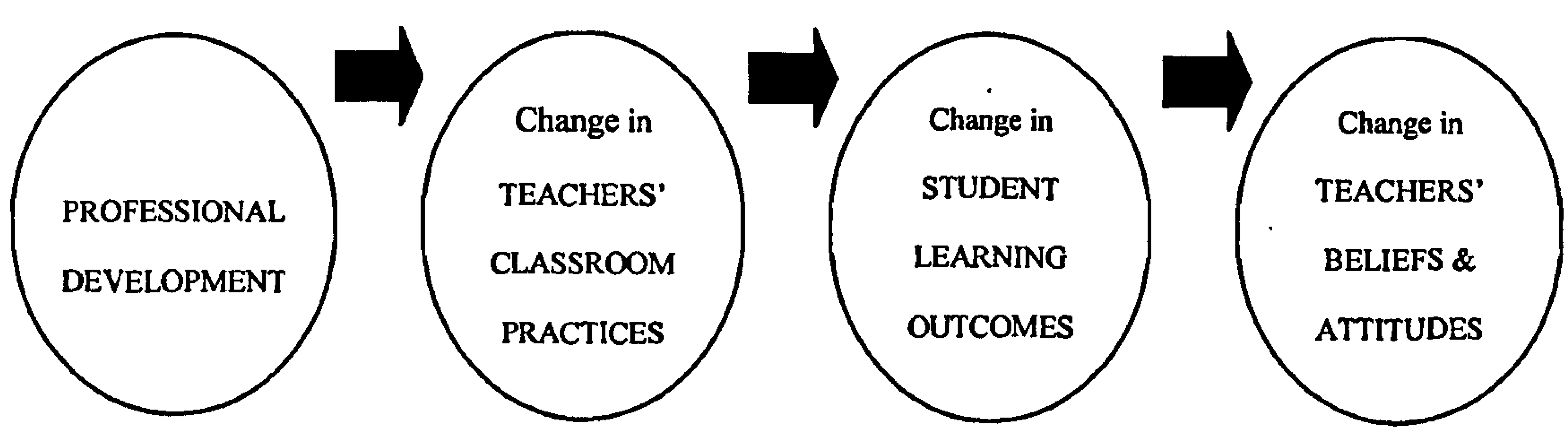

Figure 2.1 'A Model of Teacher Change' (Guskey, 2002)

The model shown in Figure 2.1 shows how professional development leads to changes in teachers' classroom practices, which in turn leads to changes in students' learning outcomes, leading to a change in teachers' beliefs and attitudes.

Guskey's model implies that the development of teachers is a linear route that progresses from one change to the next, ultimately leading to a change in beliefs and attitudes. Yet the literature on teachers' beliefs and attitudes suggests that this is difficult to achieve, and that beliefs and attitudes are fairly static. Furthermore, the literature above suggests that professional development courses have little impact on teachers' classroom practices. Guskey does point out that change is a gradual and difficult process for teachers and '*it is not the professional development per se but the experience of successful implementation that changes teachers' attitudes and beliefs.*' However, applying the same model specifically to teachers' use of graphical calculators might be more appropriate. The initial professional development may cause a perturbation, which if it causes a change in classroom practice is more likely to have an impact on pupils' learning. Also, it seems that having a positive outcome for pupils' understanding and learning is the desired outcome, rather than changing teachers' beliefs and attitudes.

A '*re-forming*' model that addresses teachers ICT development is put forward by Watson (2001). The five stages are described as

- *Orientation;* at this stage teachers consider how to integrate ICT into their teaching so that it is consistent with the school expectations.
- *Adoption;* during this stage teachers adapt current practices to teaching and learning with technology-rich environments
- *Evaluate;* they consider the strengths and weaknesses of those practices.

- *Innovation;* at this stage teachers redevelop their practices based on their experiences and their students' reactions.
- *Institutionalisation;* the final stage when teachers develop strategies to ensure that the new practices become 'traditional'.

Watson recommends that each stage includes time for reflection and the acquisition of skills as part of ongoing professional development.

This five stage model has many similarities to the model proposed by Berliner (1988). The orientation and adoption stages resonate with the notion of novice and advanced beginner, whilst the teachers who are 'proficient' work in similar ways to teachers using technology at the innovation stage. The institutionalisation stage is similar to Kissane's (2003) final stage where teachers are able to decide which topics areas to add or delete from the curriculum. The development of the teacher moves from the individual to the institution. Hargreaves (1999) describes this as a 'knowledge creating school' which allows teachers to '*tinker and experiment in an ad hoc way with new ideas, or variations on old ideas, in order to do things better.*' Again, this is unlikely for ordinary classroom teachers who usually have '*change thrust upon them*' (Fullan, 2000 p112; Scott and Dinham, 2002).

Pope and Sullivan (1998) describe the changes that a physical education teacher underwent as he implemented a sports education programme. Their seven stages are equally applicable to teachers using technology in mathematics teaching.

- *Examination;* gaining familiarity with the change and comparing with personal beliefs
- *Preparation;* getting comfortable through collegial and textual support
- *Engagement;* implementation that fits within the context

- *Adjustment;* shifting or negotiation of espoused beliefs
- *Acceptance;* acknowledgment of the potential of the change
- *Advocacy;* taking things further, sharing perceptions of the new curriculum
- *Projection;* looking to possible refinements, going beyond the immediate context

Again, these stages have similar features to the stages in earlier models. Like the other models, there is an implication that progression is linear and steady from one stage to the next. Like Berliner's (1988) model, Pope and Sullivan's model recognises that the earlier stages are prevalent in teachers' practices, and although a highest stage exists it may not always be feasible for teachers to attain that level of change or development. As with Guskey's (2002) model, the presumption in Pope and Sullivan's model is that progression through the stages will result in a change in teachers' core beliefs and attitudes.

Senger (1999) uses three elementary mathematics teachers to show that teacher change has a recursive nature. This model is shown in Figure 2.2

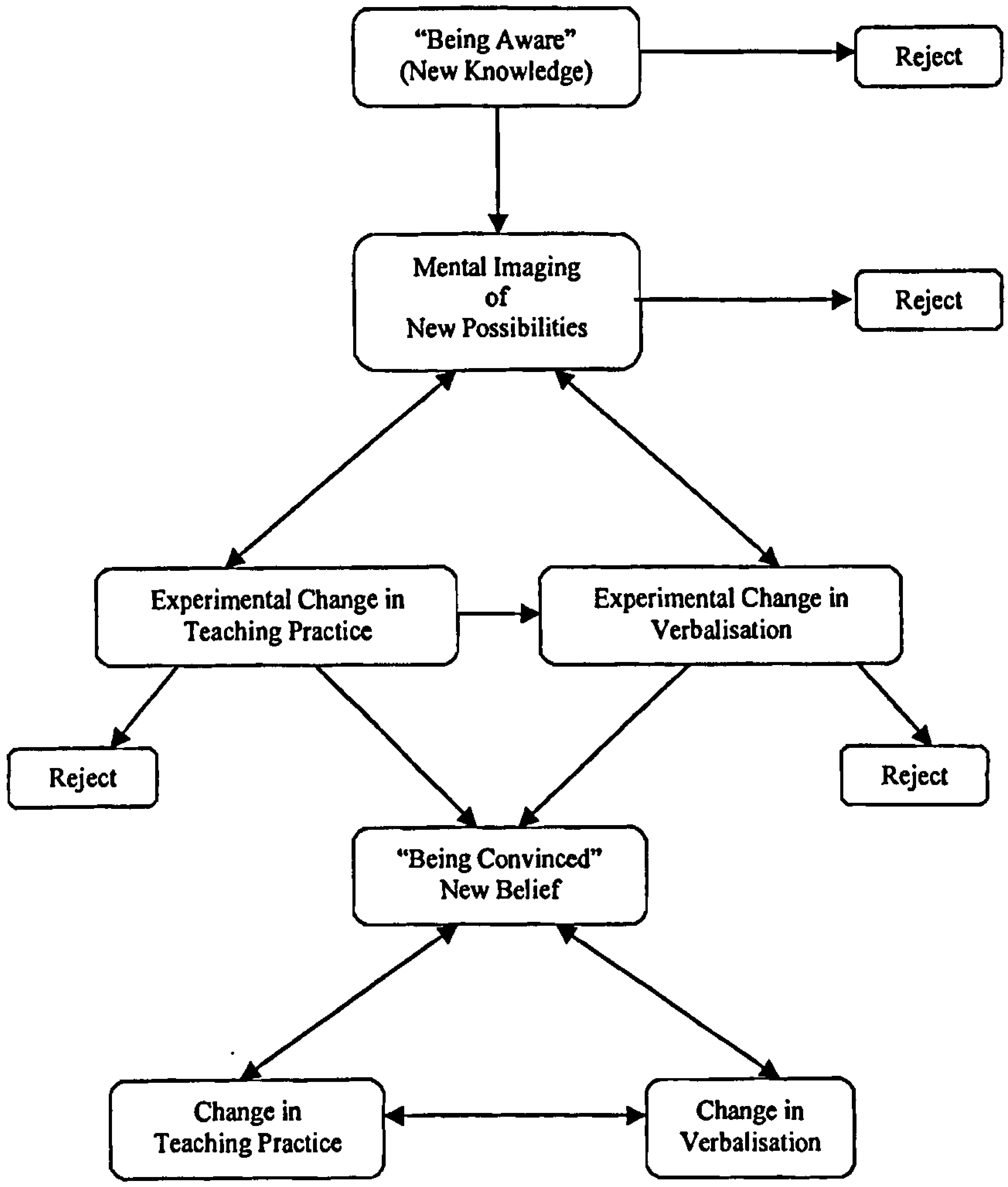

Figure 2.2 'Teachers' way of perceiving mathematics reform' (Senger, 1999)

Senger's model (Figure 2.2) does not depict change and development as a simple linear progression. Her model recognises that that there are recursive aspects that teachers will return to at various stages. These recursive aspects form the loops containing experimenting leading to a new belief and the loop containing change in teaching practice. This model places a change in teaching practice as one of the end results of teacher change, and that a change in beliefs needs to precede that. Senger suggests that the change process did not occur suddenly but was a '*complex and thoughtful process over time*', which coincides with Fullan's assertion that '*change is a process, not an* *event'* (Fullan, 2000). Senger also adds that *'teachers' deep values...do not change so easily or in the same way as their instrumental beliefs'.* This reiterates the notion that when using technology it is probably easier to change teachers' classroom practices rather than their beliefs as suggested by Guskey (2002). The most pertinent aspect of Senger's model is that it suggests that a recursive nature of teacher change, whereas the other models have implied linearity in the development process.

It has been suggested that ICT should be used to transform pupils' learning (Becta, 2003; McCormick and Scrimshaw, 2001). This particular aspect is addressed in detail by King (2007) who proposes a transformation model based on a group of English-as-a-second-language teachers learning to use technology. King's model suggests four stages that teachers go through;

- *Fear and Uncertainty;* learning a new skill can be uncomfortable for adults, but learning technology seems to generate fear and anxiety.
- *Testing and Exploring;* during this stage teachers are no longer limited to scripted instructions but able to explore different functions and applications on their own.
- *Affirming and Connecting;* teachers begin to realise that using technology should be integrated with and consistent with their prior knowledge and practice.
- *New Perspectives;* teachers begin to develop new instructional and curricular materials.

King stresses that the final stage of the journey maybe reached in days, months or years. This model, like previous models implies a linear path through the different stages. It also implies that the final stage gives teachers autonomy to adapt the curriculum to suit their new teaching methods.

The models presented in this review have many similarities;

- They imply a hierarchy of stages of development
- Transition from one stage to the next is mostly linear
- The final stage is often unattainable, requiring teachers to make institutional changes
- The first stage does not always recognise the types of practices that have been reported in the literature

2.5 Summary

The survey of the literature has raised many important points that are relevant to this thesis.

- Teachers' beliefs and attitudes play an important part in their classroom practice despite the fact that often these beliefs and attitudes are difficult to articulate or pinpoint; often these beliefs are formed before they begin teaching and are relatively stable.
- Teachers tend to believe that ICT is less effective than traditional methods, and that pupils need to master by-hand techniques before they use graphics calculators. This means that teachers make little use of graphics calculators in their lessons. However, when graphics calculators are used in the classroom, they are mostly used as an efficiency tool, rather than as a learning tool.
- Student-teachers are also influenced by their prior beliefs and attitudes. Trainees tend to privilege the real world of the classroom rather than the idealised world

presented by their university tutor. This often leads to student-teachers tending to teach the way they were taught.

- Teachers go through a variety of stages as they progress from being a novice to an expert. Generally teachers are open to change, but the change process is slow. Providers of professional development need to consider how teachers adapt to new initiatives, and they also need to consider the context of teachers' day-to-day situation.
- Models that describe teachers' use of technology suggest that there are hierarchies in levels of development. The majority of these models also imply that the route from one level to the next is a smooth progression in a forward direction, with each step being equal in time and effort.

Chapter 3. Research Methodology and Research Methods

3.0 Introduction

This chapter discusses the research methodology and the research tools used within this study.

The first section presents a brief rationale for this research and how it supports previous studies on the use of technology in mathematics classrooms.

The second section considers the advantages and disadvantages of using a case study methodology, and how the disadvantages were addressed. A consideration of the reliability and validity of the data is also presented within the second section, and how issues that were raised were addressed by employing multiple methods.

Section 3 presents a discussion of longitudinal studies and cross-sectional studies and how these two methodologies were combined together to create a 'novel' research methodology for this research, where the disadvantages of one methodology are addressed by the advantages of the other.

Section 4 gives a brief overview of the emergent theory approach, and its relevance to this research study.

Section 5 describes the research instruments and methods of analysis. Four research instruments were used within this study: a questionnaire, lesson observations, interviews and log books. The design of each research instrument is discussed, and how the data collected from each was analysed.

3.1 Rationale for this research

There are many studies into the beliefs and attitudes of teachers (Ball, 1988; Cooney, 1999; Pehkonen and Torner, 1996) or of trainee teachers (Holt-Reynolds, 2000; Smith, 1999; Virta, 2002). Similarly, there are many studies into the use of graphics calculators (Bright, 1994; Fleener, 1995; Simonsen and Dick, 1997; Simmt, 1997), but these tend to look at the specific use of the calculator or its functionality. For instance, how the graphics calculator is used in examination contexts (Boers and Jones, 1994; Graham et al, 2003; Monaghan, 2000), or how the graphics calculator is used to deliver specific topic areas of mathematics (Harskamp et al, 2000; Mitchelmore and Cavanagh, 2000; Ruthven, 1990).

Despite the volume of work on the beliefs and attitudes of teachers and how this impacts on their use of technology, very little has been reported on the use of graphics calculators in the context of teachers' beliefs or how teachers use graphics calculators within the classroom. Of the studies that do report on beliefs and attitudes and the use of graphics calculators Simonsen and Dick (1997) report on a large scale program of 36 high schools, with a small intervention of a one week summer workshop aimed at teachers. Similarly, Fleener's (1995) study reports on a survey of 94 teachers' attitudes towards using (scientific) calculators within the classroom, whilst graphics calculators are not really considered within that study. Two studies that do look at teachers' beliefs and how they affect their classroom practice are reported by Simmt (1997) and Valero (1997). Simmt (1997) describes how a group of six teachers planned to teach quadratic functions using the graphics calculators. Qualitative data from lesson observations and interviews '*provided the basis for the analysis of the teachers' philosophical* *perspectives on mathematics and mathematics education.'* However, this study only looks closely at the teaching of one specific topic in mathematics.

Similarly, Valero (1997) reports on the changes in belief systems of just one teacher '*during a semester before calculators were introduced and during the semester when the technology was introduced.'*

Bright (1994), Quinn (1998) and Walen et al (2003) all consider the professional development and in-service training of teachers, but their work is based on the use of scientific calculators. These studies consider the teachers' concerns about basic skills, and the impact of beliefs about technology on their classroom practice.

One point worthy of note about all of the research cited in the sections above is that it is predominantly based in the USA. British research on the use of ICT is focused on the use of computers (mathematical software, internet, use of video conferencing), and more recently on the use of interactive whiteboards and data projectors. Studies into the use of handheld technology covers the use of data-loggers and CAS-compatible calculators, and the use of graphics calculators is subsumed into this research. This may be for political reasons, as many of the initiatives on ICT are government funded (New Opportunities Fund, National Grid for Learning), and the current political drive seems to be towards whole school policies on creating and using network suites that are connected to the internet.

In addition, many of the studies into beliefs and attitudes about ICT in general have been largely based on questionnaires or other quantitative methods (Abboud-Blanchard and Lagrange, 2006; Crisan, 2001; Doerr and Zangor, 2000; Higgins and Moseley, 2001). They have used statistical analyses to draw generalisations, and give a wideangle view on the use of ICT within schools. The aim of this study is to provide what Cohen et al (2001 p181) describe as *'fine grain detail to complement other, more course grained, often large scale, kinds of research'.*

Despite the volume of work in the field of research into ICT and mathematics education, no British case studies of trainee-teachers or newly qualified teachers, and the affect of their beliefs and attitudes towards their use of graphics calculators in their teaching were found. The rationale behind this study was to confirm the general findings of work done by other researchers, and to investigate how student-teachers and newly qualified teachers teach using graphics calculators.

3.2 Research Methodology

3.2.1 The Use of a Case Study Methodology

This section presents a case for using the case study methodology, and a discussion of the relevant advantages and disadvantages of the methodology to this research.

3.2.1.1 Rationale for Using a Case Study Methodology

Yin (1994 p13) gives the following definition of a case study:

A case study is an empirical inquiry that

- *Investigates a contemporary phenomenon within its real-life context, especially when*
- *The boundaries between phenomenon and context are not clearly evident.*

Cohen et al (2001 p181) suggest that a case study is a '*specific instance that is frequently designed to illustrate a more general principle*'. They go on to say that the case study '*provides a unique example of real people in real situations, enabling readers to understand ideas more clearly than simply representing them with abstract theories or principles.*'

Following on from the pilot study, I realised that my investigation would be mainly qualitative. The main source of data would be field notes of lesson observations and reports of interviews (although a questionnaire and log books were used to triangulate the observation data). The case study methodology lends itself most appropriately to this type of investigation.

I wanted to investigate the cause and effect of trainee-teachers' beliefs and attitudes on their teaching practices, which, according to Cohen et al (2001 p181) is one of the strengths of case study methodology. "*Case studies can establish cause and effect, indeed one of their strengths is that they observe effects in real contexts, recognizing that context is a powerful determinant of both causes and effects.*"

Miller (1991 p22) suggests that one of the central characteristics of a case study of a person is its ability to '*attempt to discover unique features and common traits shared by all persons in a given classification*'.

With these definitions and characteristics in mind, I decided that the case study approach would be the most appropriate methodology.

3.2.1.2 Advantages of the Case Study Methodology

There are many advantages, as well as disadvantages, to using a case study methodology. The following suggestions are listed by Cohen et al (2001 p184) as being positive aspects of the case study methodology (a description of how each aspect was utilised is also given):

- *They [case studies] catch unique features that may otherwise be lost in larger scale data (e.g. surveys); these unique features might hold the key to understanding the situation.*

The lesson observations presented a unique opportunity to observe classroom practice and the interplay between educational pedagogy and the day-to-day reality of teachers' experiences. It was hoped that the observational data would offer an insight into teachers' classroom practices.

- *They are strong on reality*

The observations and interviews were all situated in context, and involved real pupils, student-teachers and their school mentors. The field work gives the data a sense of reality, and offers a window into the everyday experiences of teachers and pupils.

- *They [case studies] provide insights into other, similar situations and cases, thereby assisting interpretation of other similar cases.*

An investigation into how teachers and student-teachers work with graphics calculators may provide an insight and understanding as to how other technology-led initiatives might be received.

- *They [case studies] can be undertaken by a single researcher without needing a full research team.*

The classroom environment lends itself most appropriately to the role of researcher as participant-observer, and this role is best carried out by an individual. Although other members of the University of Plymouth Hand-Held Technology Group offered advice on the data analysis, the data collection was to be an individual exercise.

- *They [case studies] can embrace and build in unanticipated events and uncontrolled variables.*

This aspect of case study research was particularly appropriate. The classroom environment can be unpredictable, with planned lessons being altered without notice. Equipment may suddenly become unavailable; teachers may be asked to attend meetings or to cover for absent colleagues.

- *Case studies are a 'step to action'. They begin in a world of action and contribute to it. Their insights may be directly interpreted and put to use; for staff or individual self-development, for within-institutional feedback;*

I became a research student because I wanted to be a better teacher. In order to do this I needed to understand how and why teachers become the teachers they are.

The process of becoming a researcher has certainly had an impact on my personal teaching style. I am much more critical in my use of technology within my lesson planning. I am more selective about when I include the use of technology into my teaching, and I have developed a stronger preference for the use of graphics calculators, rather than computers; graphics calculators can be used spontaneously, and despite their drawbacks, I feel they are easier for pupils to access.

Retrospectively, from this list of advantages, the last bullet point has been the most relevant for me personally.

3.2.1.3 The Disadvantages of the Case Study Methodology

Despite the positive reasons for using a case study methodology there are also some inherent disadvantages. These two from Cohen et al (2001) were the most relevant to this research study and needed particular attention:

- *The results may not be generalizable except where other readers/researchers see their application.*
- *They are prone to observer bias, despite attempts made to address reflexivity.* (Cohen et al, 2001 p184)

These concerns are echoed by Yin (1994 p9) who writes that '*the greatest concern has been over the lack of rigour of case study research. A second common concern about case studies is that they provide little basis for scientific generalization*'.

However, Lincoln and Guba (1985) go on to challenge this notion, that the case study may be perceived as a description of only one specific case and that it is not relevant to any other. They (Lincoln and Guba, 1985 p316) suggest that the researcher need only provide data that is rich, so that others may decide whether transferability is possible. They put forward the ideas of '*credibility, transferability, dependability and confirmability*'. Credibility can be achieved if the inquiry was conducted in a manner to ensure that the subject was accurately identified and described. Transferability can be implied if the findings are useful to others in similar situations. Dependability attempts to account for changing conditions and confirmability is the idea of objectivity, that others can confirm the findings. Lincoln and Guba (1985) encompass these four themes into an overall notion of '*trustworthiness*'.

The other disadvantage raised by Cohen et al is the notion of '*observer bias*'.

Observer bias is clearly an important issue. Neglecting the possible effects it may have on the study can distort the way data are recorded, considered and analysed. This would have considerable impact on how the study is viewed by others, and call into question the reliability, validity, and robustness of the study. Strauss and Corbin (1998 p25) recommend that data be recorded by '*describing*'; this entails '*depicting, or telling a story without stepping back to interpret events or explain why certain events occurred*'. This method of taking field notes was used throughout the study. The observations were recorded as a series of events, and no commentary was made. The notes from the interviews were re-written and expanded from the less detailed notes written in situ. Nevertheless, in all cases, the notes are a faithful and honest account of events, incidents and comments that occurred during each episode. However, it is still worth pointing out that the notes are still only *my* recollection of the events as they happened.

The two main disadvantages, being unable to generalise and observer-bias have both been addressed as being possible flaws within the research design. Using multiple methods helps to provide a level of rigour and to triangulate the data, and the note taking was done according to Strauss and Corbin (1998).

3.2.2 Reliability and Validity of the Data

The reliability and validity, Lincoln and Guba's (1985) idea of trustworthiness, of a single case study is often questioned; '*its external validity is seen by traditional cannons as a weakness in the approach*' (Marshall and Rossman, 1999 p193).

Yin (1994 p45) suggests that '*the evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust*'. To address these important points I adapted the single case study design to include elements of cross-sectional studies and longitudinal studies. The rationale behind using multiple case study methods was an attempt to make the conclusions of this study more reliable, and to add a level of rigour to the research design. The multiple cases also provide attempts at triangulation. The data from the cross-sectional study is triangulated with data from the longitudinal study, and a final comparison of these findings is made with the data collected from the Calculator Development Project.

Mark represents the critical case within this study. He was a mathematics graduate on the Post-Graduate Certificate in Education (PGCE) course along with 21 other students. I was assigned to be his visiting tutor for his school placement and I observed his teaching on two occasions as part of his formal assessment. Along with the other 21 PGCE students, Mark participated in the trial questionnaire. From his questionnaire responses, and the two observed lessons, Mark appeared to be a 'typical' student on his teacher-training course. His comments during the feedback sessions to his formal observations confirmed this viewpoint.

Based on these three aspects Mark was chosen as the 'single case' for a longitudinal study.

Yin (1994 p38) suggests that the choice to use a single case can be substantiated if the single case *'represents the critical case in testing a well formulated theory. To confirm, challenge or extend the theory there may exist a single case meeting all of the conditions for testing the theory'.*

Initially the 'theory' being tested was work done by other researchers (for example Tharp et al, 1997; Valero, 1997; Doerr and Zangor, 1999). The emergent themes from the observations and questionnaire responses were compared to existing findings in the literature. Further data were collected and analysed, and they became part of the pilot study. Later, the single case study was used to '*determine whether a theory's propositions are correct or whether some alternative set of explanations might be more relevant.*' (Yin, 1994 p38)

Cohen et al (2001 p103) describe this way of sampling as '*purposive sampling*'. Mark is 'handpicked' as he was chosen 'for a specific purpose' and no attempt was made to suggest that Mark is representative of any wider population other than his cohort of PGCE students. The decision to select him as the single, critical case was '*deliberately and unashamedly selective and biased*' (Cohen et al, 2001 p104)

However, the desire to generalise from this study was a strong one! This led to the use of other case study methodologies, which I incorporated into my research methodology to supplement the single-case study. The cross-sectional study participants were used to triangulate the data with the critical case study. The data collected from the lesson observations and interviews from the cross-sectional study were used to support elements that could be generalised to a wider population. Most importantly, the cross-sectional study was an attempt to provide rigour and validity for the research as a whole.

The selection of participants within the cross-sectional study was based on Yin's (1994 p44-46) notion of '*replication logic*'. He states that '*The logic underlying the use of multiple-case studies is the same. Each case must be carefully selected so that it either (a) predicts similar results (a literal replication) or (b) produces contrasting results but for predictable reasons (a theoretical replication).*'

Attempts to achieve replication logic were made by selecting other PGCE students whilst Mark was also a trainee-teacher. Their data were compared alongside the data collected from Mark to see whether literal or theoretical replication had occurred. Participants for the cross-sectional study of newly qualified teachers (NQTs) and qualified teachers were chosen with the same rationale. This meant that data from the newly qualified teachers could be compared with data collected from Mark's lessons during his NQT year. This was done deliberately as another attempt at ensuring a level of reliability within the data.

3.3 Cross-Sectional and Longitudinal Studies

These types of studies are sometimes described as 'developmental research' because '*they are concerned both to describe what the present relationships are among variables in a given situation and to account for changes occurring in those relationships as a function of time*' (Cohen et al, 2001 p169).

Cohen et al (2001 p174) define a longitudinal study as one which '*gathers data over a period of time*'. Within the context of my research Mark forms the single case of the longitudinal study. Data were collected over a period of three years; during his training year, during his probationary year and then the third year of the study, when he becomes recognised as a qualified teacher. Observations and interviews over the research period offer an insight into the early development and first steps of becoming a mathematics teacher. In the analysis of those observations, and other data collected during the study, the intention was to describe the relationships between student-teacher and the systems in place that may encourage or hinder the use of graphics calculators. As Mark moved from being a student to a newly qualified teacher, I attempted to describe and explain the changes that happen to his teaching practice. This can only be done over an extended period of time, hence, the need for a longitudinal study.

The other participants in my research formed the cross-sectional study. As a student-teacher, Mark was compared to three other PGCE students. That data formed the pilot study. Three other participants were chosen during their probationary year. Data collected from Mark's probationary year (observations of lessons and interviews) were compared to the lesson observations and interviews of these three newly qualified teachers. These three newly qualified teachers had no prior connection to Mark, unlike the three PGCE students. This was akin to keeping the samples independent.

To see where Mark's journey might end, and also to account for why the journey took the route(s) it did, three qualified teachers with several years of experience were included in the cross-sectional study.

All of the participants in the cross-sectional study provide a '*snapshot of a population at a particular point in time*'. (Cohen et al, 2001 p175).

3.3.1 Strengths and Weaknesses of Cross-Sectional and Longitudinal Studies

In discussing the strengths and weaknesses of longitudinal and cross-sectional studies, Cohen et al (2001 p176) suggest that the representative sample of the longitudinal study is '*uniquely able to identify typical patterns of development and to reveal factors operating on those samples which elude other research designs*'. Furthermore, longitudinal studies are '*particularly appropriate when investigations attempt to establish causal relationships*'.

One of the greatest advantages attributed to longitudinal studies is the fact that time is readily available and is an inherent aspect of the research design (Cohen et al, 2001). Following Mark's progress over the course of three years gave '*greater opportunity to observe trends* [and] *to distinguish real change from chance occurrence*'. However, the element of time so pivotal to the longitudinal study is also linked to the methodology's greatest disadvantage, that of '*sample mortality*' (Cohen et al, 2001 p176). Sample mortality occurs when participants drop out of the research project. This was of particular concern within this study as the sample size within the longitudinal study only consisted of one participant. Yin (1994 p41) also addresses the issue of 'sample mortality' in as much as *'a potential vulnerability of the single case design is that the case may later turn out not to be the case it was thought to be at the outset'*. Both of these aspects are addressed by using the multiple case study method; the research project could continue by following the progress of another participant. If the single case study did turn out 'not to be the case' that was expected, it would still provide a view of the development and progress of a student-teacher as they become a newly-qualified teacher.

The use of a cross-sectional study was also an attempt to lessen the effect of sample mortality from the point of view of Cohen et al. Cohen et al (2001 p176) suggest the idea of 'topping up' as a way to reduce the effect of sample mortality. That is, to introduce new participants at each time frame from the same population. This idea of topping up was the basis for my cross-sectional study. Mark's teaching was compared to other participants at each stage for the duration of the study, and these comparative subjects could have provided a replacement for Mark.

Cohen et al (2001 p178-179) summarise the strengths and weaknesses of longitudinal and cross-sectional studies. Their lists seem to suggest that the weaknesses of the one are the strengths of the other. Thus by combining the two types of study, I have attempted to make my research methodology more robust and hence more reliable.

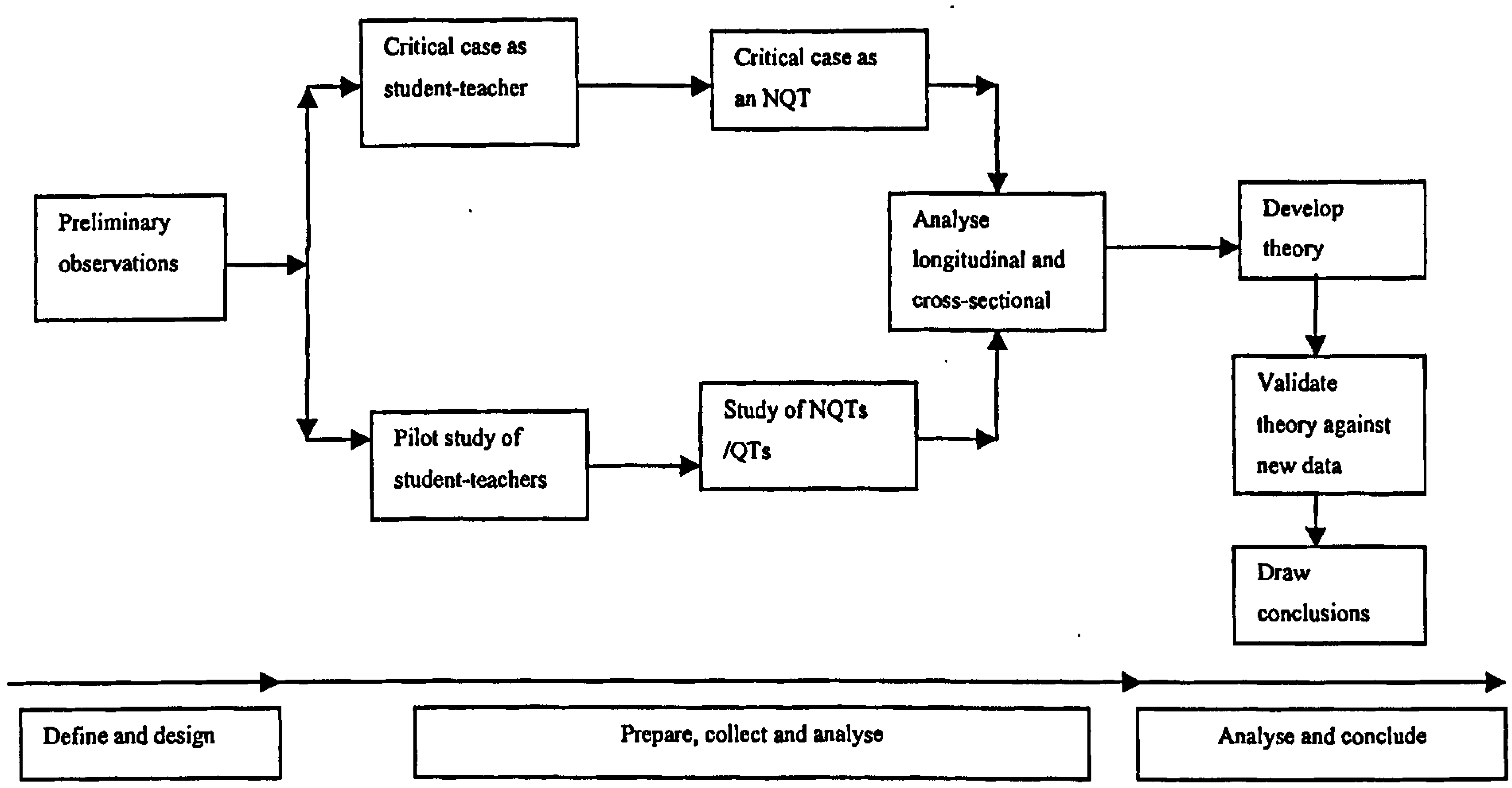

Figure 3.1 Case Study Method, based on Yin (1994, p49)

Figure 3.1 summaries the case study method that was used in this research, and is based on the case study method proposed by Yin (1994, p49).

3.4 Emergent Theory Model.

In this study an 'emergent theory model' was used. This was based on several aspects of grounded-theory methodology of research, whilst rejecting the key component of coding. The use of coding is particularly appropriate when the frequency of key words from interview data are used to form constructs. As this was not the case with my data analysis, the use of coding was considered unlikely to yield any useful data. For this reason, the grounded theory methodology is described in this thesis as 'emergent theory'. However, other key features of grounded theory were particularly relevant, and these are described here.

Grounded theory proposes that '*theories are drawn from data, [and] are likely to offer insight, enhance understanding, and provide a meaningful guide to action*' (Strauss and Corbin, 1998p12). Cohen et al (2001) describe this model as one where the theory emerges from the research and is 'grounded' on the data that the research generates. '*Theory should not precede research but follow it*' (Cohen et al, 2001 p150). I began with a research situation; the teacher and the mathematics classroom. I wanted to understand why teachers teach the way they teach. These key aspects of grounded theory provided a way to investigate this context and to reach conclusions based on the data that I gathered.

Strauss and Corbin (1998 p25) describe their grounded theory model as being a process that involves:

- *Describing – telling a story'*
- *Conceptual ordering- classifying events*
- *Theorizing- constructing from the data an explanatory scheme*

In order to begin to understand the research situation I began with some lesson observations of PGCE students. This led onto more lesson observations of mathematics classrooms which were followed up with interviews, with the same student-teachers. Several hours of mathematics lessons were observed, led by experienced mathematics teachers as well as student-teachers. Field notes of each lesson were written (*Describing*) and immediately after the lesson additional information was added, such as the classroom environment, the teacher's reactions to pupil behaviour and so on. This idea was developed from Marshall and Rossman (1999 p108) who suggest the commentary on the lesson observations could include ideas about '*emerging analytic insights and comments about the actions*'. The lessons were also 'summarised' by writing about any '*critical incidents and salient moments*' (Mason, 1994). Later, these notes were annotated and examined for similarities and differences (*conceptual ordering)*. From these notes '*emergent theories*' (Lincoln and Guba, 1985) were developed. These emergent theories provided the stepping stones for further lesson observations and interviews leading onto additional data collection. Earlier notes of lesson observations or interviews were compared to the new data and these data were then compared with findings from literature.

Research literature was accessed as it became relevant to particular aspects of the study, and used to make comparisons with the data. In the early stages of the research the literature search focussed on teachers' beliefs and attitudes about mathematics and mathematics education. This was in part to understand the events that were observed, and to check the observations against findings from previous research done by others. After several lesson observations, it became apparent that the beliefs and attitudes of student-teachers were not the only factors affecting their classroom practice. At this point, the literature review became a search for studies on the use of graphics calculators and hand-held technology in mathematics classrooms. As the literature search expanded in this field, new theories were tested against the findings of other studies, and compared with the data from the lesson observations and interviews (*Theorizing)*.

Having reached the theorizing stage, Strauss and Corbin (1998 p159) write that the theory that has emerged from the data needs to be validated. They say that, at this point, the data have become 'an abstract' and it is important to determine how well that abstraction fits the raw data. They suggest several ways of validating the theory; one is to compare it to the original data, another is to collect new raw data. In this study, the main method for validation was their second suggestion. New data, in the form of log books, was collected from a mathematics department just embarking on the use of graphics calculators. Strauss and Corbin (1998 p201) describe this as '*theoretical sampling*', where the data gathering is driven by the evolving theory and is based on the concept of making comparisons.

Using the log book data, as well as the earlier data, a new model is proposed. The new model aims to describe how teachers use graphics calculators, and the process of teacher change with respect to graphics calculators.

The constant comparison of data-to-data and data-to-literature is fundamental to my research, and forms the basis of the emergent theory model.

3.5 Research Methods

Four research instruments were used in this study: A questionnaire, adapted from Fleener (1995), semi-structured interviews, lesson observations and log books. This section gives a brief overview of these instruments. Further discussion of each instrument, the methods of analysis and the outcome, is given in the data analysis chapters.

3.5.1 The Questionnaire

The questionnaire was adapted from work done by Fleener (1995). Fleener's questionnaire concerned itself with the use of calculators by middle and secondary school mathematics teachers in the United States, and was designed to measure the '*(a) beliefs about the cognitive effects of calculator use, (b) experience with and availability of calculators in teaching, and (c) beliefs about affective results using calculators in mathematics teaching.*'

The teachers in her study were presented with 23 statements and four possible responses; strongly agree, agree, disagree and strongly disagree.

Fleener's study suggests '*experience was a factor in teachers' beliefs about the cognitive affects of using a calculator*', but that further research was needed to investigate the interplay between experience and philosophical orientation and also to '*offer insight for in-service efforts to affect change in teachers' implementation of technology tools*'.

The reason for re-designing Fleener's questionnaire was threefold:

1. As an attempt to re-examine Fleener's work within a British setting

Fleener's study involved 94 middle school and secondary school mathematics teachers. The participants in her study were all teachers from Oklahoma and had taken part in a calculator workshop.

For this study, the questionnaire was adapted so that it could be given to mathematics student-teachers working with secondary school age pupils (11-18 years). The participants in this study were all working within the British education system.

2. To include graphics calculators, not just basic calculators

Fleener's questionnaire is worded so that it refers only to basic calculators. Graphics calculators are only directly mentioned in one statement (*I have used graphing calculators in my classroom before*). Scientific calculators are also only mentioned in one statement (*I am proficient at using a scientific calculator*). All of the other statements refer only to 'calculators' which seems to imply only four-function calculators. The questionnaire for this study was designed with graphics calculators in mind. This meant that the word 'calculator' was specifically replaced with 'graphics calculator'.

It was important to determine whether participants used the particular functions available on the graphics calculators, or whether they used it instead of a scientific calculator. To this end, respondents were asked to rate their knowledge and confidence on the use of the graphing function, the table function, programming functions and statistics functions.

3. To try to understand empirical evidence from early observations of Post-Graduate student teachers.

As a tutor for several Post-graduate students on teaching practice, I had observed approximately 18 mathematics lessons by six different trainees. Over this period of lesson observations, I noted that I had not observed a single mathematics lesson that included the use of graphics calculators, despite the fact that the use of ICT including graphics calculators is prescribed by the PGCE course criteria. The student-teachers had ready access to graphics calculators, either through the department they were working with, or through the university. The questionnaire was designed to elicit responses that may account for this lack of graphic calculator usage.

Fleener's questionnaire presents participants with 23 Likert statements with four possible responses; strongly agree, agree, disagree and strongly disagree. Participants were also asked to list the type of calculator that they used during mathematics lessons and the type they use for their own work. The last question asks participants to note how often they use the calculator in class, with three options: several times a week, once a week, hardly ever.

For the adapted questionnaire used in this study, participants were able to answer with a neutral response, as well as the four options given by Fleener. After the initial trial of this questionnaire, a blank space was included at the end of the statements. Here participants were given an opportunity where they could clarify or comment on any of the twenty statements if they choose to.

The adapted questionnaire for this study consisted of two sections: the first part of the questionnaire consisted of 20 statements about mathematics and graphics calculators and respondents were asked to choose from a 5-point Likert scale, ranging from 'strongly agree' (SA), 'agree' (A), 'no opinion' (N), to 'disagree' (D) and 'strongly disagree' (SD). The second part of the questionnaire consisted of open-response questions about the type of experience they had using graphics calculators. They were asked about their experiences of graphics calculators as a student at various stages. They were also asked about their level of knowledge and their level of confidence in using graphics calculators for their own personal use. This version of the questionnaire is shown in Appendix A.

Following on from the pilot study a further change was made to the second section of the questionnaire. The open-questions were re-designed to elicit participants' responses about their attitudes towards the use of graphics calculators. The question on participants' level of confidence was retained.

The statements in Fleener's questionnaire were designed to find out about teachers' attitudes towards using calculators in mathematics teaching and learning, whether there was a relationship between using calculators for mathematics instruction and attitudes towards calculator use. Also whether there are different philosophies of mathematics instruction, and if there are, what are the beliefs and experiences of these different groups?

From the responses to her questionnaire Fleener identified three categories:

1. Beliefs about the effect and appropriate use of the calculator
2. Experience with and use of calculators in teaching
3. Beliefs about affective results of using calculators in the classroom.

Similarly, the statements and questions in the adapted questionnaire were designed to investigate the respondents' beliefs and attitudes about mathematics, teaching and learning mathematics and using graphics calculators. Table 3.1 shows the categories identified in Fleener's questionnaire and compares them to the categories identified in the adapted questionnaire.

Fleener's three categories	The three research categories for the adapted questionnaire
1. Beliefs about the effect and appropriate use of the calculator 2. Experience with and use of calculators in teaching 3. Beliefs about affective results of using calculators in the classroom.	1. Teachers' beliefs about mathematics, and using graphics calculators 2. Teachers' beliefs about teaching and learning, and using graphics calculators 3. Teachers' beliefs and attitudes towards graphics calculators

Table 3.1 Comparing Categories

3.5.1.1 Comparing the Likert Statements

Table 3.2 shows a comparison of Fleener's questionnaire and the Likert statements on the adapted questionnaire.

The numbers in column 1 refer to Fleener's statement number, column 2 gives the exact wording of Fleener's statement, and column 3 shows the category Fleener allocated to that particular statement.

Similarly, column 4 shows the wording of the Likert statements in the adapted questionnaire, where the number in the bracket refers to the statement number, and column 5 shows the research question that was being addressed.

	Fleener's questionnaire	Cat	Adapted Questionnaire	Cat
1	Students should not be allowed to use a calculator while taking math tests.	1	(1)Students should not be allowed to use a graphics calculator while taking maths tests.	1
2	Calculator use will cause a decline in basic arithmetic	2	(2) Graphics calculator use will cause a decline in basic arithmetic skills	1
3	Calculators are motivational	3		
4	Calculators make math fun	3	(3) Graphics calculators make maths fun	3
5	When students work with calculators, they don't need to show their work on paper	1		
6	Math is easier if a calculator is used to solve problems	1	(4) It is easier to solve maths problems using a graphics calculator	3
7	More interesting mathematical problems can be done when students have access to a calculator	3	(5) More interesting problems can be done when students have access to a graphics calculator	2
8	Students understand math better if they solve problem using paper and pencil	1	(6) Students understand maths better if they solve problem using paper and pencil methods	1
9	Students should not be allowed to use calculators until they have mastered the concept	1	(8) Students should not be allowed to use graphics calculators until they have mastered the concept	1
10	All students should learn to use calculators	1	(7) All students should learn to use graphics calculators	3
11	Using calculators will make students try harder	3	(9) Using graphics calculators means students can do harder maths	2
12	Calculators should be used only to check work once the problem has been worked out on paper	1	(12) Graphics calculators should only be used to check work once a problem has been worked out on paper	1
13	Calculators should be used on math homework	1		
14	Using calculators will cause students to lose basic computational skills	1		
15	Using calculators makes students better problem solvers	1	(13) Using graphics calculators makes students better mathematicians	3
16	Continued use of calculators will cause a decrease in student estimation skills	1		
17	I have calculators available for my class(es) to use	2		
18	Most of my students have access to their own calculators	2		
19	Calculators are only tools for doing calculations more quickly	1	(17) Graphics calculators are only good for doing calculations more quickly	3
20	I have used graphing calculators in my classroom before	2		
21	I am proficient at using scientific calculators	2		
22	I know ways I can use the calculator effectively in my classroom	2		
23	I have lots of ideas about how I can make use of this calculator	2		
			(10) Students should learn how to use a graphics calculators as part of their maths lessons	2
			(11) Teachers should know how to use graphics calculators	2
			(14) Graphics calculators are good for checking solutions	3
			(15) Using graphics calculators with young pupils makes them better at maths later on	3
			(16) Teachers should teach students how to use graphics calculators	2
			(18) Graphics calculators can be used for investigations	2
			(19) Graphics calculators are too complicated to be used by younger pupils	3
			(20) Money spent on calculators would be better spent on textbooks	1

Table 3.2 Comparison of the Two Questionnaires.

As Table 3.2 shows, there were several statements that were within Fleener's questionnaire that were not included in the adapted questionnaire. This was because the adapted questionnaire was primarily designed with PGCE students in mind, and as such, the questions about their teaching experience and practice were replaced with statements about their beliefs and attitudes towards teaching and learning.

The adapted questionnaire addressed the following three research questions about the use of graphics calculator. The statements from the questionnaire are given under each research question.

What are teachers' beliefs about mathematics and using graphics calculators?

1. Students should not be allowed to use a GC while taking maths tests
2. GC use will cause a decline in basic arithmetic
6. Students understand maths better if they solve problems using paper and pencil methods
8. Students should not be allowed to use a GC until they have mastered the concept or procedure.
12. GC should only be used to check work once a problem has been worked out on paper
20. Money spent on GCs would be better spent on text books

What are teachers' beliefs about mathematics teaching and learning and the use of graphics calculators?

5. More interesting problems can be done when students have access to a GC
9. Using GC means students can do harder maths
10. Students should learn how to use a GC as a part of their maths lessons
11. Teacher should learn how to use a GC
16. Teachers should teach students how to use GCs

18. GCs can be used for investigations

What are teachers' beliefs about Graphics Calculators?

3. GCs make maths fun
4. it's easier to solve problems using a GC
7. All students should learn to use a GC
13. Using GCs makes students better mathematicians
14. GCs are good for checking solutions
15. Using GCs with young pupils makes them better at maths later on
17. GCs are only good for doing calculations more quickly
19. GCs are too complicated to be used by younger pupils

In order to ensure a level of internal reliability, some of the statements were worded positively and some negatively.

The following statements were worded in such a way that a response of 'Strongly Agree' was taken as having a positive attitude towards graphics calculators: 3, 4, 5, 7, 9, 10, 11, 13, 14, 15, 16, and 18.

Whereas for statement 1, 2, 6, 8, 12, 17, 19, and 20 a response of 'Strongly Agree' would indicate a negative attitude towards graphics calculators.

The responses from each participant were coded so that they could be recorded on a spreadsheet.

- Strongly Agree → 1
- Agree → 2
- No Opinion → 3
- Disagree → 4
- Strongly Disagree → 5

In order to take into account that some of the statements were worded in such a way that a response of strongly disagree indicated a negative attitude towards graphics calculators, software was used to take values of 1 and 5 and to interchange them for the specified statements. Similarly, values 2 and 4 were interchanged.

This meant that a value of 1 represents a positive attitude towards graphics calculators and a value of 5 would indicate a negative attitude.

3.5.1.2 Administration of the Questionnaire

The questionnaire was originally tested on a group of PGCE students from just one local teacher-education institute. The findings from that survey formed the basis of the pilot study.

Subsequently, the questionnaire was amended to include a space for participants to comment on any of the Likert statements. This version, shown in Appendix B, was administered to the same group of PGCE students at the end of their initial teacher training course. This was used as part of a pre-test and post-test to ascertain whether there had been any change in the PGCE students' beliefs and attitudes towards the use of graphics calculators during their training period.

The questionnaire was amended a final time to include open-response questions on beliefs and attitudes, and this version was administered to groups of other PGCE students from another two universities as well.

The Likert questions only were also used with a small number of newly-qualified teachers and experienced teachers as part of the cross-sectional study.

A separate questionnaire was designed specifically for Heads of Department (Appendix C). The purpose of this questionnaire was to gauge the level of support that the schools offered to PGCE students in the use of graphics calculators whilst the student-teachers were with them on their school placement. It also tried to address the issue of training as raised by Fleener in her original work, by asking about the level of confidence and training that experienced teachers had with respect to the use of graphics calculators for their own teaching.

3.5.2 The Lesson Observations

Following on from the questionnaire, participants were asked if I could come along and observe them teaching in their classroom. The participants were aware that I was working on a research project and that the data from the lesson observations may be included in my final report. I had built up a rapport with these participants over a year as a visiting tutor from the teacher-training course, either as their PGCE tutor, or as a collaborator with the classroom teacher. Because of this, the participants were particularly supportive of my research. Participants were reassured that neither they nor the institution in which they worked would be identified within the report.

My role during these sessions was predominantly one of '*participant-observer*' (Cohen et al, 2001 p305). This mode of observation is less threatening than that of the '*complete observer*', which may feel more like an inspection. The role of participant-observer is similar to the peer-observation method with which student-teachers and experienced teachers are already familiar. Yin (1994 p87) describes this type of observation as one where a variety of roles can be assumed, and one '*may actually participate in the events being studied*' and not just behave as a passive observer. This allowed me to walk around the classroom, talk to pupils and look at their work. It also provided an opportunity to talk to the student-teacher/class-teacher in situ.

The lessons that were being observed were always pre-arranged, and the student-teacher and the class teacher were aware that notes would be taken during the session. In order to put the participants at ease, they were always reminded that the lesson observation and the written notes were confidential. It was made clear that the notes were for my research purposes only. This was to reassure them that there would be no discussion with any third party, such as other colleagues within the department. The PGCE students were also reassured that the lesson observation would not affect their course assessment grade.

The participants were aware that my research interests lay in the use of graphics calculators, and I was concerned about minimizing reactivity where '*respondents behave differently when subjected to scrutiny*' (Cohen et al, 2001 p116). The participants had all responded to the questionnaire before any lesson observations for the purposes of this research or any interviews had taken place. As a result of this, all of the PGCE students and classroom teachers were aware that my field of interest was in the use of graphics calculators. This meant that care was needed when asking to come and observe a lesson. Usually the participants were just asked if I could come and observe them teaching a lesson. If they inquired into the aim of my observation then they were given the vague, open response that I wanted to observe different teaching styles.

All of the participants were free to suggest the class and topic that was to be observed. Occasionally, a specific topic was suggested and the use of graphics calculators was requested. In which case, the topic was chosen such that graphics calculators would have been particularly relevant but not necessary.

By being deliberately vague about the purpose of the lesson observation, I had no idea what to expect during the lesson observation. The participants may choose to deliver a lesson involving graphics calculators, knowing it was my field of interest. In which case, I would record the type of mathematics being taught, the suitability of the topic to the use of graphics calculators, and the level of experience and confidence of the teacher and pupils. If the teachers chose not to do a lesson on graphics calculators, despite knowing my interest, then I would record whether the topic would have lent itself to the use of graphics calculators and the teacher's teaching style.

In both circumstances, the lesson observation would be followed by an interview when I would ask them about their decision to use or not to use graphics calculators.

Delamont (2002, p130-138) describes this method of observation as having the following constituent parts.

- The broad sweep – this encourages the observer to be selective and helps them to recognise what is really important and what matters.
- Nothing in particular – this is described as 'wait and see what jumps out at you' and Delamont likens it to a radar blip '*You'll know when you see it'*.
- Searching for paradoxes /Searching for problems - these two aspects encourage the observer to fight familiarity, to actively look for things that seem out of the ordinary.

This looseness in observation tactics is seen as a way of gathering information about a situation when one does not know what to expect. With the lesson observations in this study, that was certainly the case. Delamont (2002, p132) goes on to say '*It does not matter what the observer looks at, as long as the gaze is focussed on some person, object or location in a thoughtful, principled way*'.

The lesson observations were recorded using detailed field notes. There were two reasons for this; video recording within classrooms is not always permitted, and tape recorders cannot pick up everything audible as they have a limited range. The other reason is that recording equipment changes the atmosphere in the classroom. It was important to minimize intrusion and reactivity, to keep the classroom environment as natural as possible. Mason (1996, p69) suggests that the way the observations are recorded will be influenced by the practical constraints, and by an awareness that recording equipment may not pick up all the subtle nuances that may be important. She stresses that '*field notes are essential, whether you choose other methods or not*'. (Mason, 1996, p70)

The field notes were made in situ and in real time, so that all the recording of events and incidents was written as the lesson took place. Marshall and Rossman (1999, p107) recommend that '*observation entails systematic noting and recording of events and behaviours*'...and that field notes are '*detailed, non-judgemental, concrete descriptions of what was observed.*'

Cohen et al (2001, p311) give a detailed list of the types of field notes that can be used to record observations. From this extensive list I chose to use:

- Transcriptions and more detailed observations written out fully on one occasion for each participant
- Pen portraits of participants
- Reconstructions of conversations
- Descriptions of the physical settings of events
- Descriptions of events, behaviours and activities

Marshall and Rossman (1999) offer a table format for recording the field notes, shown in Table 3.3

Date/time/location	**Comments**
Description of event	Personal notes, an interpretation of the observations.

Table 3.3 Format for Recording Field Notes (Marshall and Rossman, 1999)

Marshall and Rossman also recommend that the comments section runs alongside the observation notes. This column should include '*emerging insights, and comments about actions*' and that these comments *'may also provide important questions for subsequent interviews'* (Marshall and Rossman, 1996; p108).

However, I wanted the observation notes to be validated by the participants. This meant that the notes were read out or shown to the participant at the end of the lesson. Because of this the commentary section was kept unseen, so the table format suggested by Marshall and Rossman was not used. The student-teachers were already used to seeing a description of their lessons, so only that aspect from Marshall and Rossman was shown to the participants.

The descriptive section of the field notes was a record of events and comments made by the teacher and pupils. Thumbnail sketches of diagrams drawn on the board were drawn to supplement any of the descriptions. Comments made by the teacher were written verbatim (omitting any 'umm' 'ah' 'er' and so on). At the beginning or end of the lesson, a description of the room (layout, display material, equipment) was included. These descriptive notes were available for the teacher to see at any point. The commentary section was kept separately and was not seen by the participants.

However, this method of recording lesson observation has the potential for producing bias, and several steps were taken to ensure that the data were 'trustworthy'.

3.5.2.1 Reliability of Observation Notes

Using field notes rather than a video/tape recorder to record lesson observations meant that I would need to address the issues of reliability and validity of my note taking. Cohen at al (2001, p105) suggest that validity of qualitative data '*might be addressed through the honesty, depth, richness and scope of the data achieved, the participants approached, the extent of triangulation and the disinterestedness or objectivity of the researcher*'. The lesson observation data are written with enough detail that they present an honest and accurate account of the events during the lesson. The inclusion of dialogue between teacher and class, between teacher and pupil, and between pupil and pupil add to the depth and richness of the data. The lesson observation notes were written as a description and were non-judgemental. Furthermore, the observation data were triangulated with questionnaire data and interview data. However, it would be difficult to be completely '*disinterested and objective*' as there is a degree of interpretation and theorising involved in the commentary aspect of the data collecting. At best, I can offer that the observation notes are an honest and truthful account of events during the lesson.

To reduce 'invalidity' of my data, Cohen et al (2001, p116) recommend *'ensuring inter-rater reliability [and] ensuring standardized procedures for gathering data'*.
In order to 'standardize procedures' and check the reliability and validity of my note taking during lesson observation, a joint lesson observation exercise was undertaken with another colleague from the university. Silverman (1993, p99) describes this technique as *'investigator triangulation'*. On returning to the university, both sets of notes were read out to the members of the Hand-Held Technology Research Group. The other team members were able to comment that the notes were detailed and obviously from the same lesson. Both sets of field notes highlighted the same incidents within the lesson. This suggested that the notes were objective, and not influenced by any substantial observer bias. The research team felt confident that the field notes were an accurate record of that lesson, since there was a high degree of correlation between the two sets of notes. Any differences between the two sets of notes were considered minor – for instance, one set of notes used pupils' names, the other referred to them as pupil 1, pupil 2 and so on.
Other lesson observations were conducted along the same format with field notes written during the lesson being observed. The lesson observation notes were validated by checking with the participants. Cohen et al (2001, p189) refer to this as *'respondent validation'*. Participants were given an opportunity to agree (or not) that the notes were an accurate record of the events that took place during their lesson.

None of the participants made any changes to the content of the notes.

The lesson notes were also summarised at the end of the observation and included a record of any critical incidents or salient moment. These were '*events or occurrences that might typify or illuminate very starkly a particular feature of a teacher's behaviour or teaching style*' and were events that were '*non-routine but very revealing... offering an insight that would not be available by routine observation.*' (Cohen et al, 2001, p310) These notes were not shown to the participants, but still formed part of the data for that lesson observation.

The joint observation exercise informed the depth and detail of recording that was needed for the data to be reliable and valid. Corroboration with members of the Hand-Held Technology Research Group helped to provide the inter-rater reliability needed for the field notes.

3.5.3 The Interviews

The purpose of following up the lesson observation with an interview was two-fold. Firstly, to triangulate with the data collected from the questionnaire and the lesson observations, and secondly, to '*follow up unexpected results... and go deeper into the motivations of the participants*'. (Cohen et al, 2001, p268).

Yin (1994, p84) suggests that there are three basic interview forms, the open-ended interview, the focused interview and the survey interview, whilst Cohen et al (2001, p273) put forward four types; the structured, the unstructured, the non-directive and the focused interview. Similarly, Oppenheim (1992, p67) describes interviews as being 'exploratory' or 'standardized'. The exploratory interview is more of a free-style interview and is about researching hypotheses rather than for collecting facts. For that, Oppenheim (1992, p67) refers to the standardized interview, which has a pre-set agenda, with questions formalised before the interview. Lincoln and Guba (1985, p268) add to this notion by suggesting that the structured interview is useful when the researcher is aware of what is unknown, and can ask the right questions to fill in any gaps. Whereas the unstructured interview is useful when the researcher is unaware of what is unknown, and relies on the respondent to offer ideas.

The majority of the interviews with all participants were structured interviews. The interviews were still open-ended and assumed a conversational manner, '*but followed a certain set of questions.*' Cohen et al (2001, p273) describe this sort of focused interview as one where the researcher is able to '*use the data from the interview to substantiate or reject previously formulated hypothesis*'. Occasionally, the interviews were unstructured and open ended, and these were opportunities to '*ask key respondents for the facts of a matter as well as for the respondents' opinions about event*' (Yin, 1994, p84).

3.5.3.1 Using Field Notes to Record Interview Data

The interviews were recorded using shorthand notes, and then re-annotated to '*give some general impressions of the subjects views [by] rephrasing and condensing of statements*' (Kvale, 1996, p170). There were several reasons for using hand written field notes, rather than using a tape recorder. Early in the research I used a tape recorder to record a test interview, but I found some difficulties with this method of recording. Firstly, the quality of the recording was very poor in places and several minutes of dialogue were lost. Secondly, and the main reason for opting out of using a recording device, was that I did not intend to use a systematic method for analysing the transcribed recording. The dialogue was not intended to be analysed using any statistical methods, such as coding key phrases. This led me to question whether I would transcribe every nuance of the conversation, or should I just highlight certain elements? How would I record emphases or pauses or the general mutterings that often take place in a conversation? If I chose to discard these aspects, then what else could I safely discard from the transcription? In fact, Yin (1994, p86) asserts that on these occasion a tape recorder should not be used: '*when there is no specific plan for transcribing or systematically listening to the content of the tapes, or the investigator thinks the tape recorder is a substitute for listening closely throughout the course of the interview.*' Kvale's (1996, p166) argument that transcription of recorded material becomes selective supported my decision to use written field notes. Kvale writes that it is unrealistic to expect the data from transcripts to be anything other than data that has already been interpreted.

Another reason for not using a tape recorder was that often interviewees are reluctant to open up when being recorded. The formality of setting up an interview room with recording equipment might make the participant reluctant to take part in the research process. Whereas, an interview without a tape recorder has the feel of a conversation between two people. Also, it has been suggested that '*interviewees frequently say much more once the tape recorder has been switched off, or give an entirely different* *viewpoint when having a chat over a cup of tea in the staffroom, than when they are confronted with a microphone'.* (ResInEd, 2006).

Since the purpose of the interviews was to substantiate or refute data collected from the lesson observations, and to provide '*thick data*' (Cohen et al, 2001, p22), it was felt that field notes were an appropriate method for recording participants' responses. Hence, the interviews were recorded using field notes, in the same manner as the observations, and these field notes were used to '*reconstruct* [the] *conversations*' (Cohen et al, 2001, p311). Wragg (1978, p20) also recommends the use of selected paraphrasing. He suggests guarding against being '*overly involved in transcribing data*' that does not necessarily add a great deal to the understanding, whereas more often than not '*carefully selected quotes will do.*' (Wragg, 1978, p20)

3.5.3.2 Advantages and Disadvantages of Using Field Notes

Of course, using hand written field notes to record an interview has several disadvantages. Although, as Kvale (1996, p161) says it is possible for interviews to be recorded using a '*reflected use of the researcher's subjectivity and remembering...and writing down the main aspects of the interview after the session, assisted by notes written during the interview*', there can be problems with '*rapid forgetting of details and the influence of selective memory*' (Kvale, 1996, p161).

To overcome this, the conversation was written down, almost verbatim; the um's, ah's er's were omitted, unless it seemed important to include them. Also, interviewees often repeated the same idea or sentiment using different words and phrases, reiterating their point of view. In this case, the most naturalistic wording was used to paraphrase their ideas. Kvale (1996, p161) suggests that in this method of transcription, the interviewer's *'active listening and remembering may ideally work as a selective filter, retaining those very meanings that are essential for the topic and purpose of the study'.*

There are also issues of reliability and validity. If there is an 'error' in the field notes it cannot be checked against a tape recording. Nuances and inflections in the voice are lost in the field notes (unless it was considered important at the time and included in the notes). However, the nature of the questions in the interview and the purpose of the interview data was not for any '*sociolinguistic or psychoanalysis [purpose] so there was no need [for the data] to be in a detailed verbatim form*' (Kvale, 1996, p170). The interviewees tended to make allowances for the note taking, and accepted that there were moments when nothing needed to be said.

As with the observation notes, the field notes are offered as an honest and faithful account of the interviewees' responses.

3.5.4 The Log Books

As a member of the Hand-Held Technology Research Group, I was involved in the Calculator Development Project. This separate study was an investigation of a mathematics department that had recently purchased a class set of graphics calculators. The department had volunteered to take part in a year-long study of their endeavours to include graphics calculators into their teaching.

Three teachers were chosen from the department because they represented a range of experience and expertise within the mathematics department and also with the use of technology. Celia is an experienced teacher of mathematics, but a novice user of technology. Dan is an experienced teacher of mathematics and an experienced user of computer technology, but has limited expertise with graphics calculators. Rachel is a newly-qualified teacher, but has had extensive training on the use of graphics calculators.

Each of the three teachers in this study was asked to record their use of the graphics calculator in a log book. The log book was designed by the team of researchers, and was intended to be easy to use. The log book contained pre-printed pages for standard responses: date, class, lesson objectives, whether the graphics calculators were used by the Teacher and/or Pupils, whether the overhead View Screen was used, whether the graphics calculators were used during the starter, main or plenary part of the lesson, which calculator facility was used. There was also a blank section for any additional comments. A sample is shown in Appendix D.

The teachers were also interviewed on two occasions. The interview data were used to triangulate the data from the log books.

The data from the log books were used to validate the emergent theories from the single case study and the cross-sectional study. In line with the grounded theory model, log book entries and interview transcripts from the Calculator Development Project were compared with the data from the lesson observations, interviews and questionnaire responses.

Literature on the use of written documents within mathematics teaching is very limited. In fact, no similar work using log books to record the use of graphics calculators was found in the literature. McNeil and Chapman (2005) suggest that documents such as these log books are '*secondary data*'; these are data that we can read and which relates to some aspect of the social world such as official reports but also includes personal records such as letters, diaries and photos. They go on to say that '*research into documents has all the deductive excitement of the detective story. However, it also requires a great deal of hard work because documents can be untrustworthy*' (McNeil and Chapman, 2005 p148).

One reason for being 'untrustworthy', they say, is that these personal records are very subjective if they are unsolicited. Furthermore, '*material written in the hope or expectation it will be published is going to be different from material that is never expected to be read*' (pg 152). This may account for the limited use of log books and diaries as a data source in this field of research.

Since the three teachers in the project are volunteers, there is no reason to suspect the log book entries of being incorrect. However, it is important to recognise that although the data may not have been 'falsified', it is possible that the data are not a complete record. The three teachers were interviewed on two separate occasions. The interview responses were used to triangulate the log book entries.

3.6 Summary

From a survey of the literature there appears to be a need for research on how teachers use graphics calculators. This research study attempts to address this by investigating the teaching practices of a novice teacher as he becomes fully qualified, and comparing his teaching practices with a cross-sectional study of other teachers.

The research methodology is a combination of a longitudinal study with a cross-sectional study. This type of use of multiple methods was not found within the literature survey, and is presented as a novel methodology for exploring teachers' beliefs and attitudes.

This research study uses a grounded theory model, and the proposed model of teachers' use of graphics calculators is a result of a constant comparison data-to-data and data-to-literature.

The four research tools used within this study are used to triangulate the data and the data collection methods are put forward as being reliable and valid.

Chapter 4. The Pilot Study

4.0 Introduction

This chapter presents a case study of the three PGCE students who took part in the pilot study. They were chosen from a cohort of 21 other mathematics graduates on a teacher training course. The whole cohort completed the beliefs and attitudes questionnaire (based on Fleener, 1995), and from this three of the PGCE students were selected as candidates for the pilot study. The questionnaire responses were scrutinised to find one student that seemed to have a positive attitude towards graphics calculators, one student that seemed to have a negative attitude towards graphics calculators and one that seemed to be neutral. Once the three candidates had been selected they volunteered to be interviewed and for their lessons to be observed.

The first section of this chapter considers the questionnaire responses of the three PGCE students. The questionnaire responses given by the rest of the cohort are discussed in chapter 5.
The second section presents the data collected from the lesson observations and the interviews with the three PGCE students.

4.1 Background to the Pilot Study

This pilot study was designed to investigate whether trainee-teachers modified their behaviour to meet the ideals expected of them from their university tutors whilst on teaching practice or whether they reverted to teaching the way they were taught. Their classroom practice was observed with respect to their use of graphics calculators as part of their teaching. Table 4.1 summarises the research questions posed by the pilot study and the research method used to collect the data.

Research question	Data collection method
What are the beliefs and attitudes of PGCE students about the place of graphics calculators in mathematics teaching?	Questionnaire Interview
Do student-teachers make good use of graphics calculators whilst on placement?	Lesson observations
Which has greater influence on student-teachers' teaching practice, expectations of university or expectations of school?	Comparison of Lesson observations Interview

Table 4.1 Summary of the Research Questions

The three students completed the beliefs and attitudes questionnaire at the beginning of their PGCE course and then only the Likert statements again at the end. This formed a pre-test and post-test survey and was used to compare responses at the beginning of the study with those at the end.

The three PGCE students were observed on three occasions; twice as part of their formal teacher-training assessment and once as part of this pilot study. The lesson observations were followed up with an interview.

The design of the questionnaire and the research protocols used for the interviews and lesson observations were discussed in chapter 3.

4.2 Findings from the PGCE Questionnaire

4.2.1 Summary of Responses to the Likert Statements in the Pre-Test

Appendix E shows a summary of the pre-test and post questionnaires by the whole cohort. From that summary it can be seen that student numbered 7 (given the pseudonym Nigel) gave more negative responses than the rest of the cohort. Student numbered 13 (Polly) gave more positive responses and student numbered 12 (Nina) responded 'no opinion' to more statements than any other. These three PGCE were highlighted as having predominantly negative, positive and neutral attitudes towards graphics calculators.

Table 4.2 also shows the responses given by Nigel, Polly and Nina to the 20 Likert statements. Table 4.2 also shows the overall frequencies from the whole cohort for comparison; total frequencies of less than 22 reflect a missing response by one or more students to that statement.

	Likert-scale questions on the pre-test questionnaire	Nigel	Polly	Nina	Overall frequencies				
					SA	A	N	D	SD
1	Students should not be allowed to use a graphics calculator while taking maths tests	SA	SD	N	2	6	2	9	3
2	Graphics calculator use will cause a decline in basic arithmetic skills	SA	SD	N	1	0	5	10	6
3	Graphics calculators make mathematics fun	A	A	A	4	14	2	1	1
4	It is easier to solve maths problems using a graphics calculator	N	D	N	1	8	7	6	0
5	More interesting problems can be done when students have access to a graphics calculator	A	SA	N	6	11	2	2	1
6	Students understand maths better if they solve problems using paper and pencil methods	SA	SD	N	2	7	2	9	2
7	All students should learn to use a graphics calculator	N	SA	A	8	10	2	1	0
8	Students should not be allowed to use a graphics calculator until they have mastered the concept or procedure	SA	SD	N	1	4	4	9	4
9	Using graphics calculators means students can do harder maths	SD	D	N	1	6	6	7	3
10	Students should learn how to use a graphics calculator as part of their maths lessons	N	SA	A	8	12	1	1	0
11	Teachers should know how to use graphics calculators	D	SA	A	12	9	0	1	0
12	Graphics calculators should only be used to check work once a problem has been worked out on paper	A	D	N	0	3	3	13	3
13	Using graphics calculators makes students better mathematicians	SD	N	D	1	3	8	6	4
14	Graphics calculators are good for checking solutions	A	A	A	5	14	3	0	0
15	Using graphics calculators with young pupils makes them better at maths later on	SD	A	N	1	3	11	4	3
16	Teachers should teach students how to use graphics calculators	N	A	A	7	11	4	0	0
17	Graphics calculators are only good for doing calculations more quickly	A	SD	D	0	1	0	13	8
18	Graphics calculators can be used for investigations	N	SA	N	7	10	4	1	0
19	Graphics calculators are too complicated to be used by younger pupils	SA	D	N	1	2	4	12	3
20	Money spent on graphics calculators would be better spent on textbooks.	SA	SD	N	2	0	8	7	5

Table 4.2 Summary of the Pre-test Questionnaire Data for the Three Students.

There is no particular statement that represents a consensus view, but there are several statements that have an overwhelming majority responding at one end of the Likert scale. For instance, 16 out of the 22 respondents disagreed or strongly disagreed that graphics calculators will cause a decline in basic arithmetic. The only person to strongly agree with that statement was Nigel. Having reached the end of this research project, it might have been useful to re-word this statement to ask about whether graphics calculators might cause a decline in basic algebraic and graphing skills.

18 respondents thought all students should learn how to use a graphics calculator, and 20 thought this should take place in mathematics lessons. 21 thought that teachers should know how to use graphics calculators; the only person who disagreed with this statement was Nigel. Yet despite these responses, none of these PGCE students seems to helping their pupils learn to use graphics calculators or learning how to teach with them.

4.2.2 Summary of Questions about Previous Experience

Apart from the Likert statements the pre-test questionnaire also asked some specific questions about students' previous experience with graphics calculators

Question 21 asked the respondents to list the calculators that they owned. Table 4.3 summarises their responses.

	Type of calculator	Date of purchase
Nigel	Casio scientific	1991
Polly	Casio Scientific and Texas (TI-80) Graphics	2000; 1998
Nina	Scientific (type unspecified)	1994

Table 4.3 Summary of Responses to Question 21

It is very interesting to note, that Polly has two calculators, and that one of them is a graphics calculator. However, even more interesting is that although she has a graphics calculator her most recent purchase is a scientific calculator. Both Nigel and Nina have a scientific calculator, and that has sufficed, despite the fact that both of them are mathematics graduates. They do not appear to have needed to purchase a graphics calculator for their A-levels (Nigel is a mature student, and may not have had access to graphics calculators during his A-levels). However, all three students were undergraduates on a mathematics course prior to their PGCE course, yet two of the three have managed to complete an undergraduate level degree course without needing to purchase a graphics calculator. This may be because often graphics calculators are not allowed in examinations at university level, and may explain why Polly's newest calculator is a scientific calculator.

The following tables (Tables 4.4 to 4.7) summarise their responses to questions 22, 23, 24 and 25

22. Have you been shown how to use a graphics calculator as part of your PGCE course?	
Nigel	Yes, VERY, VERY basic (5-10 minutes long)
Polly	Yes, an introduction
Nina	Yes, an introduction

Table 4.4 Summary of responses to question 22

23. Have you observed any lessons where graphics calculators were used in a maths lesson? If yes, please give details (year group, topic, number of calculators available etc)	
Nigel	No
Polly	Yes, year 12, solving trig equations. One each, most brought their own
Nina	No

Table 4.5 Summary of responses to question 23

24. Have you used graphics calculators on your teaching practice?	
Nigel	No
Polly	No
Nina	No

Table 4.6 Summary of responses to question 24

25. How would you rate your personal use of graphics calculator for the following topics?			
0 - no confidence 1 - some knowledge 2- very confident	Nigel	Polly	Nina
Programming	0	0	0
Plotting graphs	0	2	1
Transformations of functions	0	2	1
Equation solving	0	1	0
Tables	0	2	0
Iterative methods	0	1	0
Descriptive statistics	0	1	0
Statistical tests	0	1	0
Motion detector	0	0	0

Table 4.7 Summary of responses to question 25

Tables 4.4 to 4.7 suggest that these three PGCE students have had very little exposure to the graphics calculator whilst on their PGCE course, and they are not confident users either. However, their (lack of) experience and their lack of confidence do not seem to be reflected in their beliefs and attitudes.

All three have attended the same graphics calculator workshop as part of their PGCE course, none of them had used graphics calculators on their first teaching placement, only Polly had observed a lesson where graphics calculators had been used. Nigel rates himself as having no confidence on any aspect of the graphics calculator, Nina says she has some knowledge about plotting graphs, but no confidence on any other aspect.

However, Polly rates herself positively on all but two aspects. This may stem from the fact that she is the only one of the three who owns a graphics calculator. Interestingly, both Nigel and Nina have similar previous experiences, yet their questionnaire responses are dissimilar. This seems at odds with some of the literature which suggests that teachers' prior experience shapes the way the way they teach. Nigel and Nina have similar experiences and I would have expected similar responses to the questionnaire.

4.2.3 Summary of Responses to the Likert Statements in the Post-Test

The first part of the questionnaire (only the Likert statements) was re-administered at the end of the course as a post-test. This was done to see if there had been any change in beliefs or attitudes during their training year. Table 4.8 presents a summary of responses by Nigel, Polly and Nina. Further discussion of the rest of the cohort is presented in the chapter 5. Table 4.8 also shows the frequency of responses by the whole cohort, which numbered 18 at the end of the course.

	Likert statement	Nigel	Polly	Nina	Overall frequencies				
					SA	A	N	D	SD
1	Students should not be allowed to use a graphics calculator while taking maths tests	SA	SD	N	2	5	3	6	2
2	Graphics calculator use will cause a decline in basic arithmetic skills	SA	D	N	1	1	4	9	3
3	Graphics calculators make mathematics fun	A	A	A	1	15	1	1	0
4	It is easier to solve maths problems using a graphics calculator	D	N	A	1	8	4	5	0
5	More interesting problems can be done when students have access to a graphics calculator	D	SA	A	6	10	0	2	0
6	Students understand maths better if they solve problems using paper and pencil methods	SA	SD	N	2	6	1	8	1
7	All students should learn to use a graphics calculator	D	SA	A	6	10	0	2	0
8	Students should not be allowed to use a graphics calculator until they have mastered the concept or procedure	SA	SD	D	1	3	0	11	3
9	Using graphics calculators means students can do harder maths	N	A	A	0	8	3	7	0
10	Students should learn how to use a graphics calculator as part of their maths lessons	N	SA	A	5	12	1	0	0
11	Teachers should know how to use graphics calculators	D	SA	A	10	7	0	1	0
12	Graphics calculators should only be used to check work once a problem has been worked out on paper	SA	D	D	1	1	0	15	1
13	Using graphics calculators makes students better mathematicians	SD	D	D	0	2	8	7	1
14	Graphics calculators are good for checking solutions	A	A	A	1	15	2	0	0
15	Using graphics calculators with young pupils makes them better at maths later on	SD	A	N	0	6	4	7	1
16	Teachers should teach students how to use graphics calculators	A	A	A	5	11	2	0	0
17	Graphics calculators are only good for doing calculations more quickly	A	SD	D	0	1	0	11	6
18	Graphics calculators can be used for investigations	A	A	A	3	14	1	0	0
19	Graphics calculators are too complicated to be used by younger pupils	SA	SD	N	1	0	2	11	4
20	Money spent on graphics calculators would be better spent on textbooks.	SA	SD	N	2	1	3	9	3

Table 4.8 Summary of Post-test Questionnaire Data for the Three PGCE Students

	Pre-test: Number Of responses			Post-test: Number of responses			Overall change
	positive	neutral	negative	positive	neutral	negative	
Nigel	3	5	12	4	2	14	Becomes more negative
Polly	17	1	2	18	1	1	Becomes slightly more positive
Nina	7	12	1	13	6	1	Becomes more positive, but still more neutral responses than most of the cohort

Table 4.9 Change in Responses to the Post-test Questionnaire

Table 4.9 shows the difference in responses by the three PGCE students to the Likert statements at the beginning of the course as compared to the end of the course. Overall, analysis of the whole cohort suggests that there is no statistical difference between responses to the pre-test and post-test. This is discussed in more detail in chapter 5. Nina's positive responses may be due to the influence of being part of this pilot study and the positive experience she had during a lesson in which she used graphics calculators. Her experience may have helped her to consider her beliefs and attitudes, and her predominantly neutral responses to the Likert statement changed for more positive ones. Where she had previously expressed an opinion on the pre-test those responses remained consistent.

This suggests that for these three PGCE students, where they had previously expressed a viewpoint it has remained stable during the year. For instance, Polly's responses were predominantly positive and have remained positive. Nigel gave predominantly negative responses and his post-test results suggest that his negative views have become more entrenched. Nina's positive responses have remained positive; her negative response is also consistent. However, her previously neutral responses have become more positive, although she still retains a high number of neutral responses.

Other research studies have also found that beliefs and attitudes tend to be highly stable (Cheung and Wong, 2002; Senger, 1999; Virta, 2002) and that teacher-training courses have little affect on changing those beliefs and attitudes (Ball, 1988; Goulding et al, 2003).

In between the pre-test and post-test the three PGCE students were interviewed and observed whilst teaching a lesson. The next section presents a profile of their teaching based on the data collected during the interviews and lesson observations.

4.3 Discussion of the Interview and Lesson Observation Data

The lessons delivered by each student were observed on three occasions; twice as part of their teacher-training assessment and once as part of this pilot study. They were reassured that the lesson observed for this study would not influence their assessment in any way. Detailed field notes were taken during the lesson observations and a copy given to the student. These notes were available during the interviews and verified by the student as being an accurate record of the lesson. Only the lesson that was observed for this pilot study is reported in this thesis, but additional information from the assessed lessons has been included if it provides a deeper insight.

4.3.1 A Profile of Nigel

Nigel is a mature student, having graduated with a degree in Mathematics twenty years prior to enrolling on the PGCE course and had been self-employed since leaving the sixth form. His questionnaire responses suggest a tendency to be negative towards graphics calculators and he confirmed this during the follow up interview:

SH: How often do you use graphics calculators in your teaching?

Nigel: Myself, I don't use them really. I don't see a need for them; most things are just as easy without. I use them for doing tedious calculations, but other than that I *don't use them. I try to teach pupils how to do things mentally, or show them how to do things so that they can work it out without calculators. Also, the textbook doesn't use any graphics calculators, and the examples that the pupils see don't use anything, so they think that they can do it without, so that's how I show them. I do let them use an ordinary calculator if they need to do any arithmetic.*

Nigel suggests that he 'doesn't see a need for them', he has become a successful mathematics graduate without needing to use a graphics calculator and consequently feels that all of his pupils can be successful without using them too.

Similar attitudes were reported in a paper by Quinn (1998), where Peter, a trainee says '*I don't agree with the use of calculators and computers in mathematics. The children use these items as thinking types of crutches...they become mentally lazy and no longer have to think or reason through a problem*'. It seems as if Nigel's attitude is not unusual.

Nigel's predominantly negative view of graphics calculators may stem from his lack of personal exposure and experience.

SH: *Have you ever used graphics calculators?*

Nigel: *No, not really. We didn't actually use calculators at all, I didn't have one for my 'O' level, and I used a scientific for my 'A' level, I didn't use anything really for my degree. I occasionally used my scientific if wanted to check the value of a trig function in radians, so I haven't really ever used a graphic calculator.*

His exposure to graphics calculators on his PGCE course has also been limited to one half day (out of two) at university and none at all during his first teaching placement. His entire experience of graphics calculators has consisted of working an activity on transformations of functions with his peers on the PGCE course. Interestingly, in his questionnaire he notes that he accessed only 15 minutes of this workshop. The demonstration by the lecturer lasted 15 minutes, the students then had to work together to solve problems using the graphics calculators. This may account for the discrepancy between the time allocated by the course module and the time Nigel felt was spent 'learning' how to use the technology.

He is aware that many mathematics departments have access to graphics calculators in school, although he was unsure about the facilities available at his placement. He recognises that graphics calculators are rarely used. More significantly, their use has not been modelled for him during his training.

SH: *What facilities do they have here for using graphics calculators?*

Nigel: *I don't really know. I haven't seen any of the teachers use them, and I haven't heard anyone mention them either. If they have a class set like most departments then I don't think that graphics calculators are a priority here. No-one is particularly ICT orientated here.*

Observations of Nigel during his teaching practice confirmed that he makes very little use of technology. The first observation took place in the third week of his school-based placement and was part of his formal assessment. This was a lesson with year 12 on Polynomials and The Factor Theorem. He began the lesson by stating the Factor Theorem, then demonstrating how the theorem works by writing examples on the board;

the students were asked to copy these examples into their note book. At no time during his exposition did he ask any questions, and the students did not interact with him or each other. Nigel then set an exercise of problems for the class to solve from the text book.

During the feedback he was asked why he had chosen such a (didactic) approach.

'I just did it the way that C... [the class teacher] does it; I always check with her if my plan is okay before I teach it, and she gives me pointers if she thinks I need to do things differently. She prefers that I do things like the text book, so that was my reason behind doing it this way'.

Nigel's objective for this (assessed) observation was his subject knowledge and his lesson planning and he was able to meet the course criteria for those two aspects. The lesson plan had been approved by the class teacher, and Nigel had stuck rigidly to the notes he had prepared.

As an aside, he was asked if he had considered using technology at any stage during his preparation. Again, he responded that he didn't feel that the students would have benefited from using technology.

'I suppose I could have used Omnigraph [a graphing package], but to be honest, I don't think it would have added anything more to what I'd already told them'.

The last observation was not part of the assessment process and took place in his second teaching practice. Nigel was asked to plan a lesson using graphics calculators. He decided to do to straight line graphs with year 8.

Nigel asked pupils to investigate the affect of changing m and c in $y = mx + c$. Pupils were given a worksheet and they were asked to plot two straight lines by generating a table of values and plotting the coordinates on a set of axes. They were asked to write down the y-intercept. Then he distributed the graphics calculators (one between two) and gave explicit instructions to the class on how to use the graphing facility.

Pupils were then asked to plot several other straight lines and note down the intercept.

> *SH: How did you feel that lesson went?*
>
> *Nigel: I wasn't really very happy with it at all. The pupils don't know how to use the graphics calculators, so they can't really do the maths properly. And because I don't really understand them either the whole lesson was chaos.*
>
> *SH: Did you have any help from the class teacher when you were preparing the lesson?*
>
> *Nigel: Oh, yes, she suggested the topic and we chose the questions together, but she's never used the graphics calculators with that group before either.*
>
> *SH: Did you use any ideas from your seminar on graphics calculators?*
>
> *Nigel: Not really, I get most of my ideas from the school text book or the class teacher. The stuff we do at university doesn't seem to apply in real life.*

In this last statement Nigel demonstrates that he experiences '*university and school as two distinct worlds*' (McNamara et al, 2002), and also that he feels that the world at school is the real world. Since there are no teachers using graphics calculators in his 'real' world, then expecting him to include graphics calculators into his repertoire may be unreasonable.

This excerpt also demonstrates that Nigel recognises that his pupils are not proficient users of the technology. This lack of proficiency means that the class cannot engage with the mathematics without being sidetracked by having to learn the keystrokes. Nigel also recognises that he does not have the skills to use graphics calculators either, and he feels that the mathematical objectives of the lesson were not met. Lavicza (2005) points out that *'teachers' didactical beliefs and conceptions of the subject, as well as the characteristics of their classrooms and their relations to technology, are heavily affected by teaching traditions'*. This may account for Nigel's feelings about using graphics calculators in his teaching.

Another interesting point raised by Nigel, is that he still relies on the class teacher for pedagogic support, he planned the lesson with her support. Yet she is unable to help him plan effectively for the lesson with graphics calculators. The class teacher had encouraged Nigel's didactic teaching style on previous occasions and he seemed to be comfortable with that style. Nigel finds it difficult to engage in dialogue with the pupils, and this was very evident from the A level class on Polynomials. Cooney (1999) notes that teachers often equate '*good teaching with good telling*'. It seems that Nigel is wary of asking questions in case the pupils lead the lesson in a direction for which he is not prepared. This is not unusual, as many teachers feel they need to be in control of the lesson, its pace and direction. However, this could explain his reluctance to use graphics calculators in his lessons. Using any technology can be unpredictable; pupils have a 'habit' of generating error messages, pressing the keys in the wrong order, or finding themselves in the wrong menu. If Nigel is insecure about his subject knowledge when teaching A-level mathematics, despite being a mathematics graduate, then it is understandable that he should feel insecure about using a technology with which he has little familiarity and even less confidence.

During the feedback session for the graphics calculator lesson, Nigel was asked whether the technology had helped pupils' understanding of straight line graphs.

Maybe, a little. They got the idea quicker, but I don't think they learnt anything they wouldn't have done otherwise. The calculators were useful, but not necessary.

Nigel recognises that the calculators can be used as an efficiency tool, and this is often the first step towards making effective use of technology. Tharp et al (1997) found that teachers with a rule-based teaching style found it easier to try a new teaching tool, such as the graphics calculator, than alter their view of mathematics. It may be that having taught one lesson with graphics calculators Nigel might be encouraged to use them again (although this seems unlikely in my opinion).

4.3.2 A Profile of Polly

Although Polly's route onto the PGCE course was typical of others in the cohort (A-levels, mathematics degree straight onto teacher-training) her personal experience of graphic calculators was very similar to Nigel's.

'We didn't use one at school, I had my own, but we didn't really use it at all. We weren't allowed to use it on our university course at all, so I sort of got out of the habit. And on this [PGCE] course we did a bit as a group, and during my first school visit I observed an experienced teacher using graphics calculators with an A-Level class.'

Unfortunately, Polly's observation of the class teacher using graphics calculators was a disappointing experience and only served to create a negative impression of his teaching when using graphics calculators. Despite Polly's positive responses to the questionnaire statements, her lack of exposure and personal experience as a student, followed by a 'disappointing' observation seemed to influence her choices as a trainee.

> *SH:* *Have you used graphics calculators as part of your teaching?*
>
> *Polly:* *I haven't used them at all. I must admit I was put off by Mr W's experience, I don't think I'm confident enough to use them with a class unless I know that if anything cropped up, I could deal with it.*

Polly's need to be able to 'deal with anything that cropped up' is evident from her assessed lesson observations. All of the observed lessons were planned in detail, resources were well prepared, and pupil tasks were differentiated thus enabling all pupils to take part in the lesson. Her detailed planning seems to gives her security, so that she feels she is prepared for any eventuality. For instance, her A-level lesson on Polynomials included written solutions to each of the exercise questions. This enabled her to write her own questions, because she felt confident about her subject knowledge.

During the feedback for this (assessed) lesson Polly was asked to talk about her planning and preparation for the A-level class:

SH: *I notice that you have got all of the solutions to the exercise written out in full; that must have taken you ages.*

Polly: *It did, but I needed to do all the questions to make sure there weren't any tricky bits in there. Also, I wanted to check my own understanding [of polynomials], when you do the work as a student you tend to do as you're told, but now it's me that's doing the telling, so I wanted to make sure I knew what I was talking about.*

SH: *I noticed that you used some of your own examples, why didn't you follow the text book?*

Polly: *I was going to, to start off with, then the more questions I did, the better I felt about it, more confident, then I thought, well I get this topic so I'll explain it my way.*

SH: *Did you think to use graphics calculators for this lesson?*

Polly: *Not really, I don't really know how to use them with a class. And I didn't want a repeat of what happened to Mr W, not when you were coming in to observe. I might have done if you weren't here.*

Although this was one of the assessed lessons, it is reported here as is raises some important issues. Firstly, Polly is able to stray away from the text book once she feels confident about her subject knowledge. She feels more able to field awkward questions. This seems to suggest that if she were more confident about the use of graphics calculators she might be able to use the technology to extend pupils' learning because she is not reliant on questions generated from a text book. Using existing material with graphics calculators seems to lead to the technology being used as an efficiency tool, whereas creating new tasks might help to extend pupils' learning. Grassl and Mingus (2002) point out that teachers need to address issues around technology and textbooks, and Polly appears to be making small changes already. The other issue raised here, is that Polly is more concerned about meeting the course criteria. Using technology creates another layer of complexity in teaching, and she would rather avoid that when her teaching is being assessed. Polly suggests that she would be more willing to take risks with her classes, if she were not being observed or assessed. Berliner (2001) found that *'novices appear to be afraid of losing managerial control'*. This seems to be a factor that affects all of the PGCE students in this pilot study. Polly was reluctant to demonstrate a lesson with graphics calculators, which was surprising given her positive attitude towards them.

Polly: I'd rather not [demonstrate a lesson with GCs], because I'm not sure I'd be able to do it properly. So rather than do it badly, I'd rather not do it at all.

SH: What if I helped you?

Polly: [long pause] I'd still need lots of time to practice and think about things.

Her first comment seems to stem from her observation of an experienced teacher, who in her opinion conducted a poor lesson using graphics calculators. She described his lesson as 'the blind leading the blind'.

Lastly, it seems as if one disappointing observation has affected her attitudes towards using graphics calculators. The influence of the class teacher was also noted by Halbach (2000) who wrote that *'In all cases the trainees' responses seem to indicate that their perception of the teachers' role was modified as a consequence of the teacher they were observing most directly in the context of their training'.*

In the next (non-assessed) lesson, Polly demonstrated a lesson on the area of composite shapes with year 7 pupils. Polly had prepared a sheet of shapes and pupils had to dissect each shape into a rectangle and two, congruent triangles. From this, pupils developed a method for working out the area of trapezia.

> *SH:* *Where did you get the idea for the practical activity?*
>
> *Polly:* *From Mrs S; she suggested that this group like to do this sort of work, so I had a look at her worksheet and used it to make up my own.*
>
> *SH:* *What was the pupils' learning experience from this lesson?*
>
> *Polly:* *I think they learnt that area isn't a difficult topic, that they can build up from what they already know. So even if they can't remember the formula for the area of a trapezium, they can work it out by splitting the shape into rectangles and triangles. I think that they can build up most things in maths like that, start from what you know, and build up.*

Polly demonstrated that she was willing to experiment and try out new approaches, but she was still reticent to use technology in her classroom. This seemed at odds with her experimental style. She seems prepared to use a variety of teaching strategies and is not overly reliant on text books. Yet it seems that her lack of confidence with graphics calculators hinders her use of them in her lessons. She does not seem to want to spend time familiarising herself with the technology as she does with her subject knowledge. However, she realises that the PGCE course is about fulfilling the teacher training criteria and that the course assessment is a process of 'hoop jumping' (McNamara et al 2002).

'I suppose I would manage if I had to, if you said you were coming in to assess me and it had to be a lesson with graphics calculators, I would make myself learn the bits I needed, otherwise, the most useful thing would be to team teach with someone who knows about graphics calculators.'

Polly suggests that if she needed to, she would 'rehearse' the use of graphics calculators in her teaching, but only to meet set criteria. Despite her disappointing observation of a graphics calculator lesson, Polly recognises the value of collaborative teaching. As a student-teacher she has worked closely with her subject mentors. She has shown that she is able to develop her own teaching ideas. If she were to work with a class teacher who was a confident and proficient user of graphics calculators, then Polly may make good use of graphics calculators in her teaching.

Polly was asked if she has considered using graphics calculators in her teaching:

'I'd like to use graphic calculators in my teaching, but there always seems to be something more important that I have to deal with. At the moment, I'm more concerned with completing all my Dimensions for Phase Two [ITT assessment criteria]. It's not that I don't think they're important, it's just not on the top of my priority list.'

Polly is quite concerned about qualifying and meeting the assessment criteria. She does not seem to recognise that the use of ICT (which could include graphics calculators) is stipulated as one of the 'dimensions'. Using graphics calculators in the classroom would satisfy the assessment criteria, but like most other PGCE students she opts to use the networked computer room instead. Learning to use graphics calculators is perceived to be beyond the course requirements, and so it becomes a low priority.

4.3.3 A Profile of Nina

Nina's responses to the questionnaire were predominantly 'no opinion'. This suggested that she had neither a positive nor a negative attitude towards graphics calculators. In total, she gave a neutral response to 12 statements. Interestingly, other participants responded 'no opinion' at most 6 times.

Like the other two students in this pilot study, Nina has had very limited personal experience of graphics calculators.

'We didn't use them very much at school, some of us had them for our A-Levels, but because we didn't all have one, we didn't use them in lessons. We didn't use them on the BSc at all. We've done a little bit on this [PGCE] course, just a general introduction to graphing and so on. I'm teaching myself at the moment on the school one that I've borrowed.'

This was quite interesting, as neither Nigel nor Polly seemed to spend any time at all familiarising themselves with graphics calculators. Nina was asked to expand on her last comment:

SH: *What sort of stuff are you doing with it?*

Nina: *Nothing in particular, just trying to find what each of the buttons is for. I did think about using them [graphics calculators] for trial and improvement last week, but I ended up using Excel because I needed to do that to complete Phase Two [course criteria].*

Like the other two students, Nina is process driven; she recognises the need to meet assessment criteria and her planning is influenced by them. But unlike Polly and Nigel, Nina has considered using graphics calculators in her teaching. She is already beginning to experiment with the functions of the graphics calculator, but without a specific context, her experimentation seems rather aimless.

Nina agreed to use graphics calculators for one lesson (not assessed). It was agreed that she would plan a second lesson on trial and improvement with the same year 7 group that had used Excel. Prior to demonstrating her lesson, Nina requested a short 'training session'. During that session, Nina wanted to run through the keystrokes that the pupils would need. She rehearsed the running order of her lesson, until she felt confident. She wrote herself a crib sheet, which she turned into a set of instructions. These instructions then became part of the worksheet issued to pupils in the lesson. Despite her increased confidence, Nina insisted that I take on the role of 'classroom assistant'. This was an extension to the 'participant-observer' (Cohen et al, 2001) role that was the norm for other lesson observations. Acting as a classroom assistant allowed a level of flexibility in the classroom; it would allow Nina to ask me to assist pupils who might need help with their graphics calculator.

During the feedback session we discussed an incident where a group of pupils were working on $x^2 + x - 6 = 0$:

'I was so excited; they were discussing whether they could have two solutions, whether the solutions could be negative, and so on. They were actually talking about difficult maths concepts. And when I showed them how to get the graph up, they were shouting out that the solutions were where the graph crossed the axes. They're a good group anyway, but I think they learnt so much more today.'

By using graphics calculators Nina has been able to encourage her pupils to make connections between algebraic and graphic representations. Nina teaches trial and improvement as a way of finding the roots, and demonstrates this graphically. Ordinarily year 7 pupils do not encounter quadratic functions until much later on, but in this lesson quadratics are natural extensions of the lesson.

Nina also recognised that the pupils were more animated during the lesson, and the technology acted as a motivational tool. Nina saw this as a positive affect of using graphics calculators. Nina also recognises that the graphics calculators were an efficiency tool, the pupils managed to do many more functions.

Nina was asked about the disadvantages of using the graphics calculators for the trial and improvement lesson.

At first I was annoyed that half the set [of GC] was being used by the sixth form, even though I'd booked to use them, but actually it worked out fine, they had to work together and the way they shared ideas was quite good. Their exercise books look messy; it's lots of jumbled numbers, because they haven't copied any of the tables or the graphs, just the answers.

Here Nina points out that one of the reasons that graphics calculators are under-utilised on teaching practice may be that student teachers are given lower priority when it comes to having ready access to the equipment. Although Nina had pre-booked to use the class set of graphics calculators, at the last minute she was informed that the A-level class were taking an internal test and some of the graphics calculators were being diverted for their use. Lack of ready access is often cited as a reason for not using technology (Becta, 2003; Ruthven, 1990).

Nina also suggests that using graphics calculators means that pupils do not have a record of their class work. This is quite important for student-teachers, who feel that the quality of their teaching is judged by the work that pupils produce.

Asked whether she would use graphics calculators again, Nina replies:

'Yes, I would use them [graphics calculators] again, but it took a lot of time to prepare. I spent ages making sure I knew how to use it myself. I thought about all the things that

could go wrong, it took more planning that an ordinary lesson on trial and improvement.'

Despite Nina's positive and 'exciting' experience, she still has concerns about the time it takes to plan and prepare lessons using technology, but she comments that she is willing to make that commitment. Having support (although she didn't need any) in the classroom made her feel secure. Both Nina and Polly point to the need for a more collaborative, team teaching approach in schools, especially when using graphics calculators.

4.4 Discussion

The observations and interviews with these three PGCE students raised many interesting points for discussion.

The participants in this pilot study were chosen because they represented three different viewpoints about using graphics calculators. As such I had expected very different reactions and behaviours from the PGCE students when they were asked to demonstrate a lesson that included graphics calculators. Despite Nigel's strongly negative stance towards graphics calculators he was prepared to present a lesson on straight line graphs. He did not request any support or input from me in the planning stage or the actual lesson unlike Nina, who wanted training and support before the lesson. He planned his lesson with guidance from the class teacher. Nina seemed quite anxious at first, but once she had mastered the keystrokes, she was able to plan the lesson to meet her teaching objectives. Polly, on the other hand, was reluctant to demonstrate a lesson with graphics calculators. Observations of her previous lessons suggest that she has a tendency to be a perfectionist and this might also account for her reluctance to use graphics calculators. Guskey (2002) comments that '*to try something new means to risk failure'*, It seems that Polly is not prepared to risk failure when using graphics calculators, whereas she was prepared to take the risk involved with a practical lesson. She may also have an image that being in control is part of behaving in a 'teacherly way' (McNamara et al, 2002). She also points out that using graphics calculators takes up additional preparation time. Observations of Nina support the suggestion that using technology requires time for rehearsal and practice.

Discussions with these three students highlight that the PGCE course assessment criteria is a strong motivator for the way they teach. In order to pass the course they needed to impress their subject mentor, this means that they often tried to emulate their class teachers' teaching style. Yildirim (2000) found that *'teachers tend to use technology for instruction in traditional ways rather than as a tool to solve problems or improve students' critical thinking'*. This seems to be true for teachers using graphics calculators as well. The lessons by these three PGCE students were quite teacher-centred, and led from the front of the class. They would explain the topic; demonstrate the method by doing examples on the board, followed by pupils practicing the method by using exercises from the text book. They continued to use this explanation-demonstration-practice model of teaching in all of their observed lessons. Polly's practical lesson on composite shapes followed this model, but the text book exercise was replaced by a worksheet. Nina's trial-and-improvement lesson with graphics calculator followed this model: she demonstrated the keystrokes and the practice questions were on a worksheet. Nigel's graphics calculator lesson was a slight deviation from this. His worksheet was more investigative than a series of practice questions. The biggest advantage of using this teaching model is that is keeps the teacher centre-stage and in control of the pace and direction of the lesson. Hennessy et al (2005) note that many teachers think of '*ICT as enhancing current practice, rather than transforming it*', and it would appear that they see graphics calculators in the same way.

Nigel and Nina agreed to use graphics calculators in a non-assessed lesson, but the topic was still prescribed for them by the class teacher or the scheme of work. This suggests that student-teachers are prepared to use technology so long as it fits in with the school requirements.

Attitudes towards graphics calculators are not nurtured or enhanced by the schools. These PGCE students have not been encouraged to include technology in their teaching. This may be because their class mentors are not confident teachers with graphics calculators and they would not be able to support the student-teachers with queries about pedagogy. Also, poor role models seem to discourage the use of graphics calculators by the students. Polly's experience seems to have had a negative effect on her willingness to use graphics calculators in her teaching.

The experiences of these three PGCE students have not resulted in a change in beliefs and attitudes. Nigel's negative attitude was not affected by his experience of teaching a lesson with graphics calculators. Similarly, Polly has not changed her opinions about using graphics calculators. Nina's pre-test and post-test responses indicated that her beliefs and attitudes remained the same, but where she had no opinion in the pre-test she has formed a positive opinion in the post-test. This may be as a direct consequence of having taught a lesson using graphics calculators where the pupils' responses were positive and enthusiastic.

4.5 Summary

Returning to the research questions posed at the start of this pilot study, the interview data, the lesson observations and interviews have certainly provided an insight into the way that PGCE students feel about using graphics calculators.

Passing the course seems to be the major influence on the PGCE students' classroom practice: this leads them to use the explanation-demonstration-practice model of teaching. It also leads them to follow the class teacher's advice on how to teach a topic and graphics calculators are not included in that advice.

The initial beliefs and attitudes of the three PGCE students did not seem to influence whether they were prepared to use graphics calculators in their teaching. Although the questionnaire responses pointed towards three different belief bundles, the observations did not confirm that conclusion. In fact the students with the most positive beliefs demonstrated similar behaviour regarding graphics calculators as the student with the most negative beliefs. This suggests that the beliefs and attitudes questionnaire responses do not predict their beliefs and attitudes regarding their use of graphics calculators. It is possible that the responses that the PGCE students recorded were more spontaneous and instinctive. Since they have very little personal experience on which to base their responses, it is possible that their responses to the Likert statements are not truly considered opinions. If this is the case, then it is difficult to pinpoint their beliefs about graphics calculators.

Nina and Polly both said they needed time to practice and rehearse the use of graphics calculators before they would use them with pupils. They both suggest that they would need more training in how to use and how to teach using graphics calculators. This supports findings by Taylor (2003) who found that lack of time to practice was seen as a constraining factor by novice teachers. Nigel did not seem to be too interested in developing his skills with graphics calculators, although he was prepared to use graphics calculators in his teaching.

The three student-teachers in this pilot study seemed to be more influenced by their school-based experience, which they call the real-world. All three PGCE students recognised the difference between my role as their assessor and my role as a researcher; they were more willing to experiment with the use of graphics calculators if they were not being assessed. For the assessed lesson observations they stuck closely to the teaching style of their subject mentor. These student-teachers are able to rehearse and practice methods and teaching styles that are demonstrated to them by their subject mentor. Since no-one is modelling the use of graphics calculators in a classroom environment, the student-teachers have to teach themselves. Unfortunately this is not a high priority whilst they are on teaching practice. This raises issues about the university's involvement in the school-based experience and how to ensure that student-teachers are given the opportunity to observe proficient and confident teachers using graphics calculators in the classroom. One way to meet this need may be for the university tutor to act as a mentor in a classroom environment. By working collaboratively with the classroom teacher the university mentor would be able to demonstrate good practice and encourage team-teaching and joint-planning. This would provide the PGCE students with an opportunity to observe then rehearse and practice using graphics calculators in their teaching.

Chapter 5. An Analysis of the Questionnaire Data

5.0 Introduction

The main aim of this study has been to consider the factors that influence the use of graphics calculators within mathematics classrooms. As such, the major part of the data consists of lesson observations and interviews. However, some quantitative data were collected in the form of two questionnaires, and these questionnaires are analysed and discussed in this chapter. The initial questionnaire was adapted from Fleener's 1995 work. The predominant reason for adapting the questionnaire was to try and account for some of the empirical evidence from the lesson observations of the PGCE students, which suggested that despite being introduced to graphics calculators on their PGCE course, the student-teachers were making little or no use of the technology in their teaching.

The first section gives a brief overview of the background to the design of the questionnaire, a timeline of when the questionnaire was administered, and a summary of the appended tables that show the format and wording of the Likert statements and open response questions.

The second section tests the questionnaire for internal reliability by examining the correlation matrix, and discusses the results of some statistical analysis based on the Likert statements.

The third section looks at the PGCE questionnaire responses in more detail.

The fourth section of this chapter presents a brief discussion of the questionnaire survey carried out with newly-qualified teachers.

The fifth section discusses the data collected from the Heads of Department.

5.1 Administration of the PGCE Questionnaires

Table 5.1 shows the timescale of when the questionnaires were administered. The first administration was used as a pilot but also as a pre-test. The PGCE students from Institute 1 completed the pre-test at the end of the first term and then took part in the post-test by completing only the Likert questions at the end of the third term.

	Institute 1	Institute 2	Institute 3
Year 1	Pre-test (cohort A) (n= 22) X01 to X22		
	Post-test (cohort A) (n=18)		
Year 2		Cohort B (n=7) Y01 to Y07	Cohort C (n=10) Z01 to Z10
Year 3	Cohort D (n=22) X23 to X44	Cohort E (n=7) Y08 to Y14	

Table 5.1 Timetable of when the Questionnaires were Administered.

5.1.1 Samples of the Questionnaire by the Post-Graduate Students and Head of Department

Appendices A, B, C and D show samples of completed questionnaires.

The first questionnaire (Appendix A) shows the Likert statements and has the same format as Fleener's (1995) questionnaire. This questionnaire was completed by Mark, the single case of the longitudinal study, and was the version that was used in the pilot study. The second questionnaire (Appendix B), also completed by Mark, is the amended version and shows the space allowed for participants to include comments on the Likert statements. These two questionnaires formed the pre-test and post-test for the pilot study. The samples show how the questionnaire was completed by the critical case within this study.

The third questionnaire (Appendix C) is a sample of the questionnaire given to Heads of Department. The questionnaire included in this appendix has also been completed, and shows the layout, the questions and how a respondent may have completed each section. This questionnaire was completed by the Head of Department at the school where Mark subsequently completed his probationary period as a newly qualified teacher.

These three questionnaires form part of the rich data collected about Mark's use of the graphics calculator during his PGCE year, and the influences on him during his year as a newly qualified teacher.

The names and contact details have been removed from the questionnaires in order to preserve the anonymity of the participants.

5.1.2 Summary of all the responses to the PGCE Questionnaires

Appendix E gives a summary of the pre-test and post test questionnaires and Appendix F gives a summary of all the questionnaires, including a summary of the responses to each Likert statement. The responses have been recorded with numeric values such that 1 indicates a positive attitude towards graphic calculators and 5 indicates a negative attitude.

The student code indicates the teacher training institute attended by the PGCE student; for instance X01 to X22 were the students that took part in the pilot study (Cohort A), Y01 to Y07 are the students from Institute 2 and Z01 to Z10 are students from Institute 3 and so on.

5.2 Testing the Questionnaire for Reliability

Before analysing the data for evidence of beliefs and attitudes the questionnaire was tested to check that it was a reliable tool. This was done by using software (SPSS) to produce a factor analysis correlation matrix and secondly by generating a Cronbach-Alpha value for the data. The results of the correlation matrix are given in Table 5.2 below and list all the statement pairs with strong, positive correlation.

Statement Number	Statement Number	Correlation
3	5	0.544
7	10	0.742
7	11	0.586
10	11	0.605
10	16	0.559
12	17	0.561
13	15	0.625
19	20	0.549

Table 5.2 Statement pairs with a positive correlation

There were no statement pairs with strong (<-0.5) negative correlation. Since the data were imported into SPSS using the values 1 to 5, such that a value of 1 represented a strongly positive response and a 5 represented a strongly negative response to a particular statement, it suggests that participants responded consistently throughout the questionnaire. The strongest negative correlation was of -0.396 and was between statement 2 (Graphics calculator use will cause a decline in basic arithmetic skills) and statement 4 (It is easier to solve maths problems using a graphics calculators). Again, this is not entirely unexpected, as agreeing with one statement could lead to disagreeing with the other without contradiction.

The second statistic used to measure the internal reliability of the questionnaire was a Cronbach-Alpha value of 0.811; this also implies that the questionnaire was internally consistent.

5.3 Analysis and Discussion of the PGCE Questionnaires

5.3.1 Comparing Questionnaire Responses of the Pre-test and Post-test

The data from the questionnaires completed by the students in cohort A (Institute 1) were analysed with a Wilcoxon Signed Ranks Test using SPSS, to see if there had been any changes in their beliefs about graphics calculators. These students completed the questionnaire at the beginning of their one year PGCE course, and then again at the end. Table 5.3, which shows the results of the Wilcoxon Signed Ranks Test, suggested that, overall, there is no significant statistical difference between the responses in the pre-test and post-test questionnaires.

Some difference was noted between their responses to statement 3 ('graphics calculators make maths fun'). The analysis suggests that the post-test responses were more negative. There were 3 more positive ranks, i.e. they gave a higher value response in the second questionnaire, which corresponds to a more negative response.

Similarly, there was a difference between participants' responses to statement 8 ('Students should no be allowed to use a graphics calculator until they have mastered the concept or procedure'). This time, there were three more negative ranks, which corresponds to a more positive response.

It seems reasonable to suggest, that for this cohort, there was no significant difference in questionnaire responses at the end of their PGCE course compared with the responses they gave at the beginning of the course.

Statement	Pre-test post-test		Significance test
1	Negative Ranks Positive Ranks Ties	1 0 17	0.317
2	Negative Ranks Positive Ranks Ties	3 1 14	0.317
3	Negative Ranks Positive Ranks Ties	0 3 15	0.083
4	Negative Ranks Positive Ranks Ties	2 2 14	1
5	Negative Ranks Positive Ranks Ties	2 1 15	1
6	Negative Ranks Positive Ranks Ties	0 0 18	1
7	Negative Ranks Positive Ranks Ties	0 2 15	0.157
8	Negative Ranks Positive Ranks Ties	0 3 15	0.083
9	Negative Ranks Positive Ranks Ties	4 2 12	0.234
10	Negative Ranks Positive Ranks Ties	0 2 16	0.157
11	Negative Ranks Positive Ranks Ties	0 0 18	1
12	Negative Ranks Positive Ranks Ties	3 4 11	0.527
13	Negative Ranks Positive Ranks Ties	2 5 11	0.206
14	Negative Ranks Positive Ranks Ties	1 3 14	0.317
15	Negative Ranks Positive Ranks Ties	2 4 12	0.414
16	Negative Ranks Positive Ranks Ties	2 1 15	0.564
17	Negative Ranks Positive Ranks Ties	1 0 17	0.317
18	Negative Ranks Positive Ranks Ties	2 3 13	0.655
19	Negative Ranks Positive Ranks Ties	0 3 15	0.102
20	Negative Ranks Positive Ranks Ties	2 3 13	0.655

Table 5.3 **Summary of Wilcoxon Signed Rank Test**

This lack of difference may have been because all of the students in this cohort (cohort A, Institute 1) attended the same half-day workshop on the use of graphics calculators. The workshop was a basic introduction, and guided the students on how to use the graphics calculators for teaching transformation of functions at Key Stage 4. However, the student-teachers would have had a varying degree of experience during their school placements. Some of the students did not observe any lessons where the graphics calculator was used. Other students had the opportunity to observe their subject mentor using graphics calculators, whilst some even used the graphics calculator as part of their own teaching. This is summarised in Table 5.4 which collates the responses to question 23 ('Have you observed any lessons where graphics calculators were used in a maths lesson?') and question 24 ('Have you used the graphics calculator on your teaching practice?')

Not observed, not used	Observed, but not used	Not observed, but used	Observed and used
10	8	1	3

Table 5.4 Summary of responses to questions 23 and 24

Despite the variety of experiences whilst on teaching practice, the Wilcoxon Signed Ranks Test suggests that there is no statistically significant difference in beliefs and attitudes about graphics calculators at the end of the course as compared to the beginning of their teacher training. It would appear that neither the workshop nor their school placement has had any significant impact on their thoughts about graphics calculators.

This finding is surprising and at odds with some work done by other researchers. For instance, studies by Ensor, (2001), Halbach (2000), McNamara et al (2002) all noticed that the PGCE students were influenced more by their school placement than by the work done on the college course. The trainees in these studies tended to take on the dominant culture within their school when planning lessons. Conversely, a group of geography trainees attributed their skills development to the university part of their course rather than the school placement (Taylor, 2003).

However, as far as beliefs and attitudes about graphics calculators are concerned, the PGCE students in this study do not seem to be affected by their university course or their school practice.

Obviously, these results cannot be generalised outside of this sample. However, the results do suggest that there are implications for the way the graphics calculators are introduced and used on the PGCE course. It also has implications for the school-based experience of the PGCE students from Institute 1.

Overall, the Wilcoxon Signed Ranks Test suggests that there is no significant difference between the pre-test responses as compared with the post-test responses.

5.3.2 Comparison of the three Institutes

A Kruskal-Wallis Test was carried out on the data from all three institutes. This was done to ascertain whether the stability in beliefs and attitude could be attributed to the college-based experience of the PGCE students.

The three institutes had different models for the use of graphics calculators within their training programmes:

- Students from Institute 1 had one half-day workshop on using graphics calculators. This workshop provided a basic introduction to the graphics calculator, and then focused on the graphing facility.
- Students from Institute 2 had two days on the use of graphics calculators. These PGCE students were also loaned a graphics calculator for their own personal use during the course. These students had access to a class set of graphics calculators and a view screen.
- Students from Institute 3 had the use of graphics calculators embedded into all of their modules. They used the graphics calculators for solving problems in mathematics, and they used them in their lesson planning. Students from this institute were issued with a graphics calculator for the duration of the course. They also had access to a class set of graphics calculators and a view screen that they could use.

The questionnaires from Cohort A (pre-test) and Cohorts B, C, D, E were analysed using a Kruskal-Wallis Test and the results are summarised in Table 5.5. The Kruskal-

Wallis Test showed that, overall, there was no statistically significant difference (at the 5% level) between the questionnaire responses from the five different cohorts.

Statement	Significance
1	0.139
2	0.495
3	0.937
4	0.361
5	0.867
6	0.426
7	0.028 *
8	0.405
9	0.130
10	0.043 *
11	0.666
12	0.488
13	0.907
14	0.183
15	0.528
16	0.175
17	0.958
18	0.301
19	0.847
20	0.956

Table 5.5 Comparison of Institutes using Kruskal-Wallis Test

A significant difference is noted for statement 7 ('All students should learn to use a graphics calculator') and statement 10 ('students should learn how to use a graphics calculator as part of their maths lessons'). The responses to these two statements are analysed by inspection. Tables 5.6 and 5.7 (taken from Appendix F) show how participants responded to these two statements on the questionnaire:

All students should learn to use a graphics calculator

Qn7	1(SA)	2	3	4	5(SD)
inst1	41%	39%	11%	7%	0%
inst2	36%	14%	21%	21%	7%
inst3	10%	30%	40%	20%	0%

Table 5.6 Responses to Question 7

The PGCE students from institute 1 gave a predominantly positive response to this statement. The students from institute 2 gave a mixed response, with some responses in each category. The participants from institute 3 seemed to have a neutral position as to whether all students should learn to use the graphics calculator.

Students should learn how to use a graphics calculator as part of their maths lessons

Qn10	1(SA)	2	3	4	5(SD)
inst1	34%	55%	7%	5%	0%
inst2	36%	43%	14%	7%	0%
inst3	10%	40%	30%	20%	0%

Table 5.7 Responses to question 10

This statement is very similar to statement 7, but places the use of graphics calculators within the context of the mathematics lesson.

The students from institute 1 gave a predominantly positive response (89% strongly agreed or agreed) and only 5% disagreed.

The students from Institute 2 seemed to give a more positive response to statement 10 compared to their responses to statement 7 (79% agreed or strongly agreed and 7%

disagreed). The responses of PGCE students from Institute 3 were similarly more positive to this statement (50% of the participants agreed or strongly agreed, 30% had no opinion and 20% disagreed). This suggests that the participants gave a much more positive response to this statement. This may be as a result of the nature of the PGCE course at Institute 3, where the graphics calculator is embedded into the teaching programme.

Interestingly, none of the respondents strongly disagreed with statement 10.

Overall, the PGCE students from Institute 3 gave a more negative response to both of these statements as compared to Institute 1 and 2.

Overall, the Kruskal-Wallis Test suggests that there is no statistically significant difference in the beliefs and attitudes of the respondents from the three different institutes. This is a surprising result, as the students had quite different experiences in the college based activities. Students from Institute 1 were not discouraged from using graphics calculators and would have been given support if they had asked for help and guidance. Students from Institute 2 would have been encouraged to use graphics calculators, and students from Institute 3 were expected to use graphics calculators. However, the school-based experience would have been very similar for all of the PGCE students. All three institutes use the same geographic area (Devon and Cornwall), and rotate their placements within the same schools.

So, an analysis of the questionnaire seems to suggest that the college based activities have little or no affect on the beliefs and attitudes of the student-teachers.

Again, this result is surprising. A study by Lin (in press) showed that if the use of the internet is integrated into a teacher education programme the trainees feel more confident about using the internet as a teaching and learning resource. The student-teachers in that study were less anxious about using computers in their mathematics lessons. Lin goes on to recommend that ICT should be integrated into to the university course. Yet this has been the case for PGCE students from institute 3, where the use of graphics calculators is embedded into the college based course.

The pre-test and post-test analysis of the students from institute 1 showed no significant difference over a period of time. This suggests that the beliefs and attitudes remained static during their training year. Again, this is surprising, as some change would have been expected, but other studies have shown that the teacher training programme has little influence on trainees (Ball, 1996; Chuene et al, 1999; Flores, 2001) and that trainees' *'attitudes are considered to be relatively stable'* (Hannula, 2002), and their *'beliefs are usually rigid and highly resistant to change'* (Cheung and Wong, 2002).

The Kruskal-Wallis test suggests that there is no statistically significant difference between the three institutes, despite the difference in the college-based experience of the students.

5.3.3 Implications of the Questionnaire Responses

The results from the Wilcoxon test and the Kruskal-Wallis test seem to suggest that, in general, the beliefs and attitudes of these students were formed before they commenced their teacher training course and have remained static over the training year.

There is no statistical difference between the pre-test and post test for cohort A, implying that the PGCE course has had little effect on their beliefs and attitudes. Also, there is no statistical difference between the three institutions, suggesting that the course content has no effect either.

However, it is possible that their questionnaire responses are spontaneous rather than the result of some deeply held view. Although their questionnaire responses may not be indicative of any belief system that they can articulate, the PGCE students seem to be responding consistently to some sort of prior experience, and these opinions have remained stable during their training year.

This supports Virta's (2002) assertion that '*prior beliefs or implicit theories may be positive or negative, but they are generally stable*'. Although the student-teachers in Virta's study are history graduates, it is noted that they arrive at their teacher-training with pre-formed beliefs. Similarly, Ball (1988) points out that a lack of consideration of what teachers bring with them when they learn to teach mathematics may account for why '*teacher education is such a weak intervention*'.

If student-teachers arrive at teacher training college with pre-formed beliefs and these beliefs are static, then one way to account to the lack of significant difference between institutes could be that these participants have all had very similar experiences as school and university students. Daskalogianni and Simpson (2001) describe this as a '*beliefs overhang*'. This is the continuation of views about mathematics carried forward from school to university. The same mechanism may account for the continuation of views about graphics calculators being carried forward from school and/or university into teacher-training.

5.3.4 Discussion of the Open-Response Questions

This section considers the responses given to the open-questions at the end of the questionnaire. As there is no significant difference between the three institutes in their responses to the Likert statements, the responses to the open-questions are presented as a single group and no distinction is made between the different institutes.

Table 5.8 shows that the majority of the students on the PGCE course have their own graphics calculators.

Qn 21 I own ...	Notes: this question was included in the pilot study so all 68 participants responded to this section. If participants owned more that one type of calculator, the most sophisticated type was recorded.	
A 4 function calculator	1	This was a student from institute 1. He recorded having no experience and no confidence in GC use. But gave predominantly positive responses to the Likert statements.
A scientific calculator	21	
A graphics calculator	46	
A CAS calculator	0	
I do not own any calculators	1	This was a student from the same cohort as above. He left this section unanswered, so it is possible he does own a calculator of some sort. Later in the questionnaire he rates his confidence on the use of graphics calculator as 'having some knowledge' in all areas other than programming.

Table 5.8 Responses to question 21

All of these students are graduates in mathematics or a related discipline such as engineering. As such, their undergraduate courses will have involved mathematical problems in algebra and calculus, and that will invariably have required the use of a calculator. Bearing this in mind, the number of students that do <u>not</u> have a graphics calculator of their own is quite surprising. The fact that all of these students can complete a course in a mathematical discipline at undergraduate level with only a scientific calculator seems to suggest that the content of those degree courses has changed very little in recent years. In a study into the use of computer-based CAS by university lecturers, Lavicza (2005) found that there was a perception that pure mathematicians were less likely to use CAS in their teaching than applied mathematicians. Lavicza (2005) also showed that there was a reluctance to use CAS because of '*drawbacks of technology use in education*'. Some lecturers felt there was a decline in standards in the level of new entrants, others were concerned that the technology was not suitable for some types of mathematics courses. Another reason given by one of the lecturers was that he felt that '*the technology is neither cheap nor good enough and may also change, the whole format may change*'. (Lavicza, 2005). Lavicza goes on to comment that these university lecturers are involved in mathematical research, which requires rigorous mathematical reasoning which does not rely on the use of technology. Furthermore, these lecturers are still teaching in a predominantly 'traditional teaching' mode.

If these university lecturers are reluctant to use CAS, then it may be that they are equally reluctant to include graphics calculators in their teaching. The responses from these PGCE students seem to suggest that they have little or no experience of using CAS as part of their undergraduate course. They seem to have similar experience with the use of graphics calculators, with only four PGCE students using them during their university course. They seem to have had more experience of using graphics calculators at A-level. This seems to suggest that schools have taken steps to include the use of graphics calculators, whereas there is a paucity of graphics calculator usage at university. This may be, in part, due to differences in the nature of the mathematics curriculum at the two levels. School mathematics may lend itself better to the use of graphics calculators, whilst the style of lecturing and the content of undergraduate courses remain quite traditional. This finding supports work done by Goulding (2003) in which 173 mathematics PGCE students were asked to describe their undergraduate experiences. Interestingly, none of them mentioned ICT or graphics calculators. It seems that the use of technology did not have a high enough profile to be listed when they considered their undergraduate experience. The PGCE students in Goulding's study said that they felt that their school experience left them unprepared for the level of difficulty of undergraduate mathematics, in particular the rigour of proof, and that this was made more difficult by the lecturers' teaching style.

The undergraduate mathematical courses do not appear to have taken into account the fact that graphics calculators have become readily available. Certainly, there appears to be no use of CAS type calculators by any of these students, although there is plenty of research to suggest that CAS software is used with computers in schools and at university (Forster, 2006; Grassl and Mingus, 2002; Kendal et al, 2005; Meagher, 2001; Monaghan, 1997).

If PGCE course providers require prospective teachers to use graphics calculators they will need to take into account the prior experience of the students.

Table 5.9 shows that 11 PGCE students preferred to use their scientific calculator, despite the fact that 10 of them owned a graphics calculator. This seems to suggest that these students lack confidence in using their graphics calculator, or that they are unaware of the functionality of the graphics calculator.

Qn 21(b) If you have more than one type of calculator, which one do you use most?	Notes: This question was not in the original questionnaire and was added as a result of the pilot study. This question was only answered by 39 participants (cohorts C, D, E)	
4 function calculator	0	
Scientific calculator	11	10 of these students owned a graphics calculator, yet prefer to use their scientific. The other one also owned a 4 function calculator and used their scientific calculator in preference
Graphics calculator	10	
CAS calculator		No one recorded that they owned a CAS calculator
None	2	This includes the student who did not respond to the question above. The other student responded that they don't use a calculator although they own a scientific.
No preference stated (either because they only have one type or they left the question unanswered)	16	

Table 5.9 Responses to question 21(b)

Of the participants that responded that they owned both a scientific and a graphics calculator and preferred to use their scientific only four gave a reason. Two said that the scientific calculator was "easier to use", one responded that they "don't need to" and the other responded "functions are clearer". These comments suggest that these students prefer to use their scientific calculator as they are familiar with the functions and key strokes. The suggestion that "they don't need to" use a graphics calculator supports the idea, that until this point, their mathematical experience has relied on problem-solving in a traditional style. Similarly, one of the students in Walen et al (2003) comments '*I never needed a calculator and my students won't either. If you give them a calculator, they will just punch buttons and won't learn the math*'.

These results resonate with a study by Graham et al (2003) into the use of graphics calculators by sixth form students. In that study, it was found that the A-level students, who were taking a mock statistics examination, readily took two calculators to lessons. Yet they often preferred to use their scientific calculator even though they had access to their graphics calculator. The only time these A-level students made use of their graphics calculator was if the question specifically requested a graph as a solution. In interview, these students implied that they would only use the graphics calculator for things that the scientific calculator could not do, such as graphing. Their reason for this preference was that they were familiar with their scientific calculator. Similarly, Rodd and Monaghan (2002) found that some of the students in their study '*took up to three calculators into their examinations intending to use the GC for graphs only*'.

It would appear that the 10 PGCE students in my study also demonstrate a preference for their scientific calculator, and it may be that their preference is based on similar feelings of familiarity for their scientific calculator.

Qn 22 **Give a description of your experience of using a graphics calculator, as a school pupil, university student, and trainee**	Notes: This question was not in the original questionnaire and was added as a result of the pilot study. This question was only answered by 39 participants (cohorts C, D, E)	
	Responses summarised from Cohorts C,D,E (n=39)	From the pilot study (Cohorts A, B)
Used at school/university as a student	15 at school/ 4 at university	This question was not asked in the pilot study
Used on PGCE course as a student	17	27
Observed on teaching practice	1	11
Used on teaching practice as a trainee	2	7
Limited or No experience	6	0

Table 5.10 Responses to question 22

Table 5.10 adds to the discussion above, that the PGCE students in this study made little or no use of graphics calculators as undergraduates. Having used graphics calculators for A-level study, only four of the students then used graphics calculators again for undergraduate study. This goes some way to explaining their lack of confidence and experience of using graphics calculators, and why these PGCE students have a preference for using their scientific calculators. Similar results were found by O'Reilly (2006). He notes that his *'audit indicated that 14 out of 18 students had used graphics calculators before, but most rated their knowledge at the lower end of the spectrum [not at all or a little]'*. Overall, PGCE students have very little experience of using graphics calculators; they also have very little experience of observing their teachers or mentors using graphics calculators. *'Participants in this study attributed a great deal of importance to the apprenticeship of observation which has a powerful effect on the formation of beliefs and ideas related to teaching'* (Flores, 2001). This lack of 'apprenticeship of observation' goes a long way to explaining the beliefs and attitudes of these PGCE students.

Qn 23 **What are your thoughts and feelings about using graphics calculators in maths lessons?**	Notes: This question was not in the original questionnaire and was added as a result of the pilot study. This question was only answered by 39 participants (cohorts C, D, E). The following themes emerged from the responses. Samples of typical responses are given alongside.	
Useful/helpful	12	"useful for individual use" "helpful in investigations" "useful aid to understanding"
Appropriate	9	"use where appropriate" "need to be used appropriately" "as a tool if used appropriately"
Checking	4	"good for checking" "checking"
Motivational	3	"useful for motivation" "motivational"
Good	2	"good for starters" "very good"
Prefer to use PC	5	"I'd rather use Omnigraph" "slow/limited compared to spreadsheets" "okay, but PC better"
No opinion	4	"not a lot" "no worries" and 2 blank responses

Table 5.11 Responses to question 23

Table 5.11 shows that responses are generally positive and the PGCE students seem to recognise the main advantages of using graphics calculators. Their comments all relate to the graphics calculator as a teaching tool, rather than as a learning tool and only one person mentioned that graphics calculators could be used in investigations. Five students stated that they preferred to use computers, however, their preference is a positive choice because they believe that computers are "better" rather than because they have negative feeling about the graphics calculators. Rodd and Monaghan (2002) reported similar findings. They found several instances '*where teachers felt they ought not to use GC*'. The reasons were usually because they felt they ought to use computers due to school pressures, or because they want to use computer packages not available on graphics calculators.

5.4 Analysis and Discussion of Newly-Qualified and Experienced Teachers' Questionnaire Data

As part of the cross-sectional study three newly-qualified teachers and three experienced teachers volunteered to be interviewed and observed whilst teaching. They also responded to the same beliefs and attitudes questionnaire that was completed by the PGCE students. Although the sample size of NQTs (n=3) and experienced teachers (n=3) is too small for any statistical method of analysis their questionnaire responses are presented in Table 5.12 so that the set of data for this group of teachers is consistent with the data collected from the PGCE students.

	NQT1	NQT2	NQT3	ET1	ET2	ET3
qn1	3	2	3	1	2	4
qn2	2	1	2	2	2	4
qn3	1	3	1	1	2	3
qn4	2	3	2	2	2	3
qn5	2	3	2	1	2	4
qn6	3	3	4	2	4	4
qn7	1	4	1	1	2	2
qn8	2	2	3	1	4	4
qn9	2	3	3	1	3	3
qn10	2	3	1	1	3	2
qn11	2	2	1	1	1	2
qn12	3	3	2	1	2	4
qn13	2	3	3	3	4	3
qn14	2	2	2	1	2	2
qn15	3	4	3	2	3	4
qn16	2	2	2	2	3	4
qn17	2	2	2	1	2	2
qn18	2	2	2	1	2	2
qn19	2	2	2	1	2	4
qn20	2	3	4	2	4	5
qn21	2	3	2	3	2	3

Table 5.12 Summary of Questionnaire Responses by the NQTs and Experienced Teachers

Overall, the responses given by this group of teachers do not add any new insight into teachers' beliefs and attitudes about using graphics calculators. The data from the questionnaire did support some of the earlier findings that teachers' beliefs and attitudes towards graphics calculators are generally positive. The few negative responses were given by the more experienced teachers.

5.5 Summary of Heads of Department Questionnaire

This questionnaire was designed to give a context to the observation and interview responses from the PGCE students. The purpose of this questionnaire was to find out what systems were in place that may support or hinder the inclusion of graphics calculators by the PGCE students. This questionnaire was distributed at a county-wide Inset day, attended by all mathematics teachers within the area. Only heads of department were approached to complete the questionnaire. The return rate was high (15/ 18) and gives a good indication of the views of the heads of department within the schools that the PGCE students and NQTs are based.

Appendix C shows a HoD questionnaire that has been completed and Appendix G shows an overview of all the responses to the HoD Questionnaires.
This section summarises and discusses the key points raised by the responses given by the HoDs.

5.5.1 Training on the use of Graphics Calculators

The HoD questionnaire asked HoDs to describe the type and quality of ICT and graphics calculator training that has been provided for their department over the previous two years. Their responses suggest that the quality and quantity of training in ICT may be described as limited, at best. The length of inset training varies from 1.5 hours on a specific piece of software, to 25 hours of training time funded by the South West Initiative for Training (SWIFT), with most training sessions lasting about 1 day. All of the training sessions are recorded as having taken place in-school. Only three of the HoD suggested that the departmental training had 'some impact' in the classroom, the others reported 'limited impact'. Four HoDs reported no ICT training at all over the two previous years.

The case of training on the use of graphics calculators is equally limited. The length of sessions varies between an hour in school to a one-day training session held at the local university. One HoD reported their inset had had 'some impact' in the classroom, one reported 'no impact' and the remainder suggested that there had been 'limited impact'. Five HoDs reported that there had been no training on the use of the graphics calculators over the previous two years. A recent study of Flemish teachers by Tondeur et al (2007) found that '*only half of the teachers have followed at least one ICT training course during the last 5 years. Moreover, for the majority of the teachers, ICT training has only contributed 'to a lesser extent' to ICT integration in the classroom*'. It would appear that lack of training and limited impact is not restricted to schools in Britain.

5.5.2 Departmental Policy on Graphics Calculators

The HoDs were asked to describe their departmental policy on the use of graphics calculators: six responded that they had no policy on graphics calculators at all, and three said although there was no formal policy they did encourage their department to use graphics calculators. Three HoDs had a policy that recommended the use of graphics calculators with top sets and older pupils only. Two HoDs had included specific topics where graphics calculators could be used within their scheme of work. These suggestions for use included Ma1 tasks, lesson starters, and the real time motion graphing.

The HoDs were asked to describe any systems within the school and/or department that encouraged the use of graphics calculators. Nine responded that there was nothing that encouraged the use of graphics calculators within their department. Four said that their scheme of work and the availability of resources encouraged department members. Two of the HoDs said the department responded to outside influences, such as the A level syllabus and the National Numeracy Strategy.

As for factors that discouraged the use of graphics calculators, eight HoDs said there was nothing that inhibited them. Three suggested lack of time to update schemes of work, and lack of time for sharing ideas hindered the use of graphics calculators within their department. Two departments said they had difficulties accessing equipment, and another one reported lack of money to buy equipment. One HoD said the SATs hindered the department's use of graphics calculators, but didn't add any further comment to qualify that response.

These findings are consistent with work done by several other studies. Rodd and Monaghan (2002) report similar results. Teachers in their research were pressured by a lack of time for planning and training. They were also influenced by the curriculum and examinations. These findings are not restricted to Britain as Olson's findings show. He reports that *'current [Japanese] textbooks did not support this change, and calculators were forbidden in examinations. Needless to say, the teachers were reluctant to use calculators.'* (Olson, 2000). Similarly, teachers in Malaysia are heavily influenced by their curriculum (Sam and Kee, 2004).

5.5.3 Heads of Department's Descriptions of their Feelings about Graphics Calculators

The last question on the questionnaire was an open question about their feelings about graphics calculators. The answers were varied and very interesting. One of the HoDs commented:

> *I love graphics calculators and think they are a wonderful tool in the classroom, but the kids need to own their own so that they are familiar with [how] it work[s]* (HoD1)

This HoD has invested in a class set of laptops, despite the fact that he says that it was *'economically unviable'* to purchase a class set of graphics calculators. He also feels pupils should have their own graphics calculator to be able to use it efficiently in class, yet he has not extended the same reasoning to the use of laptops. The response by HoD1 is very similar to *'Many teachers suggested that for successful implementation each student must have his or her own calculator for use on homework as well as in the classroom.'* (Simonsen and Dick, 1997). This might suggest that teachers recognise that the graphics calculator is a personal technology, but it might also imply that they want to use it in a way that is equivalent to a text book.

Another HoD writes:

> *'I wish I had a team of people who were confident using them with a class so I had to order more of them!'* (HoD 4)

This HoD seems to be implying that he has not bought more graphics calculators because his staff is not confident at using them, yet without the equipment they have little opportunity to experiment and build up their confidence. Also, as head of department he could encourage use of graphics calculators by putting forward a positive policy, which was lacking at the time of completing the questionnaire.

One HoD makes a connection between graphics calculator use and the examination requirements:

> *As we move to more computers and as graphics calculators are not allowed at A-level I feel that their use will decrease as time goes on.'* (HoD5)

This department head seems to be heavily influenced by the external examination system. They had actively discouraged their A level students from purchasing their own graphics calculators since they could not be used in the exams at that time. Whereas most schools report using graphics calculators weekly/every lesson with their A level groups, this HoD says they use graphics calculators 'rarely' with all age groups. The report by Becta (2003) recognises that this attitude is not uncommon. With younger pupils, teachers are using graphics calculators with non-examination classes *'findings indicate that ICT activity reaches a peak in KS3 and falls away as GCSE examinations approach in KS4. It suggests that tried and trusted methods of preparing for examinations are favoured currently'* (Becta, 2003). The HoD questionnaire shows that the majority of graphics calculator work is done with the A-level students, and this is supported by work done by Rodd and Monaghan (2002) who found that '*GC were used most often in A-Level classes*'.

Graphics calculators are sometimes seen to have a detrimental affect on classroom management and this issue is raised by one of the HoDs:

> *Best with small, responsible groups* (HoD8)

This is a surprising comment from an experienced teacher, especially a head of department. This HoD seems to find it difficult to recommend the use of graphics calculators to the teachers of large classes (usually top sets), or for use with pupils with behavioural problems. This means that use of graphics calculators is restricted to a specific group, perhaps only the year 12 and 13 students. Abboud-Blanchard and Lagrange (2006) found that often teachers tended to use graphics calculators with older pupils for functions and statistics, whilst restricting the use of graphics calculators with younger pupils because they felt that they should be learning by-hand methods. The recommendation to use graphics calculators with 'responsible' groups may be a consequence of mistreatment of equipment by poorly behaved pupils.

Alongside concerns about classroom management issues about security and time are also raised.

Wish I had time to develop some lessons. Concerned about security. Cannot see any urgent need to use them above computers. (HoD9)

Although this department has a class set of graphics calculators and a view screen, this HoD says that they 'never' use them. She also says that she knows that she '*need[s] to use them but emphasis has been elsewhere in recent years*'.

Generally, the HoD questionnaire gives some insight into why so few teachers are using graphics calculators in their classroom. There seems to be little support in the form of adequate training (Mitchelmore and Cavanagh, 2000), ready access to equipment and resources (Ruthven, 1990), not enough time to share ideas (Demetriadis et al, 2003). The biggest hindrance seems to be that HoDs have not included the use of graphics calculators in their departmental policies or prescribed where they could be used within the schemes of work (Crisan et al, 2007; Donnelly, 2000). This comes in part because they are involved in other aspects of their jobs, and also because they have not received any training either. In short, even the heads of department are not confident users of graphics calculators and are not in a position to guide others in the department.

5.6 Summary of Questionnaire Responses

- The Wilcoxon Signed Ranks Test shows that there is no statistically significant difference between the pre-test and post-test questionnaire responses. This suggests that there is no change in beliefs and attitudes of these PGCE students during their PGCE course. This also suggests that the course has had little or no affect on their beliefs and attitudes.

- The Kruskal-Wallis test shows there is no significant difference between the questionnaire responses from the three different institutes. This suggests that there is no difference in beliefs and attitudes in the PGCE students, despite the fact that they have attended different teacher training courses. This seems to suggest that the course content has had no influence on their beliefs during the course.
- The questionnaire responses from the newly-qualified teachers and experienced teachers are comparable to the responses by the PGCE students. This seems to suggest that teachers' beliefs and attitudes towards graphics calculators are fairly static.
- The responses to the HoD questionnaire provide some insight as to why classroom teachers are making little or no use of graphics calculators. These HoDs suggest that there is very little quality training in the use of graphics calculators and that many departments do not have ready access to equipment. They also recognise that they have not integrated graphics calculators into their schemes of work, and this is attributed to lack of time.

Chapter 6. Analysis of Lesson Observations and Interview Data

6.0 Introduction

In response to the questionnaire several PGCE students and experienced teachers volunteered to be observed and interviewed for this research project. The PGCE participants were chosen because they represented a positive, negative or neutral attitude towards graphics calculators. Several experienced teachers, including the two Heads of Department, volunteered. Participants were chosen because they were subject mentors for PGCE students, although the teachers chosen were not involved in mentoring the PGCE students in this study. By observing the work of subject mentors I hoped to gain a deeper insight into the learning experience of the PGCE students. Both HoDs were chosen so that the influence of departmental structures and systems could be considered, but also to conjecture where Mark's journey may lead him. Only three NQTs volunteered, and all three were chosen for this research.

This chapter discusses the findings from the observations and considers the insights gained from the interviews.

6.1 The Lesson Observations

PGCE students	Newly-Qualified	Qualified/Experienced	Heads of Department
Nigel (Pilot study)	Kelly	Carol	Pauline
Nina (pilot study)	Martin	Sarah	Wendy
Polly (pilot study)	Alan	Mike	
Mark	Mark		

Table 6.1 List of participants

Table 6.1 shows the teachers involved in the lesson observations and interviews during this research study. The names of all the participants have been changed to preserve anonymity. The lesson observations were conducted over a period of three years. Initial lesson observations were of PGCE student-teachers whilst on their teaching practice. I was the visiting tutor for these students and those observations formed part of their formal assessment. Later, as the ideas for the pilot study developed, Mark and three other students on the same course were asked if they would take part in the research project. The lessons that were observed for this research study took place after, and were separate from, any formal assessment. This was done so that the student teachers did not feel the pressure of success or failure, and would be more likely to present a natural teaching style.

The lesson observations and interviews with the three PGCE students were discussed in more detail in the Pilot Study.

During Mark's first year of teaching as a Newly Qualified Teacher, I observed his lessons on two occasions. Both of these lessons were observed in the second term at his request. This was to give him time to settle into his new job. The data from these lesson observations were compared with data collected from lesson observation from three other NQTs. The three NQTs chosen for this part of the cross-sectional study were volunteers who had been PGCE students from Institute 2 and 3.

Mark was also observed for the final time as a fully qualified teacher. This lesson observation took place during the first half-term of the school year. This reflects his own confidence in his teaching. Also during that year, three other qualified teachers, were observed. To see where Mark's journey may take him in the future, I also observed two heads of department.

There were also several observations of qualified teachers. These formed part of the mentor-liaison programme on behalf of the teacher-training institute. No formal lesson observation notes were taken during these lessons, although I did record any critical incidents or pertinent comments. As these notes were not verified by the class teachers, they are only used to add to the data from the research observation notes. The lesson observations that are included are ones where the class teacher was fully aware that the observation was for the purpose of this research. These lesson observation notes were verified by the teacher as an accurate record of events in the lesson.

So, only the lessons which are discussed in detail are those where the participants were aware that the observation notes formed part of this research project. However, if previous observations or comments are able to account for 'behaviour', or strike a resonance with the literature, then that information is included.

6.1.1 Overview of the Lesson Observations

Table 6.2 gives an overview of the lessons that were observed as part of this research project.

O'Reilly's (2006) observations of graphics calculator lessons by the mathematics PGCE students have many similarities to the data in Table 6.2. His data also show that graphics calculators are used predominantly for teaching algebraic topics (eleven out of twenty) with straight line graphs accounting for seven of those lessons. Only one out of the twenty lessons was for number work, two were on shape and space, and six on data handling. The lessons in my data show that graphics calculators were used in six out of fifteen lessons; for four of those lessons graphics calculators were requested. All six lessons using graphics calculators were on algebraic topics, three on straight line graphs. Another comparison between the lessons observed by O'Reilly and those observed for my research is the spread of year groups using graphics calculators.

Participant	Year group	Topic	Use of GC/ICT	Additional comments
Mark (PGCE)	Yr 8	St. line graphs	Class set of GC used	Requested to use GC on a topic of his choice
Nigel (PGCE)	Yr 8	Investigate m and c in y=mx+c	Class set of GC used	Requested to use GC on a topic of his choice. Data were reported in the pilot study
Polly (PGCE)	Yr 7	Area of composite shapes	No GC/ICT used. Used practical activity	Data were reported in the pilot study
Nina (PGCE)	Yr 7	Trial and improvement	Class set of GC used	Requested to use GC on a topic of her choice. Data were reported in the pilot study
Mark (NQT)	Yr 11	Circle theorems	No GC/ICT used	
Mark (NQT)	Yr 8	Reflection symmetry	No GC/ICT used	
Kelly (NQT)	Yr 8	St. line graphs	Laptops	Requested GC
Martin (NQT)	Yr 8	Tower of Hanoi puzzle	No GC/ICT used	
Alan (NQT)	Yr 8	Algebraic substitution	Class set of GC	
Mark (QET)	Yr 7	Bar charts	No GC/ICT used	
Carol (QET)	Yr 9	St. line graphs	No GC/ICT used	Requested to observe st. line graphs
Sarah (QET)	Yr 8	St. line graphs	No GC/ICT used	Requested to observe st. line graphs
Mike (QET)	Yr 11	Transformation of functions	Class set of GC	
Pauline (HoD)	Yr 11	Statistics coursework	Interactive whiteboard	
Wendy (HoD)	Yr 9	Graph plotting	No GC/ICT used	Requested a graphing topic

Table 6.2 Overview of Lesson Observations

O'Reilly's data show that 16 of the lessons using graphics calculators were with year 8 and year 9 pupils. The spread of year groups observed is consistent, with most lesson observations of year 8 pupils. Although all of the participants in O'Reilly's study are PGCE students, they have taught the full age and ability range. However, the graphics calculators are used predominantly with top sets in the lower year groups. This trend was also evident from the lesson observations with the PGCE students in my study. This may be because PGCE students feel that classroom and behaviour management is less of an issue with brighter pupils.

6.2 Emergent Themes

Re-reading the lesson observations and highlighting the main elements of interview responses gave rise to the following common themes:

- Choice of topic when using graphics calculators

  It seems that these teachers tend to choose graphing topics, such as straight lines, when asked to use graphics calculators. However, if teachers are asked to teach a graphing topic, they do not necessarily use graphics calculators.

- Effectiveness of the use of graphics calculators

  These teachers tend to use graphics calculators more as an efficiency tool, rather than as a mind tool. For instance, graphics calculators are used to check work instead of developing mathematical understanding.

- Teaching style

  Even when teachers use graphics calculators they do not do anything differently. These teachers tend to teach in a traditional style using a cycle of exposition, example and rehearsal. The graphics calculator is subsumed into this style with the teacher asking the same type of questions and tasks as if the graphics calculators were not present.

- Teaching materials

  These teachers tend to rely heavily on the text book when technology is not being used. When graphics calculators are used in the classroom they tend to produce their own worksheets.

- Teaching key strokes instead of mathematics

  When using graphics calculators, time may need to be spent in reminding pupils about the keystrokes.

On further inspection of the data, it seemed that the trends above could be categorised into two themes. These themes are identified below and then discussed in detail in the following sub sections:

- Time
- Training

6.2.1 Time

6.2.1.1 Planning and Preparation

The PGCE students appeared to have spent more time in the planning and preparation stages when using graphics calculators in their lesson. Their lesson plans were more detailed. For instance, both Nigel (PGCE) and Nina (PGCE) had included written 'solutions' to each mathematical question they planned to set the class, and included notes on the key strokes. This is at odds with earlier lesson plans for those same groups, where less detail was given. The lesson plans highlighted page references for exercises, rather than actual questions. No 'worked solutions' are included within the lesson plan or lesson notes. The level of detail included in the observed lessons for this study, is usually reserved for more difficult topics, such as those encountered at A-level. For instance, Polly (PGCE) wrote notes for an A-level class on Polynomials which contained detailed worked solutions to every problem set in the text book. She later included questions of her own because she felt more confident about the topic. This use of detailed notes and crib sheets acts as a prop for the student-teachers. The notes seem to give them confidence and serve as a prompt sheet. As these three students are still at an early stage of their training, the need and use of crib sheets is not surprising. However, these same crib sheets appeared in all the lessons where graphics calculators were used. It was surprising to see similar lesson notes being used by Mike (QET). He is a qualified and experienced teacher and has been teaching mathematics for nearly twenty years. His crib notes included a list of functions and important key strokes.

As well as taking up extra time in planning for a lesson with graphics calculators, additional time is required for the preparation of resources.
Nigel's (PGCE) lesson on straight line graphs included a worksheet that pupils completed. This was unlike the way he usually conducts his lessons. He relies heavily on the set text book. He also used an investigative approach, asking pupils to experiment with changing the values of m and c in $y = mx + c$. This was a change from his usual (didactic) teaching style. Nigel had clearly spent additional time in preparing this worksheet. However, this is not unusual for this group of PGCE students, who often produced elaborate resources as they began to experiment with new ways to deliver curriculum topics. For instance, Polly (PGCE) created a work sheet of composite shapes. These shapes were cut out and re-arranged, to demonstrate the area of a

trapezium. Nina (PGCE) gave her pupils a worksheet with quadratic functions and blank tables that they needed to complete.

However, the preparation of additional material was also evident from the lessons with the NQTs. Kelly (NQT) produced detailed worksheets that were pre-cut into strips; each strip contained the equation of a straight line, and then these strips were collated and put into individual envelopes. The pupils then used the strips of paper to make up 'families' of straight lines. Alan's (NQT) lesson on algebraic substitution included a worksheet with blank tables that pupils needed to complete. This was essentially a pre-prepared worksheet from an Inset course, although he had deleted sections he did not want to use. Only the two very experienced teachers Mike and Pauline, both with approximately twenty years experience, did not use any additional resources other than a textbook.

The observation that teachers tend to produce their own resources when using graphics calculators has also been noted by Monaghan (2004). Teachers in his study tended to use '*safe textbook tasks*' when teaching non-technology lessons. However, they felt that they couldn't use those textbooks in technology lessons, for these lessons the teachers produced their own worksheets which the pupils used instead of the textbook.

It seems that planning to use graphics calculators requires more planning and preparation of resources prior to the lesson. Crisan et al (2007) suggest that teachers *'believed they would be more likely to make regular use of ICT in their lessons if there was a pool of ICT-based mathematics ready-to-use resources, easily and readily accessible to them and clearly mapped to the mathematics objectives of the scheme of* *work'*. (Crisan et al, 2007). It may be that ready-to-use resources might also encourage teachers to use graphics calculators in their teaching.

6.2.1.2 Teaching Keystrokes

Another 'time' factor in lessons is the time taken to teach/remind pupils of the keystrokes they need to perform during the lesson.

This was noticeable in every graphics calculator lesson. The teacher, whether they were a student-teacher or more experienced, spent time going over the keystrokes and functions that pupils would need to complete the lesson task. Often, the pupils had error messages or the incorrect screen display. The teacher then had to spend time correcting these problems with individual pupils. Even using the calculator projection screen did not alleviate all the pupils' initial problems. Getting the pupils' graphics calculators set up correctly could easily take up five minutes at the beginning of the lesson. However, once the graphics calculators were ready to use, pupils rarely had any further problems with them during the lesson, and they did not need their teacher's help with using the technology. At this point, the focus of the lesson shifts from learning to use the graphics calculator to learning the mathematical content of the lesson. Similar findings are reported by Sam and Kee (2004) '*limited time to work with graphical calculators proved to be a major constraint. ...inevitably, we had to spend time repeating sequences of keystrokes and pointing out where certain calculator functions are located. ... we must also take into account the time spent in setting up the technical equipment.*'

6.2.1.3 Classroom Management

One further aspect of 'time' that was noticeable within the lessons was the amount of time taken up by classroom management when the graphic calculators and laptops were used. Considerable care was taken over the distribution of the equipment at the beginning of the lesson. The graphics calculators were counted out, pupils were reminded about treating the equipment with care. They were also reminded that the graphics calculators '*were not a toy, anyone misbehaving will have theirs taken away, and they'll have to do the work without*' (Nigel, year 8 group). This sentiment was repeated in every graphics calculator lesson, except Mike's (QET). This may be because he is more experienced and confident about his classroom management. It may because he was teaching older pupils, and they were aware of the behaviour requirements.
The lesson needs to finish a little earlier than timetabled if graphics calculators are used, this is to allow time for them to be collected back in and counted. This counting in/counting out of the graphics calculators would often take up 5 minutes of the teaching time.

What was noticeable from the lessons where graphics calculators (or laptops) were used was that the actual teaching time that was available in the lesson was not always fully utilised. For instance, Mike (QET) used the graphics calculators to generate many examples of the same type of transformation. Even after the pupils had understood the concept, he continued to ask the pupils to generate further examples, which they were then asked to copy into their exercise book. Similarly, Alan (NQT) asked pupils to do "more of the same" when they had finished the set task. So, although the graphics calculator is used for speeding up calculations or graph plotting, the additional time is not used to extend pupils' learning but to reinforce the same concept. This means that the efficiency that has been "gained" by using the graphics calculators is lost by the repetitive nature of follow-up work. Instead of moving pupils onto "extension" work they are asked to do "extra" work.

Totalling up the time taken with management issues, such as distributing the graphics calculators, counting them at the beginning and again at the end of lesson, and the time spent on describing the keystrokes accounted for nearly 15 minutes of the lesson. With mathematics lessons generally lasting an hour, this is a large proportion of the teaching time.

Several of these themes are highlighted by other research studies:

The PGCE students in O'Reilly's (2006) study commented that they lacked familiarity with the graphics calculators and that they didn't have enough time to plan and prepare for lessons using the technology. They also mentioned having to teach keystrokes to pupils and how this contributed to the pressure of completing work in time. The geography trainees in Taylor's (2003) study also report that they found lack of time to practice their ICT skills as a constraining factor in their teaching practice. Although the lack of time to plan and prepare lessons using graphics calculators was most often reported by student teachers, experienced teachers report similar difficulties when using ICT as part of their mathematics lessons; '*lessons were planned in detail and this took a lot of time, especially early ICT-based lessons*' (Monaghan, 2004). These time pressures are also reported by Rodd and Monaghan (2002) who discuss this as being one of the major 'bogs' that slow down teachers' progress as they try to include ICT into their practice.

It would appear that using graphics calculators requires more time for planning.

- Detailed lesson notes are needed to act as props for the teacher's confidence.
- More time is spent preparing additional resources for the pupils, particularly by the student-teachers.

Using graphics calculators requires more time for classroom management.

- Time is taken up at the beginning and end of the lesson for distribution of the graphics calculators.

Using graphics calculators takes up teaching time.

- Time is re-directed from learning mathematics to learning to use the graphics calculator.

6.2.2 Training

One aspect within the theme of 'time' not discussed above is 'training'. This factor is important enough to be considered separately. From the questionnaire responses, the PGCE students have little experience in the use of graphics calculators. There appears to be sporadic use at A-level, almost no use at undergraduate level and varying use on their PGCE course. Only 6 (out of 39) PGCE students say they have no experience of using graphics calculators. The majority of their training has been during their PGCE course. The PGCE students attended a workshop where transformation of functions, including straight lines, had been demonstrated. The workshop has had significant influence on these students, as evidenced by the fact that using the graphing function to investigate straight-line graphs features heavily in the lessons observed.

There seems to be a tendency to use graphics calculators for their graphing facilities. This is probably because transformation of straight lines is the one aspect of teaching with graphics calculator for which they have received training. Even the laptop lesson by Kelly (NQT) was an investigation into straight lines.

There appears to be a strong suggestion that using graphics calculators leads teachers to teach graphing topics, whereas the converse is not so evident. Teachers asked to teach a graphing topic do not always use graphics calculators.

It seems that these trainees and teachers are able to "repeat" what they have seen on Inset course and PGCE workshops. This, according to Wiske et al (2001), is part of a development process that involves '*watching experts, practicing with advice from coaches, participating in critique, and sharing polished work.*'

The most striking lesson using graphics calculators was Mike's (QET) lesson with his year 11 class. He was using a class set of graphics calculators to teach transformations of functions. In the previous lesson they group had investigated *f(x) – a* and *f(x-a)*. At the start of the lesson, there was a discussion of the affects of *f(x-a) – k*. The pupils responded positively to the task with minimal input on how to use the graphics calculator. These pupils had remembered the keystrokes from the previous lesson and were able to engage with the mathematics.

In the next part of the lesson the pupils were guided to use the graphics calculator to draw the graphs of $y = x$, $y = 2x$, $y = \frac{1}{2}x$. Pupils were asked to make a conjecture about how changing the value of a in $y = ax$ would change the graph. Almost all of the pupils reasoned that changing the value of a caused a rotation, but one pupil suggested it had changed the gradient.

Mike: No, no... what's happened to the graph, in terms of geometry?

P1: Translated?

P2: Reflection, maybe?

P3: It's rotating.

P1: we said rotation already, just the gradient has changed.

At this point I felt that Mike become 'visibly agitated' and decided to tell the pupils that the function had been stretched. He then went to on to tell them that a gave the scale factor of the stretch. Whilst the pupils worked on an exercise from their textbook, Mike asked how he could have made that task more suitable. We discussed the use of *sinx*. Mike decided to take up this suggestion and asked pupils to look at the graphs of *sinx* and *2sinx*. Several pupils called out that their calculator 'wasn't working'; it turned out that the axes were still set for the straight lines, and not for trigonometric functions. Once that was clarified, using the teacher calculator and projection screen, the pupils were able to proceed. They went on to examine other trigonometric functions and satisfy themselves about the relationship between *f(x)* and *af(x).*

Again, whilst the pupils were on task, Mike discussed his use of the graphics calculator.

> *Mike: they can see the stretch factor quite easily using trig functions. But I didn't think to use them, they're not on their syllabus.*
>
> *SH: I see what you mean. Have you done this topic before using graphics calculators?*
>
> *Mike: No, not like this. I've only ever used graphics calculators for investigating straight lines. It saves them having to plot lots of graphs.*
>
> *SH: so this is a bit of a diversion for you?*
>
> *Mike: yeah, but it didn't really work, did it? [laughs]. I should have stuck to what I know.*
>
> *SH: where do you usually get your teaching ideas from?*
>
> *Mike: All sorts of places, books, magazines, courses. But I do use the text book quite a lot. It's geared up for the SATs and GCSEs so you know that they're getting exposure to the things they'll be tested on. I don't do anything revolutionary these days, I've been teaching for twenty years. But the graphics calculators, and computers, I have to rely on Inset for my ideas, but as you can see, I need to spend more time getting to know how these calculators can be used in lessons.*
>
> *SH: Oh, I don't know. They knew what was expected of them, and they seem to be enjoying the lesson.*

Mike: They're a really good group. But I'd have liked some Inset on how to use these calculators, make best use of them. Maybe even try out the lesson a few times before you do it with a group. Trouble is, this isn't a priority and there's not enough time to do everything.

This incident highlights many of the trends listed above, in particular the need for training and time to follow up new ideas with an opportunity to practice and rehearse lessons. If Mike had had the opportunity to discuss his lesson plan during a training session, he may have realised that using a straight line function would not demonstrate the property he wanted the pupils to notice. Discussion and experimentation with other teachers may have helped him to find functions that were on the year 11 syllabus which he would have felt more comfortable using, rather than the spur-of-the-moment suggestion of using $sinx$.

Mike comments that he usually only uses the graphics calculators for straight line graphs. This seems to be sufficiently common to suggest that all of these teachers have attended workshops or training days with similar content. However, Mike is prepared to experiment with his use of graphics calculators in the classroom. The lesson would have been more successful if he had had the opportunity to consider the mathematical concepts alongside the use of the graphics calculator. He seemed to have spent his time considering the use of the graphics calculator and not given enough time to how the technology would support pupils' learning. He is obviously confident in his mathematics as he didn't write a lesson plan, but his crib sheet for the graphics calculator keystrokes suggests that he lacks confidence in his ability to use the technology. This confidence comes with practice and experience, both of which take time. Yet Mike comments he does not have enough time to familiarise himself with all that the graphics calculator can do. He says he would like more training, and an opportunity to rehearse lessons before using them with pupils.

Mike's lesson highlights the need for teachers to be able to familiarise themselves with the graphics calculator by repeating what they have seen. It also shows that any training or Inset course needs to address more than just technical instructions on how to use the graphics calculator. Teachers need to have the opportunity to consider issues of pedagogy, and how the graphics calculator can be used effectively as a learning tool. Hennessy et al (2005) point out that '*teachers cautiously adapt the use of ICT to the traditional teacher-centred mode of teaching, which is strongly connected to the established examination system*', and it seems as if this teaching episode demonstrates Mike's cautious use of graphics calculators and how he attempts to 'fit' them into his teaching style. What seems particularly interesting about Mike's lesson is the way that he is '*simply using technology to do what [he] has always done*' (Hennessy et al 2005). Humphreys and Hyland (2002) present the analogy of teaching as jazz improvisation. They suggest that performance in teaching should not be defined in '*technicist or instrumental*' terms but rather as '*artistry*'. They go on to say that the everyday experience of teachers is to improvise and respond to unexpected events, such as lateness of pupils, strange and awkward questions and failed experiments. '*The best teachers are not only well prepared but also practiced and skilful improvisers*' (Humphreys and Hyland, 2002). Mike is an experienced and skilful teacher, yet his lack of skill at improvisation when using graphics calculators slows down the progress of his lesson. According to Berliner's (1988) definitions Mike's teaching could be considered as being somewhere between '*Proficient: guided by intuition and know-how...holistic* *recognition of similarities among contexts'* and *'Expert: intuitive grasp of situations...performance is fluid and seemingly effortless'*. Berliner adds that not all teachers reach Expert level. However, when using graphics calculators Mike's teaching falters and he shows elements of being an *'advanced beginner'*. Observations of Mike's lesson suggest that using graphics calculators is akin to risking failure (Guskey, 2002).

This theme of familiarising oneself was also evident in Nina's (PGCE) lesson on trial-and-improvement. Her lesson on trial and improvement was a follow-up lesson where she had used a spreadsheet on the computer. However, she felt that she needed 'training' on how to use the table function on the graphics calculators. This training took the form of a short demonstration during the feedback session, to the previous lesson observation. She followed this up by additional preparation time, which took place during the week before the lesson was delivered. Once she had mastered the keystrokes for herself, she rehearsed the lesson until she felt comfortable with the sequence of events. She then used this to produce her lesson plan. Leat and Higgins (2002) describe this process as *'tinkering'*, and involves an element of experimentation as teachers begin to improve their teaching repertoire.

Although, this was not formal training, she was involved in her own professional development. There was a large element of time, which she describes as being *'over and above what I would normally do for a lesson without technology'*.

Asked whether she would need to spend the same amount of time preparing for a lesson on straight line graphs, she replied *'Not really, as we were shown how to do that on the [PGCE] course.'*

'Doing what they have been shown' comes across in the other graphics calculator lessons. Nigel (PGCE) was asked to present a lesson using graphics calculator and he chose to investigate changing *m* and *c* in $y = mx + c$. He said his reason for doing straight line graphs was because the class teacher had suggested it. He seemed to lack the confidence to plan for this lesson alone and was guided by his subject mentor.

Mark's (PGCE) lesson using graphics calculators for straight lines was also prompted by the one-day workshop that all the PGCE students had attended. However, there was also an element of personal development in his lesson plan. He used the standard lesson with pupils investigating the affect of changing the values of *m* and *c*. But he used a combination of paper-and-pen tasks followed by a graphics calculator task. Pupils were asked to complete a table of coordinates and then plot the graph of a straight line by hand. Then, they were given two coordinates, asked to plot them, join them with a straight line and determine the equation. The pupils also did this by hand. One pupil struggled to do the second task, as his graph was not very accurate. He read off new coordinates from his graph to help him find the equation, but the inaccurate graph made this difficult.
It was at this point that Mark distributed the graphics calculators. He spent a little time explaining the keystrokes that the pupils needed. Then Mark asked them to use the graphics calculators to check their work.

Once Mark was satisfied that they were using the graphics calculators correctly, he set the group an activity that extended the task on straight line graphs. He asked them to *"draw a graph that is steeper than $y = 2x$, make the graph go through $y = 1$ [sic]. Then draw a graph that goes through $y = 2$, and is parallel to the first graph."*

Mark had taken ideas from the PGCE course on teaching straight line graphs ('doing what he was shown'), but he had also added to the basic task by using material from other sources. The graphics calculator task was based on an activity he had seen his subject mentor do on his first school placement.

Mark's inexperience at time management and lesson planning meant that the class did not have enough time to do the main part of the lesson. However, there was a suggestion that the task would have been appropriately challenging for the pupils. They would have extended their understanding of straight line graphs (McCormick and Scrimshaw, 2001). Mark's lesson plan hinted that he was trying to make connections between the graphical and the algebraic links for straight line graphs. He was beginning to explore how the graphics calculator could be used as a learning tool.

Alan (NQT) also used an activity he was shown on an Inset course. He used the graphics calculator to store values and substitute them into algebraic expressions. He had a pre-prepared worksheet that he had been given at the Inset course by the course leader. The pupils used this worksheet to record in a table, the value of $a^2 + 2b$, given different values for a and b. The second part of his lesson involved the reverse of this task; pupils were given values for a and b, and asked to generate expressions to give values from 1 to 20. He had seen this second activity presented as a lesson starter on his PGCE course, but he had adapted the same task to include the use of the graphics calculators.

Alan, like the others participants who used graphics calculators, was able to repeat activities that he had seen before. Again, this demonstrates that Inset courses can have a direct impact on what teachers do in the classroom. But teachers' lessons are often restricted to only doing what they have been shown. The teachers and students in this study tended to rehearse and repeat the same activity several times before beginning to make small adaptations. So, when the PGCE students and newly-qualified teachers opted or were requested to use graphics calculators they tended to choose to teach a topic that they had seen before. This seems to suggest that if they had had other topics using graphics calculators demonstrated to them on their PGCE course, or during an Inset course, then they would be more likely to use them in their own teaching.

Three participants were requested for a lesson using graphics calculators, and all three taught a variation on straight line graphs. One of the three decided to do straight line graphs using a class set of laptops.

Three teachers were asked to teach a graphing topic; none of these three opted to use graphics calculators or any other technology. They all chose to use pen-and-paper methods.

Only one person (Alan, NQT) used graphics calculators without being asked for them specifically. Also, he used the graphics calculators for an algebraic activity, rather than straight line graphs.

Where neither a topic nor the use of graphics calculators was specified, lessons covered a variety of topic areas: data handling, area of composite shapes, reflection symmetry, and an investigation.

Only Pauline's (HoD) lesson on statistics coursework used technology. Although, she used the interactive whiteboard it was only as a method of projecting work instead of writing on a conventional classroom whiteboard. None of the other lessons included graphics calculators or other technology.

The lesson observations suggest that these teachers are able to repeat what they have been shown, either on their PGCE course, on Inset courses or by another colleague. Nina (PGCE) and Mike (QET) both suggest that they would like to be able to rehearse their lessons before presenting them to a class of pupils. This suggests that these teachers need time and support from the school to be able to rehearse lessons. These teachers also say that they need training to make effective use of graphics calculators. This means including pedagogy on PGCE courses and Inset courses, as well as training on the technical aspects of using graphics calculators.

When these PGCE students and teachers used graphics calculators they tended to use the technology to make their lessons more efficient. This was usually to save time with graph plotting, or to gain instant feedback and check work. Nina (PGCE, lesson on quadratics) and Mark (PGCE, lesson on straight lines) were beginning to use the graphics calculator as a tool for pupils' learning. Pupils were beginning to extend their understanding, and make connections between the graphical and algebraic representations.

6.3 The Interviews

The interviews took place immediately after the lesson if it was possible. Generally there was a break for lunch or a non-teaching period after the lesson observation and the teachers were keen to take the earliest opportunity to discuss their lesson. If an interview could not take place after the lesson, then an appointment was made for the first available opportunity. Only on one occasion did it prove difficult to organise an interview, and that was to follow up Mike's lesson. However, it had already been agreed that scheduling an interview would be difficult, so we allocated time during the lesson to raise important issues.

The interviews were semi-structured and open. There were certain questions that were asked of each participant, but the tone of the interview was conversational and did not adhere to a rigid format. Occasionally the response given by a participant would lead to an alternative line of questioning which had not been included in the interview schedule.

The teachers and PGCE students were able to see the notes that I had written during the lesson observation. The PGCE students were given a copy to keep for their professional portfolio. Every interview began with an opening comment thanking the teacher for letting me observe their lesson, which I had enjoyed. I also thanked them in advance for their time that was allocated for the interview. The interviews lasted between 30 minutes to an hour in a couple of cases.

6.3.1 The Interviews with the PGCE Students

The first set of interviews was conducted with the group of PGCE students from Cohort A. This group included the three students in the Pilot study and also included Mark. Table 6.3 shows a brief summary of the responses by the PGCE students to the interview questions about the questionnaire.

Question	Nina	Polly	Nigel	Mark
Previous experience	None as a student; limited on PGCE	None as a student; Limited on PGCE	None as a student; Limited on PGCE	None as a student,
Number/ type of calculators owned	1 scientific, Graphics borrowed from school	1 scientific 1 graphics	1 scientific	1 scientific 1 graphics
Preference	Scientific	Graphics for graphing and functions Scientific for calculations	No calculators	Scientific for most things. Graphics for graph plotting
Reason	Never needed to use GC Familiarity with functions	Scientific for ease of use. Graphic for visual	Maths can be done without calculators	I'm familiar with scientific, but it doesn't plot graphs
Used/ observed GCs on TP	Not used Not observed	Not used Observed 1 lesson on trig functions	Not used, Not observed	Not used, Not observed.
GC facilities in current placement school	teacher calc and view screen 2 Class sets,	Teacher calc and screen no class set of GCs.	Unsure	Class set of graphics and projection screen
Advantages	Less expensive than computers. More accessible,	Visual, Efficient Motivational	Motivational, Can be used in normal classroom	Motivational Quick to plot graphs
Disadvantages	Too complicated, Intimidating for some pupils	Need to monitor each pupil. Pupils might mess about	More expensive than scientific, Time consuming to master	Might cause pupils to misbehave. Takes time in lesson

Table 6.3 PGCE Students' Responses to Interview Questions about the Questionnaire.

The purpose of this interview was to corroborate the responses given in the questionnaire and also to expand on questions 21, 22, 23, 24. These were the questions about their prior experience of using graphics calculators, whether they had used and/or observed a lesson with graphics calculators.

From these interviews it became clear that these PGCE students had very limited experience of using graphics calculators. The interview responses supported the findings from the questionnaire. As a result of these responses, the questionnaire was adapted to include a question about their choice of calculator, if they had more than one type.

Three of the four PGCE students said they owned both a scientific calculator and a graphics calculator. Nigel said he owned only a scientific.

They were then asked which type of calculator they preferred to use and why.

> *Nina*: *I prefer my scientific because I don't feel I've ever needed the graphics. I'm familiar with all the standard functions, so I don't need the graphics to sketch anything really.*

This was in contrast to a later comment were she says;

> *Nina: I'm teaching myself at the moment on the school one [graphics calculator] that I've borrowed.*
>
> *SH: what sort of stuff are you doing with it?*
>
> *Nina: Nothing in particular, just trying to find out what each of the buttons is for. I did think about using them [graphics calculators] for trial and improvement last week, but I ended up using Excel because I needed to do that to complete Phase Two [course criteria]*

In the pilot study I discussed how Nina is process driven, that, like the other students she will do what ever she needs to do to complete the course requirements. But she also shows that she thinks of her use of the graphics calculator for solving mathematical problems as being different from her using the graphics calculator as a teaching tool. This is comparable to students in the study by Walen et al (2003). They comment that *'it is therefore possible for our pre-service teachers to hold seemingly contrasting views that it is acceptable for them to use a calculator to do an arithmetic problem (since their task is not to learn, but to do), but it is not acceptable for their students (since their students' task is not to do, but to learn).'*

Nina doesn't need to use a graphics calculator herself because she can do mathematics without it, yet she is willing to spend time and effort teaching herself so that she can use the graphics calculator with her pupils. Nina's comments suggest that some teachers see the graphics calculator as a tool for helping pupils become good mathematicians, but once you have reached a certain level of competence (say, an undergraduate) then you no longer need to use a graphics calculator.

Similarly, Nigel says:

'I don't see a need for them [graphics calculators]; most things are just as easy without. I use them [calculators] for tedious calculations, but other than that I don't use them.'

Nigel seems to suggest that 'real' mathematicians do not need calculators. When asked whether he prefers to use scientific or graphics calculators he replies:

'I prefer not to use a calculator, if you really understand, then the maths can be done without calculators.'

Polly's preference for her scientific is because of its '*ease of use'*; she only opts to use her graphics calculator for graphing functions. Similarly, Mark says he uses his scientific because he is more familiar with it, and the graphics calculator for plotting graphs. When asked to explain what he means by 'familiar', Mark says he has had his scientific calculators for years, and he knows '*where all the buttons are and which order to press them in, but with the graphics calculator I have to look to find the keys, then the keystrokes are in a different order, I have to <u>think</u> about it, but with my scientific I can do it without thinking about it.'*

This seems to be a 'catch 22' situation. These PGCE students prefer to use their scientific calculators because they are familiar with them, yet they will not become as familiar with their graphics calculators unless they let go of their scientific.

They have all become familiar with their scientific calculator over a long period of time, and it may be that it will take these PGCE students a long period of time to become equally familiar with their graphics calculator.

All three of the PGCE students were asked if they had observed any of their subject mentors demonstrate the use of the graphics calculator with a class of pupils. Only Polly had observed an A-level lesson using graphics calculators. Unfortunately, this turned out to be a disappointing experience for her.

'They were doing trig equations, and the idea was to use the [graphics] calculator to show them the function so they could see how many solutions they should have...but it

wasn't really helpful, because the teacher didn't really know much about the calculators; it was a bit like the blind-leading-the-blind in a way. The teacher was really good, because he knew his stuff and the students respected him, but with the calculators the students knew as much as he did, and if they got stuck he couldn't help them and they felt a bit disappointed in him, which was a shame.' (Polly, PGCE)

Her observation of an experienced mentor, seemingly at a loss, has a negative influence on her. This is compounded by her lack of experience of using the graphics calculator as an undergraduate and only 'limited' training on the PGCE course. It is somewhat understandable that she is hesitant to use graphics calculators in her own teaching practice.

However, what this incident also highlights is the lack of training for the subject mentors in using and demonstrating the use of graphics calculators to their PGCE students. In order to encourage future teachers to use graphics calculators with their pupils, they need to be exposed to positive role models and positive experiences.

The PGCE students were also asked what they consider to be the advantages of graphics calculators. Their responses recognised the practical aspects; *'less expensive than computers, more accessible, can be used in the classroom'*. They also thought that graphics calculators were *'efficient, quick to plot graphs, visual'*. Three of the four students recognised that the graphics calculator can be *'motivational'*, yet the irony remains that very few of them are using graphics calculators within the classroom. It appears that the disadvantages, as they see them, outweigh the advantages; *'too complicated for school pupils, intimidating, time consuming to master'*. They also felt that graphics calculators may cause behaviour problems; *'pupils might mess about like they do with computers, might cause pupils to misbehave.'*

Mark's comments on this aspect are very interesting: he describes the advantages of graphics calculators as being *'motivational'* and *'quick for graph plotting'*. Yet the disadvantages are that the graphics calculators *'might cause pupils to misbehave'* and that they *'take [up] time in lessons'*. These responses seem to contradict each other. On the one had he feels that graphics calculators are motivational, yet they might encourage bad behaviour. This conflict could explain the generally positive attitude he has towards calculators, whilst insecurity about his own classroom management prevents him from making use of them with pupils. At the same time, he recognises that used properly graphics calculators can save time in lessons, yet his lack of expertise makes him feel that the time it takes to teach pupils to use graphics calculators makes them inefficient. Often teachers stress that they have *'fears for their own survival regarding control and discipline* (Leat and Higgins, 2002). Graphics calculators add another variable to the uncertainty that Mark feels about his classroom management at this stage of his teaching.

6.3.1.1 PGCE Interviews Following on from the Lesson Observations

The next set of interviews with the PGCE students took place towards the end of their second school placement and immediately after their lesson observation.

The PGCE students were asked where they usually get their teaching ideas from. Both Polly and Nigel said that the idea came from the class teacher. Nina's lesson was planned in collaboration during the feedback session to the previous (assessed) lesson observation, and Mark's lesson idea came from the PGCE course and from another teacher's lesson. None of these PGCE students presented an 'original' lesson plan. However, Mark's lesson was an adaptation of ideas he had gathered from other sources. He combined pen-and-paper task, which the pupils had started the previous lesson, with two graphics calculator activities; checking and extending.

SH: where did you get the idea for this lesson?

Mark: straight from the calculator workshop we had, and then the last bit, I saw a teacher do this with year 9. It was the only thing I could think of to do with graphics calculators that would be okay with year 8's.

I used the straight line graphs activity from the workshop, but instead of getting them to sketch lots of graphs I got them to check the ones they had plotted last lesson. Then I used a task I'd seen Mr R do with the calculators. But I think it was too hard for them. I should have adapted the activity to suit their ability. I think the one I did was for older pupils, getting them to work out an equation, that was too hard for them.

He seemed disappointed with the outcome of the lesson, saying '*It could have been better*', yet the pupils were all on task, and although they did run out of time, the extension task did not seem to be beyond their ability. The task was challenging and, if they had not run out of time, would have extended their understanding of straight line graphs. Without Mark being aware of it, the graphics calculator was beginning to be used as a pedagogic tool.

Mark realised he needs more time to plan his lessons, and he also comments that it would have been useful to observe someone else first.

Again, this incident supports the notion that the graphics calculator training on the PGCE course needs to address pedagogy as well as technical aspects. The PGCE students also need positive role models whilst on school placement. Most importantly, they then need opportunities to rehearse and repeat what they observe. Being able to rehearse and repeat activities seems to be important for these teachers in building their confidence.

Question	Kelly (NQT1)	Martin (NQT2)	Alan (NQT3)	Mark (after yr 11 lesson)	Mark (after yr 8 lesson)
How did you feel that lesson went?	Quite pleased. They seemed to get the hang of the work quite quickly and they enjoyed it.	It was okay. Not as exciting as last time.	Quite pleased. The class worked hard and managed to do a lot.	Not particularly well, not as good as usual. They were restless today	I struggle with the group. They're very noisy and badly behaved.
Where do you get your teaching ideas from?	Mostly what we did last year [on PGCE]. This lesson was from an inset course.	This one is from the scheme of work. I usually use the text book for ideas, talk to other colleagues.	I got the idea from an inset course, they showed us a few little lessons you can do with the GC.	Talking to the head of dept and other teachers. Some ideas off the pgce course. But mostly textbooks.	
Why did you choose that topic to demonstrate?	You asked for graphics calculators, which we don't have. Used the laptops instead, and this is one of my favourite activities with the laptops. Use it all the time.	It was next on the scheme of work for this group. I like doing this activity, it's practical and an investigation.	I already had the worksheet from the course, so the lesson didn't need much planning.	They've got a module test to do soon and it's a topic we needed to cover before then.	I thought if they were doing something fun they'd behave, but they were just as bad as ever. Couldn't really do the practical task with them, ended up doing text book work.
Describe the last time you taught a lesson using graphics calculators		I would have done straight line graphs with year 9.		It was the last time you came in. I did that lesson on straight lines and I ran out of time.	
How often do you use graphics calculators?		I haven't used them that often. I used them once on my TP.	I've used them a couple of times. Today, and once on TP for doing straight line graphs.	I have to admit, not as often as I'd like. I haven't used them at all this year, but I'm planning to use them soon.	
What are your thoughts about using graphics calculators (to teach)?		I think they can be fun to use. But it's important not to use them for the sake of using them.	I think they are great to use, but I'm not that confident with them yet. I need to spend more time, get familiar with the way they work.	I still think they're a good idea, pupils can learn a lot from them.	
What are your thoughts about the graphics calculator training you have had on your PGCE course?	We had quite intensive training on the PGCE course. Nearly everything had graphics calculators. It was too much at the expense of other technology.	We used the graphics calculators quite a lot. It was useful and I learnt how to use them for graph plotting.	It was okay, we spend most of the time using them for maths, rather than for teaching. I'd have liked more ideas.	I wish we had spent more time on learning how to use them in the classroom. Looking back, one workshop isn't enough really.	
What other topics would you consider appropriate for graphics calculators?	I could do trial and improvement using Excel. That's all really.	I would use them for fun lessons, use the little games you can get.	My repertoire consists of straight lines and this lesson.	The others in the dept use GC for trial and improvement, I'm hoping to get someone to show me so I can do the same.	

Table 6.4 Brief Summary of Interviews with Newly-Qualified Teachers

6.3.2 Interviews with the NQTs

Table 6.4 gives a brief summary of the interview responses by the NQTs to the interview which followed on from the lesson observations. In this section the emergent themes are discussed in more detail.

As a PGCE student Mark felt that his teaching was not as effective as he would have liked. This situation did not really improve during his probationary year. He continued to feel less than satisfied with his classes during his NQT year. After both lessons he commented that the lesson '*hadn't gone particularly well*'. One interesting and noticeable shift in his teaching style was that he was beginning to use the class textbook for his lesson planning, whereas as a PGCE student he relied on workshops, courses and his subject mentors to provide ideas for his lessons. This is often a strategy used by teachers to save time, but also to act as a way of keeping control of the class. Using a text book provides a safe environment; teachers know in advance the questions the pupils are likely to ask, they know in advance the skills and knowledge pupils will need to complete the exercises and most importantly, the pupils are generally all doing the same thing at the same time. This gives the teacher better overall control. Using technology (or conducting a practical lesson) means the teacher is not able to have complete command of the class because they cannot control how the pupils will use the graphics calculators; pupils may use incorrect keystrokes; pupils might ask awkward questions which teachers may not have the knowledge or the skills to answer. Altogether, this can make teachers feel insecure, especially novices.

Another reason for relying on the text book may be because it is prescribed by the scheme of work. This was true of Martin's lesson on the 'Towers of Hanoi' which he said was taken from the departmental scheme of work. However, graphics calculators are not often included within the scheme of work, and teachers have to resort to alternative sources for teaching ideas.

Alan's lesson used graphics calculators and his lesson idea was based on an Inset course he'd attended:

> *Alan*: *I got the idea from an inset course, they showed us a few little lessons you can do with the graphics calculator. I quite liked this one, it can be used as a starter or the whole lesson, it's simple enough.*
>
> *SH: why did you choose to do an algebraic task today?*
>
> *Alan: mostly because I'd got the worksheet on the inset course, so the lesson didn't need much planning, and also I wanted to have a go before I forgot what to do.*
>
> *SH: what other things did they do on the course?*
>
> *Alan: Oh, the usual, you know, the data-logger activity, and transformations of functions, again. [laughs]. So, nothing new, but still it was good to see it demonstrated again. And, it reminded me how to do those lessons for when I need them. I should do them with classes before I forget.*

There are several key points raised from this excerpt: firstly, that Alan has not used a text book for his lesson, but used a pre-prepared worksheet. He implies that he did not need to spend time preparing resources, and was therefore more willing to teach this lesson. He also comments that he wanted to use the graphics calculators before he forgot. This comment suggests that Alan feels time constraints in planning his lessons, and is aware that if he does not make use of inset ideas they may get forgotten or overlooked. He seems to imply that he chose this task because it was relatively simple

to carry out in class, and that it was different from the 'usual' functions type topics. The fact that Martin and Mark usually refer to textbooks for their ideas, suggests that if school text books contained graphics calculator activities, teachers would be more likely to use graphics calculators with their pupils. Having textbooks with graphics calculator activities would alleviate the need to prepare worksheets or other additional material. Secondly, Alan also highlights the fact that graphics calculator training appears to be limited in content. Most of the participants have attended workshops where they are shown how to use the graphics calculator for transformations of functions. This continues to be a popular demonstration, and uses the graphics calculator to best advantage. However, this gives teachers the impression that this is all that the graphics calculators have to offer. The same teachers will cascade this lesson to their colleagues, who in turn will demonstrate it to student-teachers. This may explain the prevalence of lessons on straight line graphs when using graphics calculators. If there are very few school textbooks with activities and investigations using graphics calculators, then it is understandable why so few teachers use graphics calculators in class.
Kelly was asked to use graphics calculators, but she opted to use laptops instead.

> *The graphics calculators we've got are old and I thought laptops would be better. We can use Autograph [graphing package] and the screen is much better than that on the calculators.*

Kelly's decision to use laptops was not because she has a negative attitude towards graphics calculators, but rather a positive choice to use laptops because the pupils will have better equipment. She says she chose to demonstrate straight-line graphs because it's one of her *'favourite activities with the laptops. I use it all the time'*. It seems that teachers tend to repeat the same task or activity several times. This helps them to become familiar with that aspect of using the technology.

Kelly makes an interesting comment about the graphics calculator training during her PGCE course. Unlike the PGCE students in this study she was a student-teacher at a different institute, one where graphics calculator use was embedded into the course structure. The PGCE students in that institute were expected to use graphics calculators for problem solving and to include it in their teaching practice.

> *We had quite intensive training on our PGCE course. Nearly everything had graphics calculators in some way or other. Looking back now, I think it was excessive. There was too much emphasis on graphics calculators; it was too much at the expense of other technology.*

Kelly is the only participant to say she felt she had too much training on graphics calculators. Yet ironically, she makes very little use of that training in her teaching. Asked what other topics she could do with laptops, she replies:

> *I always do this lesson, and I could do trial and improvement using Excel. That's it really.*

Martin's lesson on the Towers of Hanoi did not use graphics calculators (or any other technology). He chose this topic because '*it was next on the scheme of work for this* *group'*. Mark makes a similar comment about his choice of topic with his year 11 group:

'They've got a module test to do soon, and it's a topic we need to cover before then. I didn't see any point in deviating from the scheme of work, not with an exam group.'

This is in keeping with comments made by the PGCE students who would often do what the class teacher suggested. It appears that PGCE students and NQTs are comfortable doing "what they are told" (either by the class teacher or the departmental scheme of work) and presenting lessons in the "way they have been shown" (either Inset courses or subject mentors). These teachers do not appear to have reached a level of autonomy in their teaching practice yet. It seems that only when they are very familiar with a topic do they begin to experiment and adapt ideas to make them their own. Elements of this could be seen from Martin's lesson. He says:

> *'I like doing this activity. I usually get them to make the pieces and then collect their data by working in pairs and write it up in their book like a normal investigation. This time I thought I'd get them to work in larger groups of four, and get them to do a poster and a presentation.*

After a couple of times of repeating this topic, he has already made small changes to the way he conducts the lesson. The learning outcome for this lesson is different from his previous lesson on this topic.

Neither of Mark's lessons as a newly-qualified teacher included the use of graphics calculators. His year 11 lesson was in preparation for an external examination. This group was a low ability group, and they were working on calculating the mean of grouped data; the topic would have lent itself well to using the statistics and/or the table functions of the graphics calculator.

Mark admitted he had not used the graphics calculators in his classroom since his last observation.

> *SH:* *how often do you use the graphics calculators these days?*
>
> *Mark:* *I have to admit, it's not as often as I'd like. I haven't used them this year. But I am planning to use them soon. I might see if I can get that straight lines activity right.*
>
> *SH:* *Why do you think you haven't used them yet?*
>
> *Mark:* *I'm not that confident with them. I struggle with some of my classes and getting behaviour right is my priority. I'm still finding my way round the syllabus, so I don't want to add to it with things I don't need to do. I could do with some Inset as well, to get some ideas of how to use them in class properly.*
>
> *SH:* *I'd say you were a confident user*
>
> *Mark:* *I can use it myself, but to teach with it, that's different. You need to have the resources, you need to know how to ask the right questions, and set up the right activity for the pupils. For me that means getting someone to show me, going away, having a play around, trying things out till I think I can do it front of a class.*

Mark's comments highlight several of the key features demonstrated by the other newly-qualified teachers: having a positive attitude towards graphics calculators in itself is not sufficient to encourage the use of them in the classroom. As a newly-qualified teacher there are multiple pressures of time, classroom management, and beginning to make sense of examination and curriculum requirements. But Mark's feeling about his level of confidence, and how he could improve, is very pertinent. He highlights the need for training ("show him what to do") so that he has another activity that he can repeat, and then time to experiment and rehearse (" play around, try things out") before he can present his lesson plans to his pupils. This clearly will take time. Mark also recognises the difference between the graphics calculator as a tool for his own personal use in solving problems and the graphics calculator as a pedagogic tool to be used with pupils. He implies that training in technical aspects of the graphics calculator is not enough, and that training needs to consider the way graphics calculators can be used in the classroom. This is something that needs to be addressed by training and education providers.

Mark's second lesson observation, as a newly qualified teacher, was of a year 8 class. This group was working on reflection symmetry. Compared to all of Mark's other lesson observations, this group was quite noisy and uncooperative. He wanted to them to do some practical work, but their behaviour led him to decide that they '*couldn't really do the practical task, so we ended up doing text book work*'. His lesson planning was still focused towards improving his classroom management techniques. As an NQT Mark is still experiencing all the problems he had as a PGCE student but without any of the support. This makes it even more difficult for him to consider using technology in his lessons.

6.3.3 The Interviews with the Experienced Teachers

The interviews with the experienced teachers were designed to elicit responses about their own teaching practice and also to find out about the systems in place at departmental level that might support the use of graphics calculators. Their responses are discussed in this section and summarised in Table 6.5. These experienced teachers were also subject mentors for all three institutes. As such, their teaching methods and styles would have been observed by PGCE students (although not the PGCE students reported in this study). The interview responses given by the two Heads of Department are also discussed in this section, and summarised in Table 6.6.

Question	Sarah	Carol	Mike	Mark
Where do you get your teaching ideas from?	Text books, mostly. Sometimes I get ideas from other colleagues.	I use the textbooks and old exam papers. To make sure the pupils are well prepared	All sorts, books, magazines, courses. But I do use the test book quite a lot. It's geared up for the SATs ad GCSEs.	Still relying on what we did on the PGCE course, but I'm getting more ideas from others in the dept.
How long have you been teaching?	7 years, but I've had a break for maternity leave	10 years altogether	20 years	
Do you own a graphics calculator?	I have one from school that I use as my own	Not really, I use a school one.	I use the school's	
What graphics calculator facilities are there in your school?	We've got 3 class sets, projection screens and a data logger.	We used to have a class set, but some of the calculators got nicked, so we don't have a full set anymore.	We have a full set, we purchased it through a reward scheme. And we have a screen to use with an OHP	A class set and a viewscreen
Is there a departmental policy on graphics calculators?	Not as far as I'm aware. I use them when it feels right.	Not really. It would be up to individuals to decide when to use them or not.		Yes, but it's not very rigid. It says we should use them as often as we like
Are graphics calculators included in departmental schemes of work?	Not prescribed exactly, but the scheme of work shows when graphics calculators could be used.	Not exactly. They're under the national curriculum, so you could look it up if you wanted to use them and find out when they'd be suitable.		Again, it's not very rigid. It tells you which topics would lend themselves to GCs, but you don't have to use them if you'd rather do it some other way.
What training have you attended on the use of graphics calculators?	None	None	Only a twilight session in school, working with another member of the department. We were writing resources to use with KS3.	Nothing this year. It's all been numeracy strategy. That's the big drive now.
How often do you use graphics calculators?	All the time with year 12 and 13, and when I do graph work with year 10 and 11. I also use them year 8 when we do distance/time graphs by using the data logger	Only with year 12 and 13, but not all the time. I definitely use them for topics when they are allowed to use them in the exam.		Still not very often. It just doesn't get the attention it deserves. I'd like to use them, but I need more training and there just isn't the time.
Describe the last time you used graphics calculators.	I used them with year 12 last lesson. They were factorising polynomials. I got them to sketch the graph to check if their solution made sense.	I got the year 13 to use them for some numerical analysis. They were doing Newton-Raphson; they were using the calculator to substitute in values.		I did do straight line graphs again, but with year 9. It was much better, the topic was pitched at the right level.
Did you consider using graphics calculators for today's lesson?	Not really, as I wanted them to practice plotting co-ordinates.	The aim of the lesson was to calculate the gradient, and the calculator doesn't do that. It does draw the graph, but then they'd have to copy the graph anyway.		Definitely not. This group is quite badly behaved as you saw. I don't think I could trust them with the calculators.
What about the last time you used graphics calculators with the lower school?	I would have used it with year 8 at the end of the summer term, it would have been using the data logger. We do a lesson on distance/time graphs.	I haven't used them with the younger pupils this year.		
What are the advantages of graphics calculators?	Students can have one each, and it's easier than using the computer room. Students enjoy working with them.	They're cheap enough for the sixth formers to buy their own.	More accessible than the computer room. You can be a bit more flexible and spontaneous.	
What are the disadvantages of graphics calculators?	The screen is not as good as using a computer.	Not as good as using a computer. And they're not as intuitive to use. Can't use them in all the exams.	Take a long time to learn how to use them. Teaching pupils the keystrokes is time consuming.	
What advice would you give to NQTs on using graphics calculators?	Nothing in particular, but they should feel free to try out ideas.	Experiment with using them by all means, but be wary of the amount of time it takes to teach pupils how to use them. They could end up losing a lot of teaching time.	Don't be afraid to try out ideas, and to ask colleagues for help.	

Table 6.5 A Brief Summary of Interview Responses by Experienced Teachers

Question	Pauline (HoD1)	Wendy (HoD2)
Where do you get your teaching ideas from?	The way I've always done it really. I get some ideas from Inset or colleagues in the department.	Inset course, sharing ideas with others in the department during department meetings. But mostly, just the way I've always done things.
Brief description of teaching experience	25 years as a teacher, and 12 as head of department	I've been teaching for 26 years, and I've been head of maths for 10 years.
Do you have any graphics calculators and projection screens in the department?	We have a class set of 25 TI- 83 and a projection screen in each classroom	There are three class sets of graphics calculators, and a projection screen in each room. There's an OHP on each room. We've also got a data logger for doing displacement/time graphs.
Is there a departmental policy on graphics calculators?	Not really. But teachers are encouraged to use graphics calculators in their teaching. For lesson starters and so on.	No, nothing actually written down, but I try and encourage everyone to use graphics calculators.
Are graphics calculators included in departmental schemes of work?	Again, not specifically, though there are references to where they could be used if any teacher wanted to. And of course, there's reference to them in the national curriculum	There are suggestions of where graphics calculators can be used within the scheme of work, but it isn't prescribed that teachers have to use them with any particular topic.
What training has there been for your department on the use of graphics calculators?	Most of the inset we've had has been on other areas ICT, like the interactive whiteboard.. We've had school-based training on graphics calculators, but it wasn't really that useful. It didn't make any difference to what we do here.	Don't think we've really had any training on graphics calculators. The ones in the department that use them regularly are pretty much self-taught.
How often do you use graphics calculators?	I tend to use them with the sixth form. Occasionally with KS3	The sixth form use them, they've got their own so it's easier to access them for lessons. I'll use them occasionally with lower school, but not often enough.
Describe the last time you used graphics calculators	I did some work with year 8 on straight line graphs. They were investigating change in gradient.	Year 8 were using the CBR to do displacement graphs, they love that lesson. They have to reproduce a graph by altering the speed at which they walk.
Did you consider using graphics calculators for today's lesson?	Not really suitable for their stats coursework.	It's their first lesson on quadratics, so I wanted them to plot the graphs by hand, and then read off values. I might use them another lesson when we do transformations.
What are the advantages of graphics calculators?	They're cheap and portable, compared to laptops or PCs	They're accessible. You don't have to book the computer room
What are the disadvantages of graphics calculators?	You really need to have one per pupil in the class, and that can be expensive. Difficult to learn how to use them, they're always in the wrong mode.	The screen can be small, and graphs can be difficult to read. Also it takes time to teach pupils how to use them, which buttons to press.
What advice would you give to NQTs on using graphics calculators?	Be prepared to spend time getting used to them, that goes for any technology really. Personally, I'd prefer they were confident with using the IWB, then if they've still got the time and energy to have a play with the graphics calculators.	To include them in lessons as often as possible. They are a valuable teaching tool and the pupils love working with them. They're motivated in lessons when they use the graphics calculators.

Table 6.6 Summary of interviews with Heads of Department

All of the experienced teachers were asked what graphics calculator facilities were available within their school. All of the schools that were visited had adequate facilities for the use of graphics calculators, with at least one class set of graphics calculators and a view screen. Carol (QET) said her department used to have a full set of graphics calculators, but some were stolen and not replaced. However, there were still enough to be used one-between-two if the class teacher wanted to include graphics calculators in their teaching. Not replacing lost or stolen equipment suggests that it is not a priority for departmental funding. Yet, out of the 68 PGCE students only seven responded that they think that money spent of graphics calculators might be better spent on textbooks and other equipment. This seems to suggest some disparity between beliefs of the new teachers and the experienced teachers.

Despite the fact that every department owned graphics calculators no account seemed to be taken of their availability within the departmental schemes of work or policy documents. There appears to be a casual attitude to graphics calculators within departmental handbooks. All four experienced teachers and both heads of department commented that there was no formal policy; using graphics calculators was left to the individual teacher. The departmental schemes of work neither encouraged nor discouraged use of graphics calculators. As a newly qualified teacher Mark adhered to the scheme of work, which was based on the external examination requirements. If teachers are to be encouraged to use graphics calculators, then making graphics calculator use part of the examination and assessment procedures may be one way forward.

Both heads of department said that there had not been any inset training on the use of graphics calculators for their department; Pauline (HoD1) said that other areas of ICT had taken priority, such as using the inter-active white board and Wendy (HoD2) admitted that the regular users of graphics calculators in her department were mostly self-taught.

All three of the experienced teachers also said that they had had little or no training on using graphics calculators. Mike (QET) said the only training he had had on graphics calculators had been one after-school session working with another colleague. None of the teachers reported any training, led by experts, on the use of graphics calculators. Since all of the participants have said that they need more training to build up their confidence, it is easy to understand the paucity of graphics calculator use within their classroom.

Another interesting point made by all of the experienced teachers, other than Mark, is that they all say they use graphics calculators 'all the time' with A-level classes and only occasionally with lower years. This may be because they feel that graphics calculators are too complicated for younger pupils (yet only 22% of the PGCE respondents agreed with this statement on the questionnaire). Or it may be to do with the classroom management issues that concerned Mark during his NQT year, where he was reluctant to use graphics calculators with classes he perceived to be poorly behaved. He was certainly still struggling with this aspect of his teaching practice in his second year of teaching. Or, quite simply, it may be to do with lack of training and adequate resources. Both Sarah (QET) and Carol (QET) said the last time they had used graphics calculators had been with their A-level class. Sarah's group used them for checking graphical solutions to factorised polynomials, and Carol's group used them with the Newton-Raphson formula.

Carol: I got the year 13 to use them for some numerical analysis. They were doing Newton-Raphson, so I got them to write their iterative formula into the Y= function and then use the table function to enter their value. It just makes it a bit quicker for them.

SH: Have you used the graphics calculator to show them the staircase or spider diagrams, so they can see how quickly it homes in on the solution?

Carol: I've shown them by hand, but not on the calculator, I didn't realise that you could.

SH: I'm sure I've seen it done, I'll find out for you for next time.

Carol: that would be useful; I don't think I've come across it. No, all they were doing was using the calculator to substitute in values.

Carol seemed open to new suggestions and seems willing to experiment with using the graphics calculator. Again, her use of the graphics calculator is more for efficiency rather than as a learning tool. The pupils' understanding of the topic is not advanced by the use of the technology, but this may be a reflection of her own lack of experience and training in what the graphics calculator can do.

Pauline (HoD1) and Wendy (HoD2) both said the last time they had used the graphics calculator was with year 8. This slightly contradicts their earlier comments that they use the graphics calculators mostly with the sixth form. It is possible that they both interpreted the question as 'when was the last time they taught a lesson specifically including graphics calculators'. This might suggest that these teachers see a difference between the way the graphics calculator is used with the A-level students and pupils at key stage 3. The 'last' time Pauline used the graphics calculator was with year 8, on straight line graphs, and the 'last' time Wendy used graphics calculators was for distance/time graphs using the data-logger.

SH: can you tell me more about this data-logger?

Wendy: it's a bit of equipment that plugs into the teacher-calculator and viewscreen. [explains how to set it up]

SH: and do all of the year groups use it?

Wendy: every year 8, it's in the scheme of work for after they've done their end-of-year test. The pupils really enjoy it.

SH: what other activities like that are in the scheme of work?

Wendy: that's it really. After that, it's up to the class teacher. There are a couple of real experts in the department. I'd like it if we had more time for them to share their ideas, but other things keep cropping up that take priority. The department is quite overloaded with numeracy this year, sorting out lesson starters, that sort of thing.

As head of department Wendy has responsibility for writing schemes of work. If she does not make frequent and regular use of graphics calculators in her own classroom, it is difficult for her to include suitable suggestions for her department colleagues. Again, a lack of training and experience means that very little is prescribed in the departmental documents and the other teachers are led by what is recommended by their team leader. Wendy recognises that she would like to do more with graphics calculators, but other initiatives have taken priority.

Another interesting feature is that the distance/time activity is seen as a 'bolt-on', something 'enjoyable' that is done after the assessment. This suggests that the graphics calculator lesson is not considered important or serious enough to be tested. This seems to be regarded as an additional activity that does not actually teach them anything worth knowing for the end of year test. This is in contrast to the way the graphics calculators are used with the A-level groups where Carol says *'I definitely use them for topics when they are allowed in the exam'.*

Since none of the experienced teachers, other than Mike (QET), had demonstrated the use of graphics calculators they were asked if they had considered using them as part of the observed lesson. All of the teachers said that they had chosen not to use them, because the graphics functions did not fit in with their overall lesson objectives. They wanted the pupils to practice plotting coordinates by hand. Again, these teachers were not disregarding the use of graphics calculators because they had negative beliefs and attitudes, but because they felt they were offering their pupils a better way of learning the topic. It was more of a positive decision not to use graphics calculator. However, it does demonstrate their lack of awareness of how the graphics calculators can be used to enhance and support pupils' learning experience. These experienced teachers seemed to be unaware of what the graphics calculator can actually do, which again points to the need for more training.

When asked to describe the advantages and disadvantages of graphics calculators, the experienced teachers recognised that graphics calculators were more accessible than the computer room, they were cheaper and more portable. Only Sarah suggested that *'students enjoy working with them'.* They described the disadvantages as; not intuitive, keystrokes take time to learn, not as good as computers, and *'can't use them in all* *exams'* (Carol, QET). As with the PGCE students, the disadvantages seem to outweigh the advantages for these experienced teachers.

During the third year of the study Mark (QT) was observed teaching scatter graphs with a year 7 class. Mark described this group as 'badly behaved' and this tempered his lesson planning. The pupils were involved in collating data they had collected for homework, and this was plotted by hand on to graph paper. Mark had posed an interesting question 'does watching TV stunt your growth?' and pupils had collated information on how much television they had watched during the week, and then measured their height. The information was plotted on a scatter graph. Although Mark felt the lesson was noisy and chaotic, the pupils were engaged with the task. They discussed whether they should have tested weight against hours of television viewing '*because kids who watch too much TV are fat slobs, sir*'. The atmosphere in the class was boisterous and jovial, but for Mark this seemed to be seen as poor behaviour. He was obviously still concerned about classroom management. Asked whether he had considered using graphics calculators for this lesson he said:

> *Definitely not! This group is quite badly behaved as you saw. I don't think I could trust them with the calculators. It's hard enough to control them doing something out of the text book. Even the slightest deviation from the norm sets them off. And with it being quite early on in the year I want to establish a sense of routine and expectation. Otherwise I'll be storing up trouble for later on.*

Mark still feels that bad behaviour will be exacerbated by introducing graphics calculators into the lesson, rather than see them as an accepted way to teach. Along with Wendy's (HoD2) comments about using graphics calculators after the end-of-year tests, there is a sense that graphics calculators are seen as a 'treat', equipment that is used once good behaviour has been demonstrated. It seems that graphics calculators are only used when pupils can be 'trusted'. Mark seems to have overlooked his earlier belief that graphics calculators can be motivational, and that using the technology might motivate the pupils to behave better and be more involved in learning mathematics. Rather he has focused on the alternative disadvantage that the graphics calculators '*might cause pupils to misbehave*' (Mark, PGCE)

Already Mark's other priorities are impinging on his use of graphics calculators; he has to implement the new National Numeracy Strategy, which favours mental arithmetic above calculator methods; he wants to be confident with his classroom management. This means that opportunities to practice and rehearse using the graphics calculator are infrequent. He still feels that he needs more training only there is not enough time to give it the attention it deserves. Mark still has quite a positive attitude towards using graphics calculators in his teaching, but he seems to have fallen in line with all of his other colleagues; relying on the text book and scheme of work to guide his lesson planning (which does not prescribe the use of graphics calculators) and building his self confidence with classroom management so that the behaviour of his pupils is seen to be in line with the school's acceptable behaviour policy.

On a more positive note, he says he repeated his straight line graphs lesson, but with an older year group and he felt pleased with the outcome. He felt this time the '*topic was* *pitched at the right level'*. It seems that Mark is still keen to use graphics calculators whenever he can, although he is still repeating the same activity.

> *SH:* *what one thing would make you use graphics calculators more often?*
>
> *Mark:* *[laughs] don't know really. More training would definitely help, but not sure if that would make me. Probably something like if they had to be used in all the SATs, GCSEs and A-levels. If you knew there were going to be questions on the exam papers that needed graphics calculators I'd use them then. Mind you, we'd all end up just doing the minimum, like only the topics you knew you needed to do with graphics would get done with graphics. Then we'd all carry on as normal. I really would like to use them more anyway.*

6.4 Summary

Observing and talking to these teachers about their lessons has raised many interesting points:

- Most of these teachers and student-teachers say they have not had enough training.
- Most of them do make use of the limited training they have had, by teaching lessons using the resources they have acquired at these training sessions.
- Their use of graphics calculators is a repeat of what they have seen on training days.
- Most of these teachers repeat the same activity, over and over again.

- Most of these teachers use graphics calculators as efficient calculating machines, (speeding up graph plotting, substituting values into formulae and so on) rather than as a tool for extending pupils' learning.
- When these teachers do begin to use the graphics calculator as a tool for extending pupils' learning they have been motivated by an outside source such as their subject mentor or a training course.

Chapter 7. A Profile of Mark: A Case Study of a Beginning Teacher

7.0 Introduction

Mark was one of the PGCE students in Cohort A, along with Nigel, Nina and Polly from the pilot study. He was one of the 22 students from Institute 1, for whom I was assigned as university tutor. Mark's teaching was observed formally on two occasions, and he took part in the pre-test questionnaire survey. On the basis of the assessed lesson observations and his responses to the pre-test questionnaire, Mark was chosen as the critical case for a longitudinal study. His pre-test responses (Appendix A) show that he responded positively to 15 statements, gave only 1 negative response, and 4 neutral responses. These responses are 'typical' of that cohort and Mark's pre-test questionnaire seemed to imply that he was a 'typical' PGCE student. Like the other PGCE students in that cohort, Mark seemed to have a generally positive attitude towards using graphics calculators.

This chapter tells the story of Mark's journey from PGCE student to fully qualified mathematics teacher.

The first section of this chapter discusses Mark's responses to the questionnaire and how his responses compare with the other PGCE students. A discussion of his interview and lesson observation data as a PGCE student is also presented in the first section.

The second section considers the lesson observations and interview with Mark during his probationary (NQT) year.

Section three presents a profile of Mark's teaching as a fully qualified mathematics teacher after he has completed his probationary period.

Figure 7.1 shows a timeline of Mark's involvement as the critical case in this longitudinal study.

Year 1: PGCE student	Year 2: NQT	Year 3: Fully Qualified
Pre-test questionnaire and follow-up interview. Non-assessed lesson observation, and follow-up interview.	First half of Term 2: Lesson observation with year11and follow-up interview. Second half of Term 2: Lesson	First half of First Term: Lesson observation with year 7 and follow-up interview

Figure 7.1 Timeline showing Mark's involvement in this research

7.1 A profile of Mark as a PGCE student

7.1.1 Mark's Responses to the Pre-test and Post-test Questionnaires

The overall impression suggested by the pre-test questionnaire responses is that Mark has a generally positive attitude towards graphics calculators. This is in keeping with the responses given by the cohort as a whole. A more detailed discussion of the responses to the pre-test questionnaire was given in chapter 4.

The type of calculator Mark owns and the year of purchase is very interesting. He records that he uses his mobile phone as a four-function calculator; he also owns a scientific calculator as well as a graphics calculator. He purchased his graphics calculator in 1995, yet in 1998 he also purchased a scientific calculator. This seems to imply that he prefers to use a scientific calculator or that he does not recognise all that a graphics calculator has to offer in addition to the scientific calculator. This point was raised with Mark during the first interview:

> SH: *I notice your newest calculator is a scientific one, even though you have a graphics calculator. Why didn't you stick with the graphics?*
>
> Mark: *I used the graphics for my A-levels, but I needed the scientific for my degree. We didn't use graphics calculators at all at uni, so I didn't see any point in having one.*

This supports findings from the pilot study, in which Polly also purchased a scientific calculator despite already owning a graphics calculator. All three PGCE students in the pilot study implied that they did not use or need a graphics calculator for their undergraduate studies, and Mark's comment also seems to corroborate this. It is possible that the graphics calculator was prohibited from their undergraduate examinations, although none of the students implied that that was the case.

Mark's responses to the next set of questions are consistent with the responses given by the other PGCE students, and point to the lack of training and experience in using graphics calculators. Along with the majority of the other participants, Mark had participated in a short workshop on using graphics calculators where the graphing function was used to demonstrate transformations of straight lines; he had not observed graphics calculators being used by any of his subject mentors at the time of completing the questionnaire, and neither had he used the graphics calculators as part of his own teaching.

Mark rated his confidence at using the graphics calculator for his own personal use quite highly compared to many of his peers. He rates himself as being very confident at plotting graphs, solving equations, using iterative methods and using statistical tests, whilst he has some knowledge of programming, transformation of functions, tables, and descriptive statistics. The only area of which he had no knowledge was using the motion detector.

Mark's responses to the Likert statements in the post-test are exactly the same; he has not changed any of his responses. Again, this is consistent with the findings from the whole questionnaire survey, where the Wilcoxon Signed Ranks Test suggested that there was no significant statistical difference between the pre-test and post-test responses.

However, Mark's questionnaire responses are not particularly insightful, nor do they give sufficient detail to account for his teaching practices. A clearer picture of Mark as a PGCE student comes from the rich data collected during the lesson observations and the interviews.

7.1.2 Interviews on Questionnaire Responses

In the first interview, following the pre-test questionnaire, Mark was asked about his previous experience with graphics calculators:

Mark: *I used my graphics quite a bit for my A-levels, mostly for graph plotting. I found the graphics quite complicated to use at first, so I always had my scientific with me as well. I prefer my scientific because I'm familiar with it; I know where all the buttons are without having to look for them, but the graphics it's all under different menus. Apart from graph work, the graphics takes longer to do things than the scientific. The scientific doesn't plot graphs.*

SH: *What about your use as an undergraduate?*

Mark: We didn't use it at all, everything was written so the answers came out to nice round numbers. Like for trig equations it was always 30° etc and you don't need a calculator for that. I did use my graphics a bit for some stats work, but that was it. That's why I didn't bother getting a new graphics when my scientific broke.

These comments suggest that Mark does not fully appreciate all that the graphics calculator has to offer, using it only for graph plotting. He feels that the scientific calculator is easier to use and implies that the effort required to familiarise himself with the graphics calculator is not necessary as he only uses the graphing function. He also seems to imply that he does not see himself needing a graphics calculator in the future, so that when his old scientific calculator stopped working he opted to buy a new scientific rather than switch to using the graphics calculator which he already owned. This contradicts many of his questionnaire responses, which suggest that he sees a place for graphics calculators in the teaching of mathematics. One way to account for this discrepancy is that he regards the graphics calculator as a personal tool but not as a teaching and learning tool, and that despite his questionnaire responses, he has not fully considered the place of graphics calculators in mathematics classrooms.

During the post-test questionnaire follow-up interview, Mark was asked to describe his attitudes towards graphics calculators. His responses to the pre-test questionnaire may have been spontaneous, but his post-test questionnaire responses may have been slightly more informed.

SH: *Now that you have practically completed your PGCE course, have your opinions changed about graphics calculators?*

Mark: *I think I know more about them than I did at the beginning of the year. I still think they're a good idea, and I'd like to use them properly next year.*

SH: *what do you mean by "properly"?... I thought you used them quite well this year, what would you do differently?*

Mark: *I realise that they're not like using other types of equipment in class, it's not like multi-link [interlinking cubes], or scissors and glue [laughs]. There's an element of planning that's quite difficult to explain. You have to plan when you use any equipment, but with them [GCs] there's more to it.*

He suggests that his experiences during his PGCE course have helped to consolidate his generally positive attitudes towards graphics calculators. However, there is still a hint of some resistance that causes him some discomfort. He feels that he can only use graphics calculators in his teaching if he can use them "properly", and that to include them in his lessons seems to require a greater level of planning. He seems to find it difficult to articulate his thoughts about planning and preparation, although he suggests that it isn't that far removed from planning any other lesson that requires the use of additional equipment and resources.

7.1.3 Data from Mark's Lesson Observations

Mark's teaching was observed on two occasions as part of his formal assessment. His teaching style appeared to be heavily influenced by the class teachers; one teacher occasionally used open-ended tasks and practical activities, the other teacher relied predominantly on the set textbook and used that as a basis for lesson planning. The first class teacher had demonstrated a lesson using graphics calculators, and this lesson was later copied by Mark with one of his own classes. Neither of Mark's assessed lessons used graphics calculators, but he demonstrated elements of mathematical pedagogy from the university course. For instance, for his first assessed lesson he chose to teach percentages and fractions using an activity from the university course. He had created an over-head transparency which he projected onto the white board. This showed a "percentage snake" on which quantities and percentages were marked. The learning objective for the activity was to encourage pupils to calculate a percentage of a quantity as a lesson starter, but Mark's agenda for assessment purposes was about "attracting children's interest and attention"[from the Teaching Dimensions],

During the feedback session he was asked where the idea had come from.

> *Mark: it was something I saw at uni. I just copied the idea, but instead of making it completely mental I thought it would be better if I projected it, then the pupils who can't keep up, they can work at their own pace because they can still see the percentage-snake [the title of the task].*

In this episode Mark demonstrates that he is open to new ideas, and is able to copy and repeat activities that he has seen. More importantly, Mark demonstrates that he is willing to make small changes to these activities to suit the pupils he is teaching.

In contrast, Mark's second assessed lesson observation was on algebra. The pupils' learning objective was about collecting like terms and they used a textbook exercise. Mark's own assessment agenda was on classroom management and "establishing and maintaining a purposeful working atmosphere" [Teaching Dimensions]. After the lesson he commented that the lesson was '*a bit boring, but they worked quietly so that was okay*'. Mark seemed satisfied that although the lesson was not particularly inspiring the pupils had behaved well and worked on the exercises from the textbook. Whilst the pupils worked Mark walked around the class, but he did not engage with any of the pupils, in fact he actively discouraged any sort of discussion. This time Mark suggested that the class teacher had recommended a '*quiet text book*' lesson as he was going to be assessed on behaviour management. Jones (2001) notes that because of the nature of trainee assessment, student-teachers are often discouraged from '*exploring alternative, slightly more risky strategies, thereby promoting an uninspired "play-it-safe" attitude*'. It also appears that Mark equates good behaviour management with pupils working quietly, and this impression is given added weight by the class teacher. Berliner (2001) suggests that novice teachers '*appear to be afraid of losing managerial control*' and this certainly seems to be true for Mark.

During the feedback session to the second assessed lesson Mark was asked if he would demonstrate a lesson using graphics calculators for this research study. He seemed quite receptive to the idea. Some episodes from this non-assessed, graphics calculator lesson were discussed in Chapter 6.

Mark's graphic calculator lesson was based on an activity from the graphics calculator workshop and combined with an idea from a lesson he had observed during his first placement. Although he repeated much of what he had seen, he did make some changes to the way he taught the topic. Pupils used the graphics calculators to check graphs of straight lines, which they had previously plotted by hand. This was a change from the lesson he had observed, where he said the class teacher had only used the graphics calculators to produce graphs of straight lines. In the second part of his lesson, Mark used an activity that would have extended pupils' learning, but the class ran out of time and the activity was not completed. However, he was beginning to use graphics calculators differently from the way he had observed. This suggests that although he needs to be shown how graphics calculators can be used, he is able to make small changes based on his observations. This enables him to produce tasks that are more suitable for his classes. Unfortunately, because Mark's planning did not take pupils' prior knowledge fully into account, the task he had chosen for his class took longer than he had allowed. He saw this as a disappointing outcome. He attributed this partly to poor behaviour by the pupils.

> *Mark: I think it [the task] was too hard for them. I should have adapted the activity to suit their ability. I think the one I did was for older pupils, getting them to work out an equation, that was too hard for them.*
>
> *SH: I thought they were getting the idea. When you asked them about parallel lines, Peter [pupil] seemed to know that he needed to adjust the value of the intercept.*

Mark: The trouble is they don't listen. I think they might have got more done if I hadn't had to sort out all the error messages. I couldn't figure out what Richard had done to his calculator, it just wouldn't show the graph. And then the pair of them were being silly.

Perceived poor behaviour by the pupils creates a tension in Mark's teaching. The novice teachers in Donnelly's (2000) study showed similar reactions; they commented that the pressure of poor pupil behaviour limited their range of teaching approaches. Mark also seems to lack confidence in his behaviour management skills when the pupils are using graphics calculators. Spillane (1999) suggests that positive experiences when using new teaching approaches motivate teachers to make greater efforts to reconstruct their teaching. Mark's interview suggests that the converse is also true; that negative experiences can hinder teachers' motivations. Mark appears more relaxed when the class is working on standard textbook exercises, as he can control its behaviour. Using text book exercises means that any problems that occur are mathematical, and as he is a confident mathematician he can deal with any questions the pupils might ask. Yet using graphics calculators in the classroom introduces an element of insecurity. He cannot be in control of how the pupils use the technology; they may press the wrong keys which he feels he is unable to correct. His lack of knowledge and confidence with graphics calculators means that he feels his authority within the class is undermined.

I have noticed that most teachers have a strong desire to be 'in control', and that using technology often means having to relinquish some of that control. For novice teachers this can have an affect on their teaching; often opting for safe textbooks and worksheet exercises (Monaghan, 2004). This does not necessarily mean that teachers and novices prefer to use teacher-centred didactic teaching methods, only that they feel that they need to be able to deal with any situation as it occurs. Mark has demonstrated that he is able to teach in a pupil-centred way, by using graphics calculators with a group of pupils. Yet he found it difficult when he couldn't solve a technical difficulty for a pair of students. His frustration transferred itself onto the pair of students, whose banter whilst waiting for their teacher to attend to them, was seen as poor behaviour.

Mark suggests that it would have been useful for him to observe good practice using graphics calculators.

> *Mark: It would have been helpful if I could have observed the class teacher [for this group] using graphics calculators.*
>
> *SH: What would you have liked to observe?*
>
> *Mark: Not just how he controls the class, but also how he teaches. How he goes through the topic, the pace, what questions to ask. That sort of thing.*

Modelling good practice seems to be Mark's preferred learning style. He uses his observations of his mentors as a way of developing his own teaching style. Although he uses teaching methods from his PGCE course, and adheres to the PGCE course requirements, he is more strongly influenced by the class teachers. The PGCE course has provided him with teaching ideas, but these haven't been put into the classroom context. It seems that Mark needs to be shown what to do in the classroom context; he then uses these ideas to develop his own lesson plans. Mark seems positive towards using and including graphics calculators in his teaching, but he needs to address his lack of confidence and lack of expertise.

Mark demonstrates many traits in common with the three other PGCE students from the Pilot Study:

- As a student-teacher Mark has a generally positive attitude towards graphics calculators. But for assessed observations he preferred to "play it safe" and demonstrate a didactic teaching style, where he can be in control of the classroom.
- He was able to demonstrate a lesson using graphics calculators using a lesson plan based on his observations of his subject mentor. Although his lesson plan was slightly amended from the lesson he had observed, he included an activity that would have extended pupils' learning. His inexperience meant that he did not take pupils' prior learning into account which in turn meant that the class ran out of time. As a novice, Mark is prepared to experiment with his teaching.
- Mark's self-evaluation of his graphics calculator lesson was that it was disappointing. He based this assessment on pupils' behaviour, which he described as "silly" and the fact that the lesson ran out of time. However, he didn't fully appreciate their achievements during the lesson.
- Mark suggests that he needs his teacher mentors to model good practice, so that he can copy and repeat activities in his own classroom.

7.2 Profile of Mark as a Newly-Qualified Teacher

Mark was observed twice during his first year of teaching. The first time he was teaching a year 11 examination class and the second observation was of a year 8 group.

Prior to both of these observations Mark was asked about his experiences of being a newly-qualified teacher:

Mark: It's a lot harder this year. I can't believe how much there is to do all the time.

SH: What you mean?

Mark: I don't think as a student you realise just what is involved, you don't get the real picture. For instance, as a student you only have to teach a couple of lessons a day, and it takes you all your time to prepare those lessons. Now I'm teaching nearly every lesson, and the planning and marking load is horrendous. And then there's meetings and things on top.

SH: What have the others in the department suggested that you do, to make life a bit easier?

Mark: Anne [HoD] has given me a folder of the department schemes of work, so I don't have to think about which topic to teach, and that's got suggestions for exercises from the text book. I still have to do some of the questions myself, but I guess that'll get easier as I go along. Then the others have given me worksheets, so I can use those if I want to do an investigation.

NQTs often comment on the sudden reality shock of teaching a full timetable, so Mark's reaction is not unusual. He notes how planning and preparation take up a lot of his time, and he is already using shortcuts as a survival technique. Leat and Higgins

(2002) suggest that this is not an unusual reaction. They say that teachers have *'fears for their own survival regarding control and discipline; concerns about planning and organization; and a need for reassurance and practical guidance. In short, they need activities, and advice on how to use them and routines'*. Some of that reassurance comes from his head of department, who recommends that he use the scheme of work to ease his planning burden. This has the effect of creating uniformity within the department. It also absolves Mark from having to think entirely for himself. Added to this he is using worksheets prepared by his other colleagues. All this suggests that Mark might be moving away from his preferred teaching style and adopting the cultural norms of the department. This was clearly evident from the year 11 lesson observation and confirmed during the follow-up interview.

SH: *Where do you get your teaching ideas from these days?*

Mark: *Talking to Anne [HoD] and the others in the department. I still have my resources folder off the PGCE course, but mostly I use the text book. It matches the scheme of work, that way I can check I've covered everything.*

SH: *Is that why you chose stats for the year 11's?*

Mark: *Yes, they've got a module test to do soon and it's a topic we needed to cover before then.*

SH: *Did you consider using the graphics calculators with this group. The stats functions, perhaps?*

Mark: *Can't say I had. I don't think this group have ever used them [GCs] before; they're a bottom set, so probably not. And to suddenly introduce* *them now wouldn't be worth the trouble. And with the exams being so close I don't want to waste time teaching them how to use them, when they can't take them in the exams anyway.*

SH: *Oh, can't they?*

Mark: *I don't think so, and even if they could, they'd have to have their own. It's a struggle for some of them to bring a ruler.*

As a PGCE student Mark's lessons were always based on the scheme of work, and in collaboration with the class teacher he would produce worksheets and other resources to accompany the textbook exercises. But as an NQT he seems to rely entirely on textbook material. This change in style seems to be supported by the department, and it seems that he is neither encouraged nor discouraged from producing his own lesson plans. Mark still relies on guidance from more experienced colleagues, and they do not appear to be encouraging him to include technology in his lessons.

Mark is also influenced by the examination syllabus; he suggests that he follows the programme of study quite rigidly. This is understandable for a novice, as he may feel that he needs to be seen to be promoting good examination results. NQTs often resort to replicating a culture that is seen as being successful (Basit, 2003). However, he also seems to have put aside some of the pedagogical ideas he was introduced to on the PGCE course, and is beginning to adopt a more didactic, teacher-centred teaching style. This was observed during his lesson on statistics with the year 11 pupils, which did not deviate from the textbook. Whereas earlier impressions of Mark were that he was willing and able to take ideas from the PGCE course, from other teachers and from textbooks and adapt them to suit the group, now it seems that he is more inclined to use the textbook exercises as they are presented. There may be several reasons for this; the textbook exercise meets his lesson objectives, he may not have additional resources available on that particular topic, he may not have any experience of teaching that topic (he may not have observed any of his subject mentors when he was a PGCE student), or he may not have had the time to prepare his own material.

Mark's comment that he had not considered using graphics calculators with this group is interesting; he knew it was one of the key aspects of this research project, he also knows that the graphics calculator has facilities for statistical work (he made use of the statistical functions as an A-level student and again as an undergraduate). He also has ready access to a class set of graphics calculators which he could use. He implies that the graphics calculators would be a distraction for the pupils and that it was important for them to complete the topic in time for their exams. He is clearly unsure of the examination requirement regarding the use of graphics calculators, either way he suggests that he does not expect this group of pupils to have their own graphics calculator. He seems to imply that being a low ability group these pupils would not benefit from using the graphics calculators as a learning tool, and that the time and effort involved in teaching them how to use the calculator '*wouldn't be worth the trouble*'. Again, this is quite surprising as Mark has shown a predominantly positive attitude towards graphics calculators during earlier stages of this research.

SH: *What are your thoughts about using graphics calculators as an NQT? How are they different from last year?*

Mark: *They're not really. I still think they're a good idea, and that pupils can learn a lot from them. But I'm not as confident as I'd like to be. I can't* *just get the box from the office and teach a lesson with them. Like today, it wasn't till you said, and now I'm thinking, why didn't I use the graphics. But even if I'd wanted to, I wouldn't know what to do. Like how to set up the lesson so that it's about the topic and not about the calculators.*

SH: *What about the training you had last year?*

Mark: *Now that I'm in the real world, I realise that we didn't do enough. I wish we had spent more time on how to use them in the classroom. Looking back, one workshop isn't enough really.*

Mark suggests that he would still like to make more and better use of graphics calculators in his teaching, but he is hindered by his lack of confidence and lack of training. He says he would like to have more training, but linked to teaching and learning in preference to training on technical skills. Mark highlights what Flores (2001) calls the '*gap between theory and practice*' and points to the difference between the 'real world' of teaching and the 'idealised world' of teaching as portrayed by the university course. Interestingly, he also points to the difference between using technology to teach mathematics, rather than using technology for the sake of it, showing that he recognises the difference between using graphics calculators as tools for teaching and learning, rather than using graphics calculators to teach technical skills. He would have liked more opportunities to consider how to use graphics calculators in the classroom whilst on his PGCE course, and recognises that one workshop is not enough to cover both pedagogy and the technical aspects.

In the pre-test questionnaire Mark records that he knows how to use the graphics calculator for statistical topics, he also says that he used the graphics calculator for some statistics work as an undergraduate, but Mark seems to have overlooked the possibility of using them for statistics with his year 11 group. This may be because his only experience of teaching with graphics calculators has been for straight line graphs. Also, there was no prompt in the departmental scheme of work to suggest that graphics calculators may be used. Similarly, the text book is not presented in such a way as to require the use of graphics calculators. This may have implied that teaching with graphics calculators is not appropriate for this topic. One other possibility is that Mark might feel that introducing graphics calculators changes the atmosphere and dynamics in the classroom, whilst he prefers to maintain the status quo. Dunham (2000) points out that 'one *of the most profound impacts that graphics calculators have is in changing the climate of the classroom'* and this is often cited as a reason why teachers exclude the use of graphics calculators from their classrooms. It may be that if Mark tends to prefer the status quo, he might be reluctant to use graphics calculators.

One further point that is raised by this interview is Mark's comment that introducing graphics calculators to the year 11 group '*wouldn't be worth the trouble'*. It is worth asking the question whose 'trouble' is being considered. Is it 'trouble' for the pupils to learn to use the calculator and the time taken would hinder their progress at a point so close to their examinations, or is it too much 'trouble' for Mark to plan and prepare a lesson? Mark has already suggested that he lacks the time to plan and prepare lessons, so it is possible that the trouble Mark is referring to is the trouble he would have to take to teach himself how to use the graphics calculator for this topic, and then plan a lesson on statistics. This is supported to some degree by Gibson (2001) who suggests that '*the* *use of computers has neither made teachers' jobs easier nor their mission clearer'.* Although his comments are directed at computers, it could be equally true of graphics calculators. Certainly, graphics calculators have been seen as an additional burden by Mark, rather than a way of improving his efficiency.

Mark's second lesson observation as an NQT was with a year 8 group. This time he demonstrated a practical lesson on reflection symmetry. His lesson starter was a kinaesthetic activity from the PGCE course, and was presented without any adaptation. The main activity was based on a worksheet from another colleague, and Mark had made some changes to suit his group.

SH: In what way is it [the worksheet] different?

Mark: Instead of just getting them to draw the reflection, the last two questions I give them the reflections and they have to draw in the line of symmetry. Then the practical task at the end where they have to play the symmetry game, I got that off the internet.

Senger (1999) suggests that teachers have a penchant for '*rethinking, pre-playing and replaying*' ideas in their heads. This is part of Mark's strategy when he observes and collects teaching ideas from his colleagues. He observes how other teachers use resources, and then runs through the lesson in his own mind. This allows him to make certain changes and adaptations to the lesson. Part of this is evident from this lesson on symmetry. Unlike the previous lesson, Mark was beginning to move away from the text book. His lesson plan showed elements of personal development, he was beginning to experiment with ideas and adapting them to make them suitable for his class. Unfortunately, poor behaviour by some of the pupils resulted in Mark withdrawing the practical activity and asking the pupils to work from the text book, in silence. Gobbo and Girardi (2001) note that motivation helps to increase confidence and competence, which in turn generates greater motivation. However, the converse may also be true. In Mark's case, poor behaviour by his pupils makes him withdraw activities, and discourages him from using similar activities. From the pupils' point of view, they are unmotivated to behave, and tasks that may have encouraged positive behaviour are withdrawn. This generates a cycle of withdrawal and poor motivation in both teacher and pupils.

Behaviour management was still an area of concern for Mark, and many of his moment-to-moment decisions were affected by how pupils responded in the classroom. He tends to resort to safe text book exercises whenever he feels he is not fully in control. This could also explain why he has made no use of graphics calculators in his teaching. Despite the fact that he recognised the motivational effect of using graphics calculators as a PGCE student, he seems to be focused on the disadvantages he highlighted on his questionnaire that pupils might misbehave.

Lesson observations and interviews with Mark during his NQT year resonate with many of the findings from the data from the other three other newly-qualified teachers in the cross-sectional study:

- As a newly-qualified teacher Mark is beginning to rely on the textbook in preference to producing his own resources. This is probably because he feels he does not have enough time to plan and prepare every lesson in the detail he did as a PGCE student. Mark comments on the difference between the ideal world presented to him as a PGCE student and the real world of a newly-qualified teacher.

- He is still concerned about classroom management, and resorts to safe text book exercises as a method of controlling pupils' behaviour. His attempt at a non-text book activity results in a disappointing experience.
- Despite having a positive attitude towards graphics calculators, Mark overlooks an opportunity to include them in his teaching. This may be because the scheme of work did not suggest the use of graphics calculators. However, he feels that he needs more training on how to include the use of graphics calculators in his teaching. As an NQT Mark has had no additional training or support in the use of graphics calculators. Graphics calculators appear to have a low priority in his day-to-day decision making. Despite the need for more training, it is unlikely that Mark's training needs with graphics calculators will be met.
- Many of Mark's non-text book lessons are repetitions of activities that he has observed, or discussed with his colleagues. This "show me so I can repeat it" style is Mark's preferred method for increasing his teaching repertoire.

7.3 Profile of Mark as a Fully Qualified Teacher

Mark's last lesson observation for this project was as a fully qualified teacher. He was observed with a group of year 7 pupils, working on a task using scatter graphs. Despite having gained a year's teaching experience Mark was still reluctant to use graphics calculators with groups of pupils that he perceived to be badly behaved, and he comments that '*I don't think I could trust them with the calculators*'. Mark is still concerned with '*survival, rather than professional development*' (Farrell, 2003), and his teaching is still limited by pupils' poor behaviour.

In the final follow-up interview Mark was asked some general questions about teaching with graphics calculators. He admitted that he still didn't use graphics calculators as often as he would like.

> *Mark: It just doesn't get the attention it deserves. I'd like to use them, but I'd need more training and there isn't the time. I'd like to know how to teach with them, not just how to use them. But I need guidance'.*
>
> *SH: What training have you had?*
>
> *Mark: Nothing this year so far, or last year. It was all numeracy strategy. That's the big drive now, and using calculators doesn't fit in with the idea of mental skills.*

Mark implies that he is keen to include graphics calculators into his teaching, but the school systems and curriculum demands hinder his planning. His in-service training has been prioritised by the governmental drive to improve mental arithmetic. Mark recognises that this has the effect of pushing calculator use (both scientific and graphic) to the sidelines; it also means that his professional development choices are restricted to those courses on the list approved by the school, department and local education authority. Mark also implies that there is little or no time set aside for support from more experienced colleagues. Earlier interviews have shown that Mark prefers to be shown how to use graphics calculators within a classroom context; he repeats the activity and eventually begins to make changes and adaptations to suit his own classes. Mark was keen to report that he had used graphics calculators since the previous interview. He had repeated the straight lines lesson that he had demonstrated as a student-teacher. Berliner (2001) points out the novice teachers in his study preferred situations where they could repeat the same activity twice. This gives them an opportunity to 'iron out the snags'. This is possibly true for Mark. Having taught the lesson once, and reflected on the outcomes, Mark is better prepared for the problems he might encounter. This time, he said, the lesson had gone well.

> *I did do straight line graphs again, but with year 9 this time. I did pretty much the same as last time. They didn't run out of time, it was much better, the topic was pitched at the right level, and they worked well. I'd do that activity again with next year's year 9 class. I feel more confident with that lesson now.*

This comment highlights some of the themes from earlier lesson observations and interviews: Mark is able to repeat an activity once he has observed the lesson in context. Repeating the same activity gives Mark an opportunity to rehearse his teaching and hence helps to build his confidence. Once he is confident, he is better able to make changes and adaptations. This points to a need for more modelling and demonstrations by experienced colleagues as part of an on-going professional development programme for novice teachers. This progression of '*watching experts, practicing with advice from coaches, participating in critique and sharing polished work*' is highlighted by Wiske et al (2001) as being a recognised route for professional development. On a positive note, Mark seemed keen to try using graphics calculators again; this experience seemed to motivate him to try again, albeit in a year's time. Leat and Higgins (2002) point out that '*an individual teacher can just try one strategy with one class using an existing exemplar*'. This strategy seems to be evident in Mark's planning; he is still relying on improving his confidence with one lesson plan. However, Demetriadis et al (2003) suggest that teachers adopt ICT in stages, and this may also be true of graphics calculators. They go on to say that as teachers become more comfortable with the technology they start to deliberate about the potential benefits. As Mark grows in confidence he may begin to make greater use of graphics calculators in his teachings.

Mark's lesson observation and interview responses support the data collected from the other qualified and experienced teachers in the cross-sectional study (discussed in chapter 6):

- As a fully qualified teacher Mark was less concerned about classroom management issues, although when he felt under pressure his teaching decisions were still affected by pupils' behaviour.
- He was still using materials from the PGCE course, but relying more on materials from his colleagues. He continued to make regular and frequent use of the textbook and the departmental scheme of work for his lesson planning.
- Although Mark wants to make better use of graphics calculators in his teaching they are still a low priority compared to other top-down initiatives, such as the national numeracy strategy.
- Mark suggests that he needs more guidance and training on how to teach using graphics calculators, rather than how to use graphics calculators.

- When Mark used graphics calculators he relied on the graphics calculator workshop from his PGCE course and the lesson he observed during his first placement. He is still repeating the same activity.

7.4 Summary

Overall, Mark has a positive attitude towards using graphics calculators in his teaching. However, this is not evident from his classroom practice. He relies heavily on text book exercises, and occasionally on worksheets produced by other teachers. When he is not hindered by pupils' behaviour, Mark produces his own resource materials using ideas from the PGCE course, other teachers and the internet.

When Mark uses the text book he has a didactic, teacher-centred teaching style, and tries to maintain this style when using graphics calculators. This seems to cause him some discomfort as he does not feel totally confident and in control of the situation. Although Mark suggests that graphics calculators can be motivational, he does not try to use them as motivational tools with disaffected or poorly behaved groups.

Mark has been observed using graphics calculators once, and reported using them on one other occasion. On both occasions he repeated the same activity. This was an activity which he had observed during his teaching practice. He suggests that he will repeat this activity again in the following year. This activity uses the graphics calculator as an efficiency tool, helping pupils to check their work. The activity also encourages pupils to extend their understanding of the topic, by posing some questions beyond the syllabus.

Chapter 8. The Calculator Development Project

8.0 Introduction

One of the key themes that emerged from the study of Mark was his need for good role models. He often commented that he needed to observe other teachers using graphics calculators with classes, so that he could repeat the lesson for himself. Novice teachers like Mark often need colleagues who can model good practice in teaching with calculators. This raised the question of what constitutes "good practice". In order to answer this question it was necessary to study how teachers use graphics calculators in their teaching.

The Calculator Development Project (CDP) was an opportunity to study three teachers' use of graphics calculators over a period of one academic year. The tasks that these teachers presented to pupils were recorded in log books and then categorised against the three levels of use presented by McCormick and Scrimshaw (2001).

This chapter presents the findings from the Calculator Development Project. The first section gives the background to the CDP, and discusses the use of the log books. The second section presents an overview of McCormick and Scrimshaw's (2001) model of ICT use. Section 3 examines the log book data and compares the entries against the three levels given in McCormick and Scrimshaw (2001). Section 4 summarises the findings from the CDP and in section 5 some suggestions are made for the inclusion of a fourth level of use that could update the model put forward by McCormick and Scrimshaw (2001).

8.1 Background to the CDP

Both the pilot study and the case study of Mark suggested that teachers use graphics calculators in different ways. Nigel (PGCE, pilot study) used graphics calculators in the same way as he would have used a text book exercise. The graphics calculators were used to produce graphs of straight lines, quickly and efficiently. But the questions and tasks for the pupils remained essentially the same as if he had not used graphics calculators. Nina (PGCE, pilot study) used the graphics calculators to motivate the pupils, but her task was presented in a way such that it extended pupils' learning beyond the syllabus for their year group. Similarly, Mark (PGCE) used the graphics calculators as an efficiency tool, but was beginning to extend pupils' learning with the task he had planned. Kelly (NQT) used laptops to present an activity on straight lines that helped to motivate pupils and produce graphs efficiently. However, the task did not extend pupils' learning beyond the syllabus. Alan (NQT) used graphics calculators to motivate his group of year 8 pupils. The pupils used the technology to check their answers, essentially using graphics calculators as an efficiency tool. Mike (QT) used graphics calculators as an efficiency tool, to produce graphs of functions, but again the questions he asked remained consistent with a textbook. These observations show that teachers use graphics calculators in many different ways. Some teachers use the graphics calculator in the same way as they would use a textbook exercise; they pose the same type of questions and present the same type of tasks to their pupils. Other teachers begin to use the graphics calculator in a way that encourages pupils to ask their own questions, and to experiment with their own ideas, as was the case with Nina's lesson (PGCE, pilot study).

The CDP was an exploratory study of three teachers and their teaching practices as they began to include the use of graphics calculators in their teaching. The mathematics department of a local secondary school had recently purchased a class set of graphics calculators. Three teachers representing three different levels of expertise with graphics calculators were chosen from that department to take part in this study. Celia was an experienced teacher of mathematics, but a novice user of technology. Dan is also an experienced mathematics teacher, and experienced user of technology but had limited experience of using graphics calculators. Rachel was a newly-qualified teacher of mathematics, but had received extensive training in the use of graphics calculators as part of her PGCE course.

Each teacher's progress was followed over a period of one academic year. They were interviewed formally on two occasions, but they also met informally with the researchers for advice and support on the use of graphics calculators. The interviews were used to develop profiles of these three teachers, and that aspect of the research is presented in Berry et al (2007).

As part of the CDP the three teachers agreed to use log books to record their use of graphics calculators during the year.

8.1.1 The Log Books

Each of the three teachers in this study was asked to record their use of the graphics calculator in a log book. The log book was intended to be easy to use and contained pre-printed pages for standard responses; date, class, lesson objectives, whether the graphics calculators were used by the teacher and/or the pupils (T/P), whether the overhead view-screen (VS) was used, whether the graphics calculators were used during the lesson starter, main or plenary part of the lesson (S/M/P), and which calculator facility was used. There was also a blank section for any additional comments that the teacher might wish to record. Appendix D shows a sample page completed by one of the three teachers.

8.2 An overview of the three levels of ICT use by McCormick and Scrimshaw

McCormick and Scrimshaw (2001) propose three levels in the integration of ICT. Their work is presented as a general model for ICT across the curriculum and with computers in particular. These three levels are used to describe the use of computers and ICT in general, but they seem equally appropriate for describing graphics calculator usage. *Any implementation of ICT in schools requires a level of change in practice. We examine three such levels – namely, where existing practice is made more efficient or effective, where it is extended in some new way, and where it is transformed.* (McCormick and Scrimshaw, 2001)

McCormick and Scrimshaw describe the first level as one where the teacher '*aspires to provide a more effective means of doing what is already being done*'. The ICT is used to replace a traditional resource, but the lesson is essentially unchanged from previous practice.

The second level of change is described as one where the ICT is used '*to provide a major extension to what can be achieved, one goes well beyond the efficiency level. In this case the ICT extends the reach of the teacher, the learners, or both.*'

The third level goes beyond extending, and is described as transforming. At this level '*the technologies may transform the nature of a subject at the most fundamental level*'.

The transformative level is described as having the most impact on teachers' knowledge and pedagogy.

Using McCormick and Scrimshaw's three levels, the log book data entries by Celia, Dan and Rachel were analysed.

8.3 Discussion of Log Book Data

8.3.1 Celia's Log Book Data

Celia recorded the use of graphics calculators on four occasions. Her log book entries are represented in Table 8.1.

Date	Class	Lesson objectives	T/P	VS	S/M/P	Calculator facility	Comments
20/9	10(7)	Spot a rule to solve a problem?	T	Yes	Starter	Program (BEARS)	Gave a visual approach, random screen gave a 'fun' element. First time used in lessons! 1 pupil so taken by it I had to send him away or he would have missed his bus.
11/10	10(7)	Addition practice	T	Yes	Plenary	Program stugrid	Random facility of grids is useful
4/12	8(1)	Investigate different types of sequence	T & P	Yes	Main	Numerical	Pupil got into a programme that I couldn't get out of; so they had to share. The calculators were new to pupils, none had used one before, they were more interested
11/12	8(1)	Calculate next number in a sequence	T & P	No	Main	Program 'Sequence' & 'Variable'	It was a different approach to normal. If they got the wrong answer they were told the correct answer. 1 or 2 lazy individuals found they would get the correct answer, so they didn't try very hard. Going over what we did last week and using the two programs was not enough for the length of the lesson. If done again I would add other activities. On this occasion the pupils wrote some sequences of their own and swapped with their neighbour. Although the more able were in the extension session the rest of the group found all levels of 'Sequence' very accessible. A further level to stretch them further could be attempted with questions on the board and using the calculator. Answers to be written in exercise book and what they had to do to generate the answer. It would reinforce previous week's work.
?	?	?	?	?	?	CBR	Class session led by member of research team. Teacher helping/observing how the equipment was used
Examples of lessons where graphics calculators could have been used but were not (when you used computers or no technology at all)							

Table 8.1 Summary of Celia's log book data

Celia's first recorded use of the graphics calculators is with a year 10 group. She uses just the teacher calculator with the view screen for the starter part of the lesson. She comments that the idea was to introduce a 'fun element' to the lesson and seemed to have had a positive response from the pupils. The pupils' enthusiasm seems to have encouraged Celia to use the teacher calculator and view screen again with the same type of activity. In both of these lessons, the main purpose of using the graphics calculator seems to have been to motivate and capture pupils' interests. Seeing pupils' positive responses seems to encourage Celia to make small changes to her teaching practice. This was noted by Spillane (1999) who also found that '*seeing students' interests in, and success with, the mathematics and new teaching approaches, teachers were motivated to proceed with their efforts to reconstruct their teaching.*'

However, the graphics calculator was not used as an efficiency tool, nor was it used to teach pupils new mathematical concepts. The technology was not used in any way that could be matched against the three levels of use as suggested by McCormick and Scrimshaw. This seems to imply that McCormick and Scrimshaw's model is not sufficient to describe all the types of activities that teachers present to their pupils.

In the next recorded episode Celia uses the class set of graphics calculators, the teacher calculator and the view screen, during the main part of the lesson. The lesson was on sequences, and pupils were revising work they had already completed. Celia felt that the work was too easy for the pupils, and that harder sequences were needed. Again, Celia's use of the graphics calculators does not appear to match any of the three levels of use. The pupils are not introduced to new mathematics; their learning is not extended or transformed. It is possible that Celia intended to use the graphics calculators as tools for efficiency, but this is debatable. The pupils may have completed their work more quickly but the time that was gained was not used productively. Pupils were not encouraged to explore sequences in greater depth or to explore new types of sequences. Instead they repeated what they had already learnt.

Overall, using McCormick and Scrimshaw's model, Celia does not appear to have made good use of the graphics calculator. Her use of the technology has not made her classroom practice or her pupils' learning more efficient. Neither does it appear to extend or transform what happens in her classroom. However, it is important to recognise that Celia does make some use of the graphics calculators in her teaching. Also, there seems to be a sudden step change in her use of the graphics calculator. She moves from using the calculator in a tentative way, where she uses only the teacher calculator for part of a lesson, to using the calculators for the main part of the lesson as well as using the class set of graphics calculators. This could have been in response to a session with the research team. The sudden step-change is in marked contrast to the way the other two teachers used the graphics calculators. Having moved suddenly to using the graphics calculators for the main part of the lesson, there is an abrupt halt in her use of the technology. There is a sense in the log book entry that Celia felt that the graphics calculators were not adding to the learning experience of her pupils and this may be why she does not use them again. Even after she attends a practical session run by one of the research team, where the calculators and motion detector were used with Celia's class, Celia does not seem to be motivated to include graphics calculators in her teaching.

During the interviews, Celia comments that she would have liked more time to familiarise herself with the calculator, and that she would like someone who is more proficient to show her what the calculators can do. When an opportunity such as this was arranged, a demonstration lesson by one of the research team, she wasn't able to follow up with similar work. Celia suggests that it is because she cannot follow up the observation with an opportunity to practice;

'By the time I get the opportunity to do something like that, it will be too long a space of time for me to feel totally confident. In all these things you need hands on all the time.'

Celia implies that she is unable to adapt the observed graphics calculator activity for another year or ability group, which means that she does not have an early opportunity to repeat the activity. By the time she reaches the equivalent point in the scheme of work, a year may have elapsed, and she might have forgotten how the activity was organised. This comment also points to the integration of graphics calculators into the departmental scheme of work. Where the technology is integrated into the teaching plan, it is used as a matter of course. For instance, the whole department including Celia uses spreadsheets, Logo and databases every year with their groups because it is an integral part of the scheme of work and time is allocated in the computer room for teaching these topics. But activities such as the motion detector are treated as bolt-on activities, and Celia had already 'opted out' by saying she doesn't think she'd be confident enough to teach that lesson.

In all four instances when Celia has used the graphics calculators, she shows an awareness of many inter-related and often conflicting issues. She would like more external input, but then has little time to implement the ideas in her own classroom. She would like to be more confident and proficient, yet she needs to spend more time familiarising herself with the technology. This is consistent with findings from the pilot study, the case study of Mark as well as other research (for instance, Becta, 2003; Mitchelmore and Cavanagh, 2000).

Celia implies that, in the early stages, classroom management of the graphics calculators is a hindrance to the pupils' mathematical progress. She finds it difficult to sort out pupils' technical problems, and the time taken up dealing with these technical aspects detracts from her teaching of mathematics.

'when we first used them they played with the keys and so on and they get into a mode and because you are concentrating on what you are teaching rather that what they are doing with it, it is difficult sometimes how they get out of a mode that they have got into'.

Celia lacks the knowledge and expertise to correct pupils' keystroke errors. This seems to stop her from experimenting in class, and compounds her lack of confidence. As a consequence, Celia's teaching is restricted to the calculator functions with which she is familiar.

Celia is aware that the use of graphics calculators can make her classroom practice more efficient. She comments on the usefulness of the view screen:

'It [the view-screen] is very useful when you want to describe what you want to do....I am sure with the graphical ones [lessons] it would have been far more apparent, especially if you zoomed in and so on.'

Later, she notes that if her pupils were more proficient at using the graphics calculators, then they could check their own work and so free her for other tasks. Again, she adds that her lack of confidence and experience hinders her use of the technology, even when she is aware of the benefits.

Celia says that the reason she had included the graphics calculators in her lesson on sequences was mainly because the use of technology had been highlighted in the department's scheme of work. More importantly, Celia questions what else can be done using the graphics calculator;

'There was something in the sequences and that was why I brought it up in one of our meetings. I looked it up and it said you can use graphics calculators for sequences, so what can I do? That was how that came about. I did ask if there was anything for simultaneous equations, but I could see it was too advanced and complicated for the time I had. I was hoping there was a similar thing I could do without it being too complicated.'

Celia appears to be keen to include graphics calculators into her teaching, but lack of confidence and proficiency are her main barriers. She seems to need help from more knowledgeable others, followed by opportunities to practice and rehearse her skills, before being able to use the technology within her lessons. From small successes she begins to ask questions about other facilities the graphics calculator has to offer. She also begins to question her own classroom practice, and how her pupils' learning could be made more efficient with the use of technology.

Celia's interview responses raise several important points about teachers' use of graphics calculators. She highlights the need for someone to model and demonstrate how to teach with graphics calculators within a classroom context:

'Almost to the extent of watching other people using them and seeing what problems occur'.

Celia seems to need to be shown what to do, and then time to rehearse and practice those skills until she feels confident and proficient. She says '*I would rather be shown how to apply and then practice and then use'.* She frequently comments that she needs an expert to model the use of graphics calculators for her.

'[if] you could pick out a topic to focus on, say specifically year 8 and pick out a topic on a strategy you could use and then having gone through what to use and how to use it and we would then have a chance to go out and try it out'.

This cycle of observation and repetition seems to work well for Celia, and she raises it as an important way for her to develop her own skills with the graphics calculators. Celia is asked to describe her use of computers in her teaching and she comments that she is able to use the same activities on an annual basis - *'that one [Logo task] is fine because it is something we do every year'.*

Similarly, she says she will be able to repeat the sequences task using the graphics calculators. This is at odds with her earlier comments about the CBR lesson, where she says she does not have the confidence to repeat the activity as too much time will have elapsed. One reason for this apparent discrepancy is that a technician is available during the computer lessons. Celia says that not having to worry about technical aspects frees her to focus on the mathematical concepts of the lesson. This support is missing from the graphics calculator lessons, and Celia has to be in control of the mathematical as well as the technical aspects.

Overall, Celia seems to have a positive attitude towards using graphics calculators in her teaching, yet she makes very little use of them in her teaching. She recognises that they can be a useful addition to her teaching, by providing pupils with visual cues, and also as a way of motivating them. However, lack of confidence caused by insufficient training and few opportunities to practice and rehearse have meant that she makes ineffective use in her teaching. Although she does not use graphics calculators in a particularly efficient way, it is important to recognise that she was beginning to make some use of them, and also to question what other topics she could use them for. Celia's use of the technology adds very little to the pupils' learning experience, other than to give pupils an opportunity to use graphics calculators in mathematics lessons. Her desire for good role models reinforces the findings from the longitudinal study of Mark. Both Mark and Celia say that they benefit from observing the use of graphics calculators in a classroom context, so that they can copy and repeat what they have seen.

8.3.2 Dan's Log Book Data

Dan's log book records, summarised in Table 8.2, show that he planned to use the teacher calculator and view screen for the starter part of one lesson. He notes that he had to abandon that plan as there were problems with the over-head projector. Dan also records that on two occasions when he could have used the graphics calculators, he chose to use the networked computers instead. However, during the interviews, he recalls at least one lesson when he has used the graphics calculators with a year 8 class, which is not recorded in his log book. He also discusses his use of graphics calculators with his A-level group; again, these lessons are also not recorded in his log book. It is possible that there may have been other episodes that have not been recorded in his log book, but it is unlikely as he does not mention any other episode during the interviews.

<table>
<tr><td>Date</td><td>Class</td><td>Lesson objectives</td><td>T / P</td><td>VS</td><td>S/M/P</td><td>Calculator facility</td><td>Comments</td></tr>
<tr><td>17/10</td><td>8(2)</td><td>Practice mental arithmetic</td><td>T</td><td>Yes</td><td>Starter</td><td>Program Countdown</td><td>The lesson was planned to use 'Countdown' program as a mental starter, but due to a clash with the OHP, I didn't end up using the calculator, but played 24 game instead.</td></tr>
<tr><td colspan="8">Examples of lessons where graphics calculators could have been used but were not (when you used computers or no technology at all)</td></tr>
<tr><td>25/9</td><td>13</td><td>Transformations of functions (pure 2)</td><td colspan="2">Used Autograph</td><td colspan="3">I was confident using Autograph, larger. Colourful screen on a PC. Unsure about YVAR function on the graphics calculator. I would consider using a GC for this lesson in future.</td></tr>
<tr><td>9/10</td><td>10(3)</td><td>Means from frequency tables</td><td colspan="2">Used excel</td><td colspan="3">Used Excel because the pupils are confident with it. Able to show formulas for each row, which ties in with the written method I use. I was unsure of how to do what I wanted on the graphics calculator. I might use a GC for this lesson in future</td></tr>
</table>

Table 8.2 Summary of Dan's Log Book Data

Given that Dan has not recorded using the graphics calculators at all during the year, it is not appropriate to compare his use with McCormick and Scrimshaw's three levels. Despite the lack of evidence in the log book, Dan's interview responses address many important issues concerning teachers' reasons for not using graphics calculators. The interview data corroborate many of the findings from the pilot study, the case study of Mark as well findings from the cross-sectional study of NQTs and experienced teachers. It would appear then that Dan has opted out of using the graphics calculators. This seems at odds with the fact that he is the ICT coordinator for the department. His job would normally be to encourage other members of the mathematics department in their use of technology. However, Dan comments that the use of graphics calculators is not explicitly addressed within the scheme of work, and only passing reference is made in the programme of study in years 8 and 9. Dan also suggests that his responsibility is for the use of computers rather than graphics calculators. He goes on to suggest that Rachel is the colleague that the department would turn to for support and advice. Ironically, Rachel is an NQT and probably does not have the authority or experience to make changes to the curriculum.

Dan seems to make a positive decision to use the networked suite of computers, rather than a negative decision not to use the graphics calculators. He feels that the graphics calculators offer a poor substitute for the clarity of display and flexibility that pupils get from a computer.

'I mean, with anything in technology, it is the servant rather than the master.....It was year 8, and we spent quite a lot of time on coordinates, and I liked the way that I was teaching it. Doing it by coordinates and then drawing it, (4,1) (4,2) etc. there were some nice things coming out of that, but if you do y = and you get that, but then you can't do x =, you can't plot. Because it's all y = something, isn't it? Again, you go back to Autograph, put in y = 4 and you can rub it out and put x = 4 and it will plot that. That, to me, is easier.'

Given his lesson plan, and his objectives of teaching equations of horizontal as well as vertical lines, his decision to use a computer package is reasonable. He goes on to say that he believes pupils feel that graphics calculators are dated and primitive compared to modern hand-held games consoles and mobile phones. Another reason given by Dan for not using graphics calculators is that the scheme of work suggests places where computers can be used, rather than graphics calculators. He readily admits that there has been no change to the departmental policy since they purchased the equipment. Hennessy et al (2005) point out that teachers are reluctant to adopt technology which they think is incompatible with the existing school culture; this may lie at the heart of Dan's reluctance to use graphics calculators. Dan also implies that there has been little change in his perceptions of graphics calculators as a teaching tool.

'I wouldn't say [there's been] no change,... I have spent longer with them than I would have done if you hadn't been coming in. To be honest, on the list of priorities, it has been last on the list for me. It has fallen by the wayside.'

Dan gives typical responses for not using graphics calculators; lack of confidence and proficiency and lack of training. Both of these hindrances are recurring themes within his interview comments:

'Well, yes, I feel I'm not completely confident with them myself. ...one lad had got it all up in dots rather than a curve and immediately you think where's the reset button. Yes,

training is a big issue. That is the biggest reason why I don't use it'. [Dan, first interview]

'What stops me doing it [teaching with GCs] at the moment is lack of confidence within myself in knowing what I am doing. I can sit at home and work it out, but you know what kids are like, they just press the buttons and they have the screen in a certain mode.' [Dan, second interview]

These statements contradict his responses to enquiries about his confidence and training in the use of computers and mathematical software. He says he has had very little training, yet he rates his confidence levels quite highly. Whereas Dan is happy to experiment with using the computer, when it comes to familiarising himself by *'fiddling about [and] playing'* (Taylor, 2003) with the graphics calculator he says he does not have the time.

Dan seems to be confident with the use of computer technology but his lack of experience and confidence with the graphics calculators deters him from making better use of them in the classroom.

Dan recognises that familiarity and confidence in using the graphics calculator require more time than he has available. He admits that until he has the time to become familiar with the graphics calculator he is unwilling to move away from using the computer.

He is aware that in order for his teaching to become more effective and efficient, he needs to spend more time experimenting with the graphics calculator. Yet he also says *'I want to be confident enough and know it's not going to add to the planning'.*

The time required to plan lessons that use technology seems to be an issue for all of the teachers in this research study, and Dan is no exception. Olson (2000) suggests that the *'shift to CAL [computer assisted learning] brings "bugs" in smooth classroom running and involves didactic and pedagogic ideas foreign and unacceptable to many teachers. If teachers view these new approaches as "wild", it is not surprising that they "domesticate" them'.* Dan (like Mark, Nigel [PGCE] and Mike [QT]), seems to want to subsume the use of graphics calculators into his normal teaching style. Yet some researchers (for instance, Tharp et al, 1997; Watson, 2001) have pointed out that using graphics calculators changes the nature of the lesson and teachers need to adopt a different teaching style. This may explain why teachers like Dan find it difficult to incorporate graphics calculators into their normal lesson planning. Dan seems happy with his teaching practices, and his pupils respond positively to his lessons. It is worth asking whether it is appropriate for Dan to change his teaching methods, *'Change should not be imposed for the sake of it'* (Basit, 2003). Furthermore, Olson implies that using technology is not the most important aspect of good teaching.

Despite the lack of use of graphics calculators Dan comments that he would like to be more confident and to make more use of them in his teaching. He says that training would help to boost his confidence.

Using McCormick and Scrimshaw's model of ICT use, neither Celia nor Dan have made efficient or effective use of the graphics calculator. They haven't transformed or extended their classroom practice and the use of graphics calculators has had little or no impact on the teaching and learning of mathematics.

Yet there has been some use of technology. The graphics calculator has been used by Celia as a motivating tool for pupils, it has been used as a response to the research team and some pedagogic issues have been addressed. However, this level of usage is not really described in the McCormick and Scrimshaw model. Both Dan and Celia have questioned how the graphics calculator could be used in their teaching, and where else in the curriculum the graphics calculators can be beneficial. Questioning and reflecting on how the graphics calculators can be used in the teaching of mathematics is an aspect of teachers' development that is not specifically addressed by McCormick and Scrimshaw.

8.3.3 Rachel's Log Book Data

Rachel's use of graphics calculators was quite prolific compared with the other two teachers in this study. Her log book recorded 35 entries where graphics calculators were used. Appendix H gives a summary of the log book data, and Table 8.3 shows briefly the number of times graphic calculator lessons took place and with which year group.

Term	1	2	3	Total
Year 7	5	5	2	12
Year 8	3	0	0	3
Year 9	3	2	0	5
Year 10	1	1	0	2
Year 11	4	1	0	5
Year 12	4	0	0	4
Year 12/13	2	2	0	4
totals	22	11	2	35

Table 8.3 Summary of Rachel's use of Graphics Calculators during each Term

The majority of the lessons using graphics calculators are in the first term. She records frequent uses of the graphics calculators with all of her year groups during the first term, with the exception of year 10. However, the frequency of use decreases over the academic year, and in the last term she only uses the graphics calculators twice. On one occasion Rachel makes a decision not to use graphics calculators when they would have been appropriate. She chose not to use them with her year 10 group for drawing quadratics and finding roots of quadratics because she couldn't rely on sensible behaviour. This attitude of withdrawing graphics calculators with poorly behaved groups was also noticed with Mark. Both Mark and Rachel are novice teachers and this may account for their insecurity regarding their own classroom management.

During the first term, Rachel used only the teacher-calculator and the view screen with her classes. Use of the graphics calculator was mainly small APPS (pre-loaded programmes from the manufacturer's website) at the start of the lesson, although she did begin to use the teacher calculator and view screen during the main part of the lesson after a while. These APPS are used with all of her classes, and she repeats the same activity several times, irrespective of the age or ability group. She does not link the use of the graphics calculator to a specific topic on the curriculum, and as such the activity is treated as a bolt-on. Used in this way, the graphics calculator does not enhance or extend pupils' learning, although it is used to motivate the pupils. However, Kendal et al (2005) suggest that the downloading of these APPS onto the class set of graphics calculators is '*an indicator of [her] interest and expertise*'.

Rachel's first recorded use of the graphics calculator was with her year 12 GCSE re-sit class; she used the teacher calculator and the probability simulator APP to simulate experimental probability. The lesson did not go quite as she expected and immediately Rachel makes suggestions as to how to improve the lesson.

'I was using it to illustrate theoretical probability versus experimental. Unfortunately the experimental probability was the same as the theoretical very quickly. In future maybe I could set it up beforehand and store some results.'

Despite her teaching inexperience, Rachel begins to reflect on how to use the graphics calculator in her teaching. In her first interview, Rachel recognises that there is more that she could do to make better use of the technology.

'I was confident in using it. I could see that there were other things that could be done with it which I wasn't experienced [in] and I needed more time to do some of those things'.

Like the other teachers in this research, Rachel points out that she needs time to develop her expertise and increase her repertoire of lesson plans. Her log book records show that almost all of her graphics calculator lessons have used the APPS, and have been used to motivate pupils, rather than to enhance or extend their learning in any way. This is probably because it is her first term as a full time teacher, and reflects her inexperience. Rachel's first use of the class set of graphics calculators was with the same year 12 GCSE re-sit group which took place at the end of the first term. The students had to investigate straight-line graphs using the graphical facility of the calculators. Rachel notes in her log book that '*There were all sorts of things [on the screen] to clear before they could start*'.

Her way of overcoming this was to give the students different calculators whilst she cleared the menu and screen for each individual. Rachel is able to sort out the calculators, but not able to instruct the students. She is aware of a 'default' facility and comments that she will '*put the defaults program onto the class set*'. Again, incidents like this highlight Rachel's confidence with the technology but her inexperience as a teacher. Rachel records that the students' reaction was quite positive initially; they found it '*quick and easy to see a variety of graphs, they can try things out*' and it was '*motivational*'. However, the mathematics was not challenging enough to maintain their interest and '*some students very quickly abandoned the task in favour of playing with Prob-Sim*'. Despite this, Rachel used a similar activity on two more occasions with the same group. This is not unusual; the theme of repeating the same activity several times has been noted in the teaching practices of the other teachers in this research study. In the same way that she uses the same APPS on several occasions, she uses the same graphical tasks. It seems as if this repetition enables Rachel to develop her teaching practice, and it may help her to understand how the pupils respond to the graphics calculators. Repeating the same activity may also help to build her self confidence. It may also give her the opportunity to hone the activity to suit her teaching style so that she can add it to her repertoire.

'*Straight lines was more successful than quadratics... I would probably do more preparation beforehand, I would put a lot more up on the board so that I have got them there instead of wasting time drawing them...you can react very quickly to questions you get from them*'.

Rachel begins to reflect on how the calculator activity supports pupils' learning. Although she uses the technology predominantly to motivate pupils and to help the class develop a familiarity for the calculator functions, she is aware of how the graphics calculator can be used to make her teaching more efficient. Reflecting on and familiarising herself with the way she uses the graphics calculators helps her to move from using the technology as a bolt-on activity to using graphics calculators as an integral part of the lesson. This aspect of teachers' development with graphics calculators is not specifically addressed by McCormick and Scrimshaw's (2001) model. Her year 7 top set has regular exposure to the graphics calculator. However, use is limited to the APPS with only the teacher-calculator and view screen during the lesson starter. Even when this group begins to use the class set of graphics calculators, the pupils still only use the same programs. The year 7 pupils are not introduced to new mathematics during these lessons, and only use the graphics calculators to revise mathematics they have already covered. One reason for this is that the graphics calculators are used when a large proportion of the pupils are withdrawn for 'extension' lessons. This has the advantage of creating a smaller, more manageable group, but has the disadvantage that there are two distinct experiences within the group. The 'top' of the group is withdrawn and consequently has limited access to graphics calculator technology. Her reason for only using graphics calculators with the smaller group is that there are not enough graphics calculators for each pupil to have one each otherwise. With many of the group missing, it may explain why she feels it is not appropriate to introduce new topics.

Rachel uses similar APPS with her year 8 and 9 classes. The programs are used as lesson starters, using the teacher-calculator and view screen. On one occasion the year 9 pupils use the programs on the graphics calculators themselves. This style of usage is repeated throughout the log book. Rachel uses graphics calculators to introduce new mathematics on 3 out of 35 recorded lessons (introducing equations of asymptotes to year 12/13, solving equations using a program with year 7, and the distance/time graphs using the CBR with years 7 and 11). On all other occasions Rachel recorded that the graphics calculator was used to reinforce, revise or motivate the pupils, and she does this by repeating the same activity several times.

As her confidence grows, Rachel begins to experiment with the CBR. She chooses to use the CBR with her year 7 reduced-group (when the more able pupils are withdrawn for 'extension' lessons). Rachel repeats this lesson as part of a cross-curricular activity at the end of the year. Twenty 'able and talented' year 7 pupils are chosen to take part in a circuit of three CBR/CBL activities. Rachel worked collaboratively with a Science teacher to set up a circuit of three activities. Two of the tasks went well and the pupils '*found the activity easy and enjoyable*', the third task had to be abandoned because the software didn't respond in the way they expected. Although Rachel had used the third activity during her teacher training she does not record whether she had prepared a lesson plan for this session. It appears that neither of the two teachers had 'rehearsed' the lesson before they presented it to the pupils. Rehearsing was an important part of lesson planning when using the graphics calculators for the teachers in the cross-sectional study, as well as the student-teachers in the pilot study. Rehearsing gave them an opportunity to familiarise themselves with the keystrokes and anticipate any technical difficulties that might arise.

Rachel's log book data highlight the way she repeats the same activity on several occasions. This may be so that she can iron out any snags (Berliner, 2001); it also provides an opportunity for her to reflect on the success of the lesson plan. The activities that are unsuccessful are either not repeated, or she does not use the graphics calculators with that particular group. This could be because she looses self-confidence and returns to the activities with which she is comfortable. This may also explain why the frequency of graphic calculator lessons drops towards the end of the year.

Rachel is a confident user of graphics calculators in the classroom, and as her experience increased over the duration of the project there is evidence to suggest that she became more willing to experiment. Although she does not seem to be experienced enough to consider the pedagogical issues surrounding graphics calculators Rachel does reflect on how the graphics calculator could be used in her teaching. Rachel also gives classroom management a high priority and makes the choice not to include graphics calculators if she thinks that they will have a negative affect on pupil behaviour.

Rachel is aware of her lack of teaching expertise, she comments that

'they are much more experienced teachers they might come up with ideas of using them...also they might find problems that I may not have spotted'.

Rachel also cites lack of preparation time as being a hindrance,

'There are things I am not using it for which I know it can do but I haven't got the time to prepare for it'.

She needs time to prepare her lessons in advance in order to consider the usefulness of graphics calculators in her lesson, but doesn't have that time to give because it is of a low priority. However, she is confident enough to use the calculator facilities she is familiar with because they do not need any additional preparation time. This is evident from her log book, which shows that the same type of activity is used on most occasions.

Comparing Rachel's use of the graphics calculator with McCormick and Scrimshaw's model, she begins to make efficient use on only a few occasions (solving equations using a program) but the extent of the mathematical content is very limited. The graphics calculator is used predominantly as a motivational tool and the mathematics appears to be secondary to the classroom management. One important element of including the graphics calculator is Rachel's attempt to make the pupils familiar with the technology. With time and continued use, her pupils will become confident users of the graphics, and it may be, that at a later stage the mathematics will be brought to the forefront of her lesson planning. However, during the first two terms of her teaching Rachel makes regular use of graphics calculators, she repeats the same activities on many occasions. Her log book records show that in the third term, Rachel only used the graphics calculator twice. This may be because Rachel realises that she cannot continue to use the APPS, having used them exhaustively in the first two terms. The only other activity in her repertoire is graphs of straight lines, which she has already taught. It would seem that Rachel needs some stimulus, some external influence to introduce more activities into her teaching repertoire.

8.4 Summary

Despite the fact that none of the three teachers uses graphics calculators in a way that could be described as effective, efficient, extending or transforming, it is important to recognise that they are using them in the classroom albeit only to a limited extent.

Their log book entries and interview comments hint at better classroom practice; there are suggestions that they are beginning to ask questions of the technology and what else it can offer to the teaching and learning of mathematics. They are influenced by external motivators, such as the scheme of work, being part of this research project and watching more proficient colleagues. Above all, the three teachers say, they need time to think about how to incorporate graphics calculators into their teaching and how to develop their own skills and understanding.

Unlike Rachel, both Celia and Dan are reluctant to use ICT as a bolt-on activity. They seem to prefer to use graphics calculators in a way that will support pupils' learning, and they prefer to use graphics calculators when they are integrated into the scheme of work. Again, it is difficult to assign one of the levels of use when the graphics calculators are used as a bolt-on, as is often the case with Rachel's log book data.

The main theme that occurs in all the interviews is the need to be shown what to do with graphics calculators. Once an activity has been modelled for the teachers, they need an opportunity to repeat it with their classes as soon as possible. This helps to fix the task within the teachers' repertoire. Once an activity has become part of the teachers' repertoire they tend to repeat the same activity, or a version of it, on several occasions until they have honed it to suit their classes. As they become more confident using that activity, the teachers begin to reflect and question what else is possible. It is at this point that they are ready to move onto a new activity.

8.5 Returning to McCormick and Scrimshaw's three levels of ICT use.

McCormick and Scrimshaw's model description of the three levels of use does not adequately describe the data collected during the CDP. Although their model is intended for the use of ICT in general, it was assumed it would be equally appropriate for graphics calculators. One development of McCormick and Scrimshaw's 2000 model that would take my observations into account is to assign another level below the efficiency level, which could be described as a 'rudimentary' level. This rudimentary level is where the graphics calculators are being used in the class room, but little mathematics is being taught or developed. This level describes the use of graphics calculators for motivation and familiarisation. It describes graphics calculators being used as a bolt-on to the main objective of the lesson.

A second development of the model considers how teachers progress from one level to the next. McCormick and Scrimshaw's model has elements of "progression" within it; i.e. progression from efficiency to extending occurs smoothly and in a forwards direction, with respect to time. Their model hints that teachers will naturally move from one level of use to the next, and that progression is only in a forward direction. However, these teachers demonstrate that there is a cyclical, repetitive element to their development. They do not necessarily progress from one level to the next, they may move backwards as well as forwards; sometimes making effective use, and sometimes using graphics calculators as a bolt-on. They use the same facility within the graphics calculator on several occasions, until they become familiar with it. Ideas from external sources are taken up, perhaps in a limited way, and used within their planning. They experiment with a single task, making adaptations, gradually increasing their experience. A critical point is reached and they begin to ask their own questions of the technology; what else can it offer? As they use more facilities, and begin to make regular use, their confidence begins to build, and they are able to ask pedagogic questions about their pupils' learning. At this point, they are ready to move to a higher level of use.

These aspects of how teachers use graphic calculators in their teaching are not fully addressed by the model put forward by McCormick and Scrimshaw. The three levels of use are not really sufficient to describe the way the teachers in the CDP made use of graphics calculators. It may be that McCormick and Scrimshaw's three level model is not an appropriate model to describe graphics calculator usage. This point is addressed in the next chapter, where data from the CDP, the longitudinal and cross-sectional studies are compared with other models.

Chapter 9. Proposal of a Model to Describe Teachers' Use of Graphics Calculators

9.0 Introduction

The log book data have already been compared to the three levels in McCormick and Scrimshaw (2001), and it was found that their three levels of use did not fully describe the data collected from the Calculator Development Project. The log book data suggested that there should be another level of use, below the level of efficiency, to describe some of the teachers' lessons in the CDP. The three-level model doesn't fully address how teachers progress from one level to the next. It may be that McCormick and Scrimshaw's model of ICT use is not an appropriate model to use to describe the log book data.

The first section of this chapter addresses this point and compares the log book data to other models.

Section 2 of this chapter proposes a new model that better fits the way that the teachers in this study use graphics calculators. The proposed model is an amalgamation of existing models that describe how teachers' use of graphics calculators develops, and describes the stages that teachers go through as part of their professional development.

9.1 Comparing the CDP data with other models in the literature

9.1.1 Models that Describe Teachers' Use of ICT

One of the discrepancies that was noted with McCormick and Scrimshaw's model of ICT use was that the transformation level did not seem to be attainable by the teachers in the CDP or the other teachers discussed in this study. The inference is that teachers working at the transformational level will take their pupils' learning beyond the scope of the school syllabus, as well as instigating institutional change. This seems highly unlikely for the teachers involved in the CDP, as well as the Heads of Department in the cross-sectional study. As discussed in chapter 8, the lowest level does not fully describe the way teachers in the CDP used graphics calculators as motivational tools. It seems that McCórmick and Scrimshaw's model could be enhanced by including a level of use below efficiency.

Ruthven and Hennessy (2002) give a more detailed description of how teachers use computers. Some of the features of their model, shown in Figure 9.1, can be used to describe how graphics calculators are used.

The themes in their model are arranged such that '*those processes afforded most directly by use of technology lie on the left of the diagram, and those corresponding to ultimate teaching aspirations lie on the right*'.

Their use of computers to '*enhance the ambience*' describes how '*technology use was seen as something of a break from routine*', and where motivational effects were attributed to the '*novelty of the situation*'. The teachers in Ruthven and Hennessy's study described their use of computers as '*playing around*', and graphics calculators as '*toys*'. Using technology to overcome drudgery (using calculators for calculations; using the computer to draw graphs) is described in their model as '*alleviating restraints*', and is similar to the efficiency level. When technology is used for '*tinkering*' pupils are engaged in processes of trial and improvement, and self-checking. Again, this resonates with the notion of using technology efficiently. At the other end of the model, Ruthven and Hennessy suggest that pupils' engagement in the task is intensified, their pace and productivity is affected, thus helping to establish ideas.

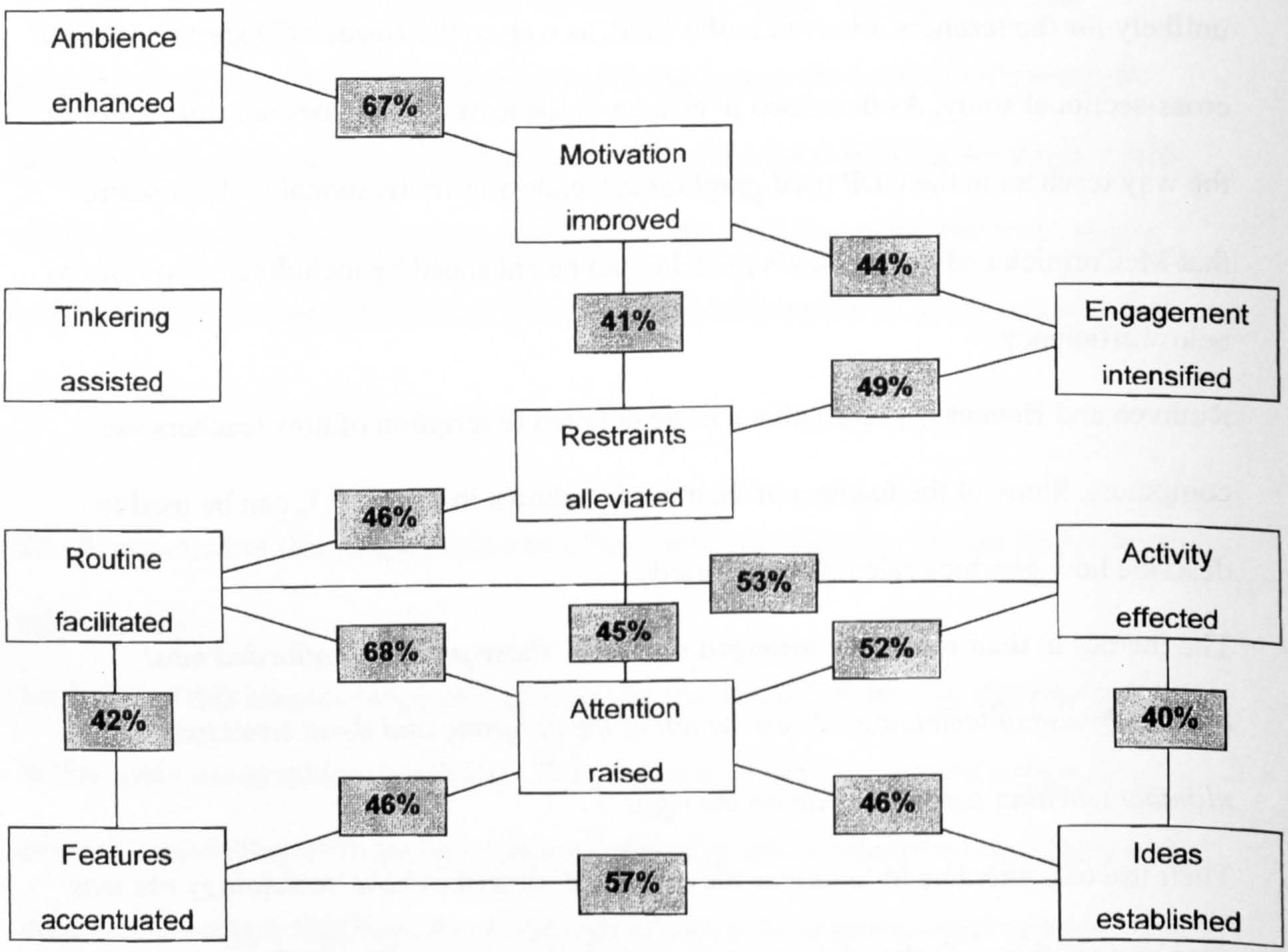

Figure 9.1 Model of computer-based tools and resources (Ruthven and Hennessy, 2002)

Using Ruthven and Hennessy's model describes the log book data the '*ambience enhanced*' aspect can be seen from all three records. Celia, Dan and Rachel all comment on the motivational aspect of using graphics calculators. The '*tinkering*' element of pupils' use of the graphics calculator can not only act as a motivator for pupils' learning, but it can also act as a motivation for the teachers to make greater use of the graphics calculators in their teaching. For instance, pupils may be motivated to ask what else the graphics calculator can do, which in turn may encourage the teacher to develop her own expertise. However, '*tinkering*' is also associated with the fear that pupils will end up in the wrong part of the graphics calculator menu and this creates a tension for the teachers. None of the log book records or the interview responses suggested that Celia, Dan or Rachel were able to use graphics calculators in a way that intensified engagement, or established ideas. More importantly, Ruthven and Hennessy suggest that teachers are not necessarily going to reach the higher levels just because they have made some use of ICT.

Ruthven and Hennessy's model has some similarities with the McCormick and Scrimshaw's (2001) model, but they (Ruthven and Hennessy) recognise that sometimes teachers use graphics calculator purely as a way of motivating pupils. Ruthven and Hennessy also recognise that movement 'along' their model is not a progression in a linear way with respect to time, but that teachers react to different aspects of using technology that may or may not result in extending pupils' understanding. However, their model does not address how teachers make changes to their practice given the contexts within which they work.

Another model that describes the way teachers use ICT is described by Van den Dool and Kirschner (2003). They describe three '*worlds*' of learning:

- '*within frame of reference*': this describes the type of ICT use where teachers are involved in traditional types of learning, and are concerned about acquisition of skills.
- '*extending the frame of reference*': when teachers develop new ideas but still inside a recognised frame of reference.
- '*building a new frame of reference*': when teachers identify new issues and they design their own solutions.

The first '*within frame*' level can be used to describe the way that the three teachers in the CDP were using graphics calculators, but only in a limited way. Only Celia and Rachel were interested in acquiring more skills, whilst Dan was more focussed on maintaining the status quo. Again, these three teachers were not able to extend their frame of reference; they were not able to develop their own repertoire of tasks and relied only on the activities they had already used. None was able to introduce their own frame of reference. Van den Dool and Kirschner model also implies that each level has an effect on the way teachers teach, yet the teachers in the CDP seemed to be consistent with their teaching styles and showed no change during the year. These three worlds seem to be equivalent descriptions of the efficiency, extending and transforming levels, and hence do not adequately describe the way that Celia, Dan and Rachel use graphics calculators. A notable difference between McCormick and Scrimshaw (2001) and van den Dool and Kirschner is that the latter do discuss how teachers might progress from one level to the next. They present a circular loop which includes beginning with a gallery of mind tools, and building upon that with reflection and professional development (shown in Figure 9.2). However, the model presupposes that teachers already have a repertoire of mind tools at the outset.

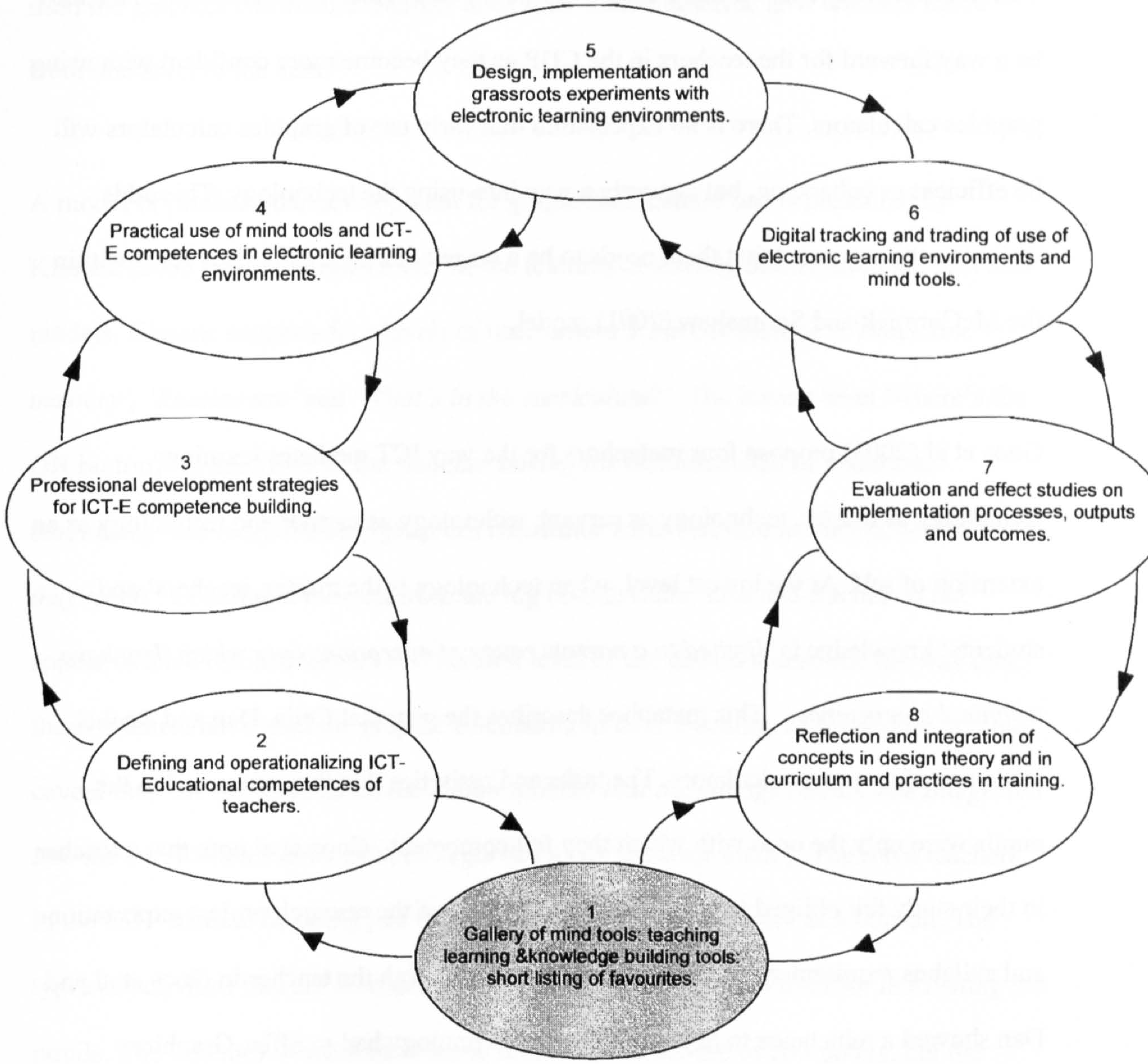

Figure 9.2 Model of Educational Function of ICT (van den Dool and Kirschner, 2003)

The data collected from the three teachers in the CDP suggest that this is not necessarily always so, and their case is not completely addressed by this model. Bright (1994) suggests that '*the initial hurdle is to get teachers to use calculators the first few times. Then teachers may become more concerned about actual learning outcomes*'. This may be a way forward for the teachers in the CDP as they become more confident with using graphics calculators. There is no expectation that early use of graphics calculators will be efficient or enhancing, but is purely a way into using the technology. This adds weight to the argument that there needs to be a stage before the efficiency level within the McCormick and Scrimshaw (2001) model.

Goos et al (2003) propose four metaphors for the way ICT mediates learning: technology as master, technology as servant, technology as partner and technology as an extension of self. At the lowest level, when technology is the master, teachers' and students' knowledge is '*limited to a narrow range of operations over which they have technical competence*'. This metaphor describes the way that Celia, Dan and Rachel made use of graphics calculators. The tasks and activities that they presented to the pupils were only the ones with which they felt competent. Goos et al note that a teacher in their study felt obliged to use technology because of the research project expectations and syllabus requirements, this was also true of Dan. Both the teacher in Goos et al and Dan showed a reluctance to explore what else technology had to offer. Graphics calculators were the master for Celia and Rachel as well, but they were restricted by their lack of knowledge and experience. Comparing the log book data with these four levels of use, in the majority of the lessons technology was the master. In a couple of episodes Rachel used graphics calculators as the servant (speeding up pen-and-paper calculations when plotting graphs), but the graphics calculators were not used to '*amplify cognitive processes*' as the lesson was on reinforcing previously learnt skills. Again, these metaphors do not adequately describe the way that Celia, Dan and Rachel used the graphics calculators. Neither does their model describe how teachers move from one level to the next.

A model of professional development for graphics calculator use is presented by Kissane (2003) and highlights many of the features of already discussed in the previous models. Kissane suggests four levels of use: '*where's the ON button?*', '*Black line mastery*', '*Routine use*' and '*What's in the curriculum?*' The lowest level 'where's the ON button?' is described as the '*teacher having the technical skill to undertake confidently and independently graphics calculator tasks relevant to the mathematics they teach*'. Looking at the data from the log books, Celia, Dan and Rachel do not appear to have reached this level. This first level of use does not describe the way that these teachers have used the graphic calculators in their teaching. Kissane does add the caveat that '*the model rests on the author's belief that technology ought to be integrated into the curriculum, rather than be regarded as an optional extra*'. The three teachers in the CDP seem to be doing just that, treating graphics calculators as a bolt-on. The types of activities that are recorded most often are lesson starters used for motivating the pupils. The schemes of work have some references to the use of computers, but the graphics calculators have not been integrated into the curriculum. So, although Kissane's model is specifically directed at the use of graphics calculators, it does not describe the data from the CDP. Kissane's model does recognise that moving from one level of use to the next involves professional development. The highest level 'what's on the curriculum?' suggests that teachers will become involved in curriculum development. This is unlikely for the majority of classroom teachers in the UK, who have the curriculum imposed upon them. Kissane's model, like the others discussed here, seems to suggest that teachers make steady progress from one level to the next, and that they always work at their highest level. The data from the CDP, the pilot study and the case study of Mark suggests that this is not necessarily the case. Teachers may work at a higher level, but they also continue to use tasks and activities from the lower levels too.

Comparing the log book data with the models that describe teachers' use of ICT and graphics calculators raises several points for discussion:

- The lowest level of graphics calculator use does not always adequately describe the data recorded in the log books from the CDP. Only Ruthven and Hennessy's (2002) model recognises that sometimes teachers use graphics calculators just as a motivational tool, rather than as a mind tool. The data from the CDP log books suggests that there is a level of graphic calculator usage that exists below that of efficiency. Teachers working at this 'rudimentary' level use graphics calculators as a bolt-on. Often their intention is to use the technology as a motivational tool, and no consideration is given to using it as a mind tool. Far from being a pejorative situation, this provides pupils with an opportunity to come into contact with using graphic calculators. Both the teacher and the pupils gain experience and build on their confidence and may gradually begin to make use at a higher level, given the right support and guidance. Gobbo and Girardi (2001) suggest that '*motivation could be considered a mediating factor that works as a loop; it increases the disposition to become more competent, and* *when competent, the teacher's motivation to try new strategies and roles increases'.* It would appear that motivation as a mediating tool could work for the teachers as well as the students.

- Other than van den Dool and Kirschner (2003), the other models imply that movement from one level to the next is a progression in a forward direction with respect to time; i.e. that teachers will naturally move to the next level and continue making progress. Van den Dool and Kirschner suggest that there is a loop of development to help teachers progress from one level to the next. The log book data, data from the pilot study and data from the case study of Mark all suggest that progression is not linear. The teachers tend to repeat the same activities on several occasions. They make small changes and adaptations, but essentially repeat tasks that they have seen before.
- There is also the implication within the literature that teachers only work at their highest level. This is not corroborated by the log book data. Having added to their repertoire of lessons, the teachers in the CDP do not discard earlier activities. They continue to use lessons which are purely motivational, despite being able to use the graphics calculator as an efficiency tool. The models discussed here imply that the range of teachers' expertise remains fixed, whilst the level of use improves. The data from the teachers in the CDP (as well as the other teachers in this research) suggests that the range of teachers' expertise increases. They continue to use tasks and activities from lower levels, even when they have progressed to a higher level.

9.1.2 Models that Describe Professional Development and the Change Process

The models that describe how teachers use ICT do not seem to take into account how teachers become expert users. These models imply that teachers will be involved in some sort of professional development and that once teachers start using graphics calculators they will "just become" more experienced and more confident and hence use the technology in a way that will extend and transform pupils' learning. The data from the log books suggests that this is not always the case. The teachers in the CDP received several training sessions on specific topics, yet very little progress was made. One way to make these models more applicable to the log book data is to consider how teachers make progress from one level to the next, and that involves a consideration of teachers' professional development and teacher change.

One such model is proposed by Guskey (2002). The model presents a linear progression where teachers move smoothly forwards in time, with '*significant change in teachers' attitudes and beliefs [which] occurs primarily after they gain evidence of improvements in student learning.*' Guskey's model shows professional development leading to a change in teachers' classroom practice, which in turn leads to a change in student learning outcomes, which finally leads to a change in teachers' beliefs and attitudes. Guskey points out that '*teacher change is probably more cyclical than linear*'. The data from the CDP certainly supports this idea. With this in mind, a better model of teacher development would support Guskey's model, but would also go further by suggesting that the model ought to present teacher change as cyclical rather than linear in sequence, but also to suggest that the four elements of Guskey's model are repeated for each level of competency and form a cycle. The changes described by Guskey would be small incremental steps, where the teacher repeats activities until a small change occurs in classroom practice. This cycle repeats itself at each level of use.

The need for professional development to '*engage with teachers' hearts and minds*' is discussed by Watson (2001), who offers a '*re-forming*' model for effective professional development, which in turn is developed from a model by Taylor (1998, cited in Watson, 2001). This model identifies '*necessary stages [of] orientation, adoption, evaluation, innovation and institutionalisation*'. At each of these stages a different approach to the professional development of teachers is needed. The teachers in the CDP demonstrated that they were beginning to orientate themselves with using graphics calculators, but they needed time for reflection and the acquisition of basic skills, discussion and the consideration of alternative practices before they are able to start the adoption stage of the model. These '*necessary stages*' are taken into account within the proposed model and take place during the cycle of reflection.

Another linear model was presented by Pope and O'Sullivan (1998), and shows seven levels of teacher change: Examination, Preparation, Engagement, Adjustment, Acceptance, Advocacy, and Projection. The first three steps involve teachers beginning to use and '*get comfortable*' with the innovation, but still within their current context. This resonates strongly with the proposed 'rudimentary' level of calculator use. During the Adjustment and Acceptance phases, teachers begin a '*shifting or negotiation of espoused values*' and there is more of a '*fit between context and culture*'. In the final stages of Advocacy and Projection, teachers begin to '*take things further [and] look to future and possible refinements*'. The teachers in the CDP had begun to examine and make some preparations, but their engagement was limited.

Pope and O'Sullivan's 1998 model for the way a physical education teacher implements a new sports programme lists 7 stages for change at a personal level: '*Examination, Preparation, Engagement, Adjustment, Acceptance, Advocacy, Projection*'. The first stage involves the PE teacher, Barry, '*gaining familiarity with the change and contrasting personal values and assumptions with the innovation*'. The teachers in the CDP show some elements of this stage. The repeated use of the same graphics calculator functions and programs suggests that they are trying to become familiar with those aspects of the technology. However, they have not made any progress towards the next stage, which includes '*planning and creating documentation for the new initiative [and] getting comfortable through collegial and textual support*'. It is worth pointing out that Pope and Sullivan's model refers to the way the teacher begins to implement a new sports programme and is not related to the use of technology. However, the earliest stage does seem to describe the way the teachers in the CDP behaved when they began to use graphics calculators and it may be that the other stages could also be relevant to the use of graphics calculators. Pope and Sullivan also describe Barry's anxiety in the early stages, and this was also noted in the interview responses with the three teachers in the CDP. Interestingly, Pope and Sullivan also say that '*although the model follows a hierarchical structure, the stages are not finite. It became evident that at times it was necessary for Barry to revisit earlier stages before confirmation and progress occurred. It was also apparent that the amount of time spent at each stage was determined by Barry's willingness to attempt and experience the characteristics of the next stage*'. This '*revisiting earlier stages*' is an important aspect that is missing from many of the other models. The teachers in the CDP often showed aspects of '*revisiting*' and for this reason this aspect is included in the proposed model. Pope and Sullivan's model also recognises that moving through the stages is '*signalled by some behaviour that may have announced a shift in beliefs or underlying assumptions*'. Pehkonen and Torner (1999) describe this as a '*perturbance*'. Pehkonen and Torner go on to suggest that the '*growth graph is not a straight line nor, more generally, a smooth curve. There are tens of small incidents that continually influence teachers' belief systems and the growth curve is more like a step function*'. This idea of 'step-changes' is also built into the proposed model.

Work by Wiske et al (2001) describes the path that teachers take as they begin to make changes to their practice. They also suggest that this path is cyclical and that professional development activities are most effective when '*teachers experience cycles of learning new approaches...and then go onto the next loop on the spiral to learn something new*'. Furthermore, these spirals include '*cycles of practice, reflection and revision [within] a setting where new approaches can be tried out*'. Clearly, this cyclical aspect is important within the proposed model, as it describes the way the teachers in the CDP used graphics calculators. The cycle of practice, reflection and revision has also been noted in the data from the pilot study, the study of Mark and the teachers in the cross-sectional study. Senger (1999) calls this the '*recursive nature of change*' which involves moving back-and-forth between '*different ways of experimenting, rather than a linear movement in stages*'. This is addressed within the proposed model by suggesting that teachers move between levels in a forward as well as a backwards direction, depending on the nature and the context of the task. Stipek et al (2001) also comment that teachers '*move back and forth among a variety of settings to learn new instructional strategies, to try them out in their own classrooms and to reflect* *on what they observed in a collaborative setting'*. This finding is also supported by McNamara et al (2002). Reflection-on-action and reflection-in-action seem to be critical for teacher development (Eraut, 1995; Fullan, 2000; Schon 1983) and this element is included in the proposed model.

The models of professional development and teacher change discussed above all suggest that change is not a linear process, but instead that it is cyclical. The process is not necessarily always in a forward direction, and often involves going backwards and repeating and reflecting on tasks and activities. The path is not necessarily smooth, but may involve sudden step-changes in response to complex and often contradictory situations.

These models also support the idea that there is a level of graphics calculator use below that of efficiency which includes teachers' use of the technology as a motivational tool, rather than as a teaching and learning tool.

These aspects from the models of teacher development and change were combined with the models that describe how teachers use graphics calculators and ICT in general. Using this amalgamation a new model is proposed.

9.2 Proposal of a Model that Describes Teachers' Use of Graphics Calculators

The proposed model, shown in Figure 9.3, attempts to describe the data that has been collected from all the teachers in this research. The proposed model highlights the different levels of use, and includes a rudimentary level to describe the use of graphics calculators purely for motivation. The model also attempts to describe how teachers might move from one level of use to the next.

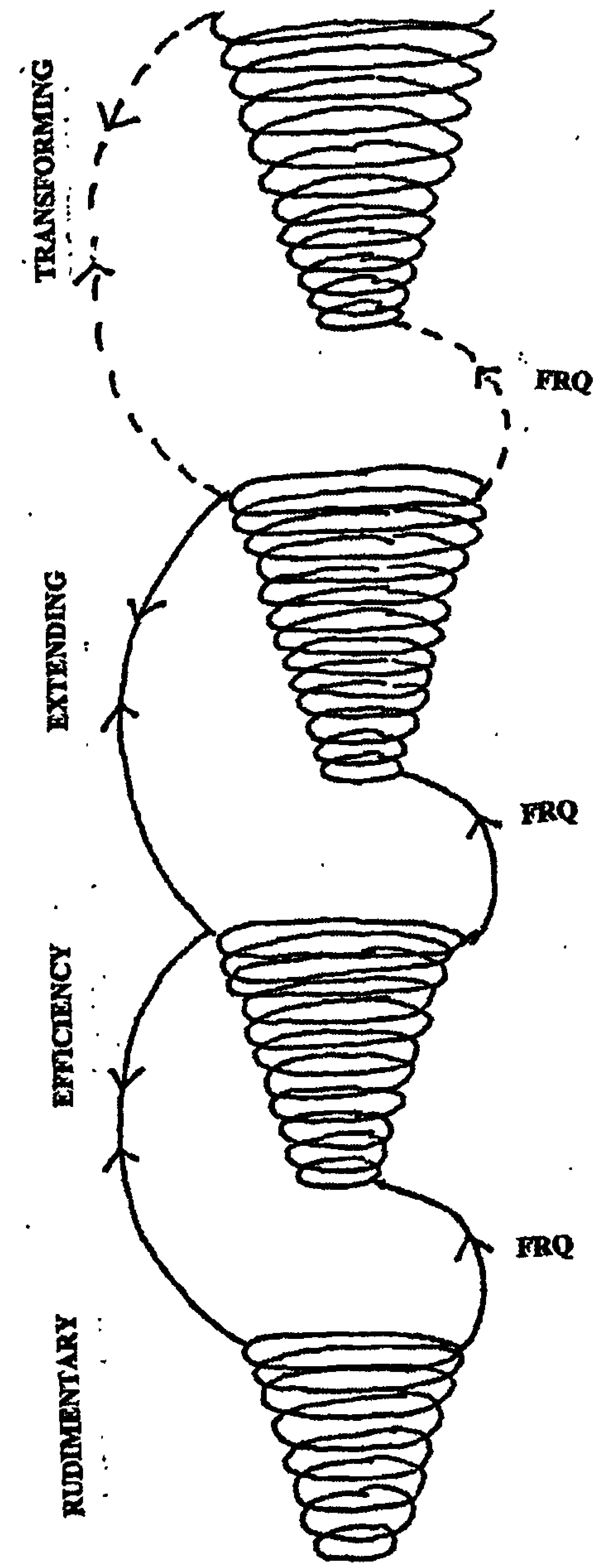

Figure 9.3 Proposed Model to Describe Teachers' use of Graphics Calculators

9.2.1 The Rudimentary Level

At the bottom of the 'vortex' the teacher is working at a rudimentary level. At this level they use the calculator as an aid to calculation, or as a means of motivating pupils within the classroom. They tend to use the teacher calculator and view-screen, rather than using the class set of graphics calculators; this gives them greater control of the technology within the classroom environment.

They use the calculator because of some external stimulus, such as an in-service training course, or because they need to meet some professional criteria such as appraisal, or because the use of graphics calculators is stipulated by the scheme of work.

The way that they use the graphics calculator is not linked to any specific pedagogical consideration. The type of tasks used at this level may be pre-loaded programs that have a game-like quality. The teachers have limited knowledge of the functionality of the graphics calculator, relying heavily on one or two aspects with which they are familiar. They tend to use the same lesson plan on several occasions, by repeating tasks that they have observed. After a few repetitions of teaching the same lesson with the same resources, they begin to make small changes and adaptations to the lesson. This cycle continues until they have 'perfected' the lesson plan and it becomes part of their repertoire.

As they begin to develop a familiarity with one or two functions of the graphics calculators and they make some use of them within the classroom situation, the teachers begin to feel more confident. They begin to reflect on their action, and then question what else the calculator can do. They begin to consider how the graphics calculator can be used to enhance the learning experience of their pupils. They move around this rudimentary level of the vortex: becoming more familiar and confident with the one or two functions of the calculator, questioning and reflecting-on-action. This is labelled as 'FRQ': familiarisation, reflecting and questioning. They ask questions about other functions that are available on the graphics calculator. To answer these questions they need support and guidance from other experts (colleagues, training institutions). Familiarisation, reflection and questioning with support can lead to a step-change in their use of the graphics calculator.

9.2.2 The Efficiency Level

At this point they begin to use the calculator as an efficiency tool. During this stage, they become familiar with further functions of the calculator, they continue to reflect-on-action and to ask what else the calculator can do. As with the rudimentary level, they repeat the same tasks over and over until they feel confident and proficient with the new functions of the graphics calculator. At this level they use tasks that make pupils' learning more efficient. They may use the graphing function to speed up the process of graph plotting, or they may use the graphics calculator for checking solutions. However, they continue to use earlier tasks as motivational tools, without necessarily considering the learning objectives.

They move around this second level of the vortex, repeating the same few lesson plans until they are acted upon by another stimulus. This may be an internal or external motivator; seeing an improvement in pupils' learning, seeing an improvement in their own teaching, or being directed by the scheme of work or school policy. During the FRQ phase they seek guidance from other experts in response to problems that they pose themselves. They begin to ask their own questions about pedagogy. In considering the answers to questions about teaching and learning a step-change leads them to use the graphics calculators to extend pupils' learning.

9.2.3 The Extending Level

Teachers using the graphics calculators to extend pupils' learning continue to repeat tasks and activities, occasionally returning to tasks used to motivate pupils, or to use graphics calculators for efficiency. However, new tasks are used to take pupils further with topic areas; considering cubics as well as quadratics when solving equations with year 9 pupils, or looking for multiple solutions when doing trial and improvement to find the roots of equations with year 8.

Teachers working at this level experiment with new functions without the support of other experts; their motivation becomes predominantly intrinsic. As these new functions become available to them, they become more familiar with the technology and their confidence and proficiency also improve. They have a greater repertoire of tasks. They continue to reflect-on-action and question what else the calculator can do. They consider questions of pedagogy in greater detail and how the use of graphics calculators can support pupils' learning. They find their own solutions to the problems they encounter; occasionally they need support from other experts. They continue to move back and forth between the rudimentary, efficiency and extending levels, repeating tasks until they have added them to their repertoire.

9.2.4 The Transformation Level

Occasionally, teachers are able to move beyond the extending level to a transformation level. At this level they are able to make institutional changes, and act as mentors for colleagues working at the lower levels. Their practice becomes transformed by their use of the calculator, as they continue to move around the last phase of the vortex. This phase is heavily self-motivated, the stimuli are predominantly internal. Questioning and reflecting-on-action are the main features of this level of the vortex. During the FRQ phase they may become involved in action research, examining their own practice.

As teachers progress through the levels, their field of experience is widened; they have more skills in their repertoire, and use previously learnt functions more proficiently. They continue to use tasks added to their repertoire from earlier stages. Being actively involved in the FRQ phase acts as the catalyst for the 'perturbation' that moves them to the next level.

9.3 Summary

The proposed model addresses the aspects that were missing from McCormick and Scrimshaw's three levels of use, by describing a rudimentary level and considering the possible movement between levels. The additional, rudimentary level fits with the data collected from the CDP log books. It also describes the way that teachers use the same tasks and activities on several occasions. The theme of repeating the same lesson has been observed in the Pilot study, the case study of Mark and the cross-sectional study of qualified teachers. The proposed model recognises that progression from one level to the next is not automatic, nor is it a simple smooth curve upwards. Instead progression is cyclical, with teachers repeating and rehearsing tasks. Only when they are confident with one aspect do they begin to consider new tasks. The proposed model also highlights that these is a movement back-and-forth between the levels; even when a teacher has used activities that extend the reach of their pupils, they will continue to use tasks purely for motivation when they feel it is appropriate. Thus teachers have an ever widening repertoire of lessons and tasks.

The proposed model also recognises that many teachers will not reach the transformation level. The tasks and activities that have been observed during this research have been at the efficiency level and occasionally begin to address some aspects of the extending level.

The proposed model also addresses teachers' professional development; familiarisation, reflecting and questioning helps teachers to consider pedagogical aspects of using graphics calculators. Familiarisation helps to build confidence, and encourages teachers to ask 'what else?' questions about how the technology can be used to enhance their teaching practice.

The proposed model is presented in this thesis as an enhancement of the previous models suggested in the literature.

Chapter 10. Conclusion

10.0 Introduction

This chapter summarises the findings from this research project. The first section returns to consider the initial research questions and whether the research has been able to address all of the key aspects. Section 2 of this chapter locates this research and the findings within the wider context, and how those findings support earlier studies. Section 3 discusses the implications of this research and the findings on teacher education and my own professional development. Section 4 suggests areas for further research.

10.1 Returning to the Research Questions

The research questions that were initially posed have given rise to difficult, complex and often contradictory ideas.

10.1.1 Why do teachers teach the way they do?

Where do they get their teaching ideas from?

What are the influences that affect teachers' teaching styles?

Trying to explain why teachers teach the way they do has been one of the most complex issues addressed in this thesis. It is, perhaps, best summarised by Hargreaves (2000) who lists four grounds teachers use to justify their practices:

- *Tradition (how it has always been done)*
- *Prejudice (how I like it done)*
- *Dogma (this is the 'right' way to do it)*

• *Ideology (as required by the current orthodoxy)*

Whichever of these four reasons teachers use, it is most likely to be a result of some belief that they hold. Whilst it is still difficult to describe the mathematical philosophy of the teachers in this study, aspects of their educational philosophy were evident from their classroom practices. Most teachers hold various views of the nature of mathematics depending on the context. Schraw and Olafson (2002) summarise this by saying that '*teachers are consistent in their epistemological beliefs, and can thus be characterised by only one of three world views at any particular point in time...it is rare for hybrid positions to occur*'. One could argue about the number of world views, but each teacher in this study has shown various viewpoints at different times. One particular observation that is worthy of comment, is that the teachers in this study react to pupils' behaviour. The teachers' practice changes in reaction to how the class behaves. For instance, some overriding belief about how pupils ought to behave in a mathematics classroom supersedes any belief they may have about how they ought to teach.

10.1.2 Are Teachers' beliefs about mathematics, teaching and learning evident from their teaching practices? Do their beliefs about mathematics teaching and learning influence their use of graphics calculators in the classroom? What motivates teachers to use graphics calculators?

Whilst teachers hold views about teaching and learning (albeit difficult to label), they do not seem to have views about mathematics. The teachers in this study would not be able to define themselves as 'a Platonist' or 'an instrumentalist', for instance. However, teachers' beliefs about teaching and learning are evident, to some extent, from their teaching practices. For instance, teachers who believe that teaching is about passing examinations will often encourage rote learning; teachers that believe that pupils should construct their own understanding will often set up tasks that encourage pupils to explore a particular topic. But their classroom practices are not consistently a result of their beliefs. Teachers will adopt a constructivist attitude because the scheme of work for a particular topic tells them to and fall in line with the cultural norms of the school that they work in, '*the socialisation effect of the context is so powerful that despite having different beliefs about mathematics and its teaching, teachers in the same school are often observed to adopt similar classroom practices*' (Ernest, 1994).

However, regardless of whether they are transmissionist or constructivist at any given point in time, it has been difficult to forecast whether they will have a positive attitude towards using graphics calculators in their teaching. Their beliefs and attitudes towards graphics calculators do not seem to fit in with the way they teach mathematics. There were some teachers that used open-ended investigations or used practical experiments but seemed to be unwilling to use graphics calculators, whereas some teachers with a didactic teaching style were prepared to teach with graphics calculators. Contrary to expectations, the use of graphics calculators does not seem to be predicated on teachers' beliefs about mathematics.

10.1.3 When teachers do use graphics calculators, what type of tasks are they using?

Are teachers making good use of graphics calculators?

How do teachers integrate the use of graphics calculators into their lesson planning?

How does teachers' use of graphics calculators develop over time?

The teachers in this study all seemed to use tasks that they had come across whilst on teaching practice or observed during an in-service training session. These tasks fell into two categories: graphing, predominantly straight lines, to produce many graphs quickly and efficiently or programs with a game-like aspect to motivate pupils. All the teachers who used graphics calculators in this study reported that they had observed someone else do something similar. Only Nina (PGCE, Pilot Study) wanted to do something specific, which she had not observed before. She overcame this by asking me to go through how I would teach the lesson so she could repeat it with her class.

It is difficult to define 'good' in the context of using graphics calculators. Using McCormick and Scrimshaw's (2001) three levels of ICT use 'good' use is when teachers make teaching and learning efficient, or they extend or transform pupils' understanding of mathematics. Using these three levels as benchmarks, the teachers in this study rarely made 'good' use of graphics calculators. Only Nina was able to extend pupils' learning. Several teachers in this project used graphics calculators to make their lessons more efficient. The graphing function was used to alleviate the tedium of having to plot straight line graphs, for instance. However, the time that was gained by using the technology was not fully utilised, thereby negating any efficiency 'gains'.

The teachers in this study did not really integrate the use of graphics calculators into their lesson planning. This was for several reasons: they only really had one lesson plan (straight line graphs or a variation), they weren't confident enough to introduce tasks of their own design, and the pre-loaded programs that were used as lesson starters were not linked to the content of the main lesson. Generally, the graphics calculator was treated as a bolt-on extra.

The main influences on whether teachers use graphics calculators or not seem to be their level of self-confidence and expertise. The more confident they are they more willing they appear to be to explore the use of the graphics calculators. However, in the early stages they need considerable guidance about the pedagogical aspects as well as the technical skills. Unfortunately the systems in place work against this, and more often than not teachers are left to flounder by themselves. Initial teacher education has limited impact as the student-teachers devalue what the educational institutions have to offer by privileging the world of the classroom. In-service training courses also have little impact as there is no opportunity to reflect, rehearse, repeat and report back. Teachers are left to do this on their own, and there is little impetus to do so. In order to increase confidence levels teachers need to be <u>shown</u> what to do with graphic calculators in a classroom context. They need opportunities very soon afterwards to repeat what they have observed so that they become <u>familiar</u> with that aspect, and then to <u>reflect</u> on the pedagogical aspects. This encourages them to <u>question</u> what else the technology can do. This, in turn, leads to the next cycle of familiarisation, reflection and questioning. Only when teachers have reached a certain level of self-confidence can they continue this cycle alone. Until then they need support and guidance from other experts.

10.2 How this thesis supports work done by other researchers

This thesis has drawn on many earlier studies, but it has also attempted to support and advance work done by other researchers.

Doerr and Zangor (2000) note that '*The relationship between teachers' knowledge and pedagogical strategies and their use of the graphing calculator is largely unexamined. Many studies... do not report or describe the role of the teacher in the classroom or the teachers' knowledge and skill with the graphing calculator or the teachers' beliefs about the efficacy of or kinds of uses of the graphing calculators in mathematics learning.*' Similar comments have been made by Crisan (2004), Simmt (1997) Harskamp et al (1998), Aguirre and Speer (2000), and Demetriadis et al (2003) amongst others. Observations and interviews from this research have added rich data on how teachers use graphics calculators, and it is hoped that this thesis goes some way to addressing the points raised by Doerr and Zangor.

The research methodology used in this thesis supports the work of Schraw and Olafson (2002), who noted that '*there is a great need for cross-sectional and longitudinal studies of epistemological development. Of special interest is how epistemological beliefs and world views change due to instruction and experience during teacher preparation, and how these changes affect teaching practice.*' Most of the work to date had been single case studies of an individual, or of a department. Some research has been done on how pupils use graphics calculators or CAS type calculators. Other studies have been of large scale surveys into beliefs and attitudes. The use of a longitudinal study alongside a cross-sectional study, as reported in this thesis, was not found in the literature on mathematics teachers and the use of graphics calculators. It is hoped that the longitudinal case study of Mark adds to the information about how teachers develop their teaching practice, and that the cross-sectional study contributes to the way that teachers beliefs and attitudes affect their teaching practices.

Work by several other researchers has been corroborated by the findings from this study: for instance, Leat and Higgins (2002) point out that teachers find it easier to try just one strategy with one class at a time using an existing exemplar. Wiske et al (2001) suggest that teachers are involved in a cycle of observation, reflection and revision. The data collected from the CDP can be used to verify Kissane's (2003) model of teachers' use of graphics calculators. The data from the other teachers in this study supports Senger's (1999) claim that '*Teachers have a penchant for rethinking, pre-playing and replaying ideas, concepts and classroom scenarios in their heads.*'

However, as well as corroborating work done by other researchers, this thesis attempts to add to their findings by proposing a new model that describes aspects of teachers' use of graphics calculators not previously considered within the wider context of their classroom practices.

10.3 Implications of this study

The findings from this research suggest that university tutors need to work more closely with the school-based subject mentors. This came from the analysis of the questionnaire data which suggested that the PGCE course had little or no influence on the trainees' beliefs. The student-teachers tend to privilege the real world of the classroom, and university tutors need to take this into account. Team-teaching with the class teacher would place the university pedagogy into the classroom context.

Continuing professional development needs to provide an opportunity for teachers to observe, rehearse, repeat and report back, especially when using graphics calculators.

The training in graphics calculators needs to be situated in a classroom context, and needs to include technical and pedagogical aspects.

Teacher educators need to model the use of activities that extend and transform pupils' learning rather than present tasks that use graphics calculators as efficiency tools. They also need to demonstrate how graphics calculators can be used for all curriculum areas, such as statistics, modelling, problem solving and not the narrow area of graph plotting.

10.4 Limitations of this research

Despite great efforts to ensure that this research would be valid for a general population of mathematics teachers, it is unlikely that all teachers' use of graphics calculators can be described by the proposed model. The data collected in this thesis is specific to the geography of the local schools and local teacher training institutes, and many of the assertions may not apply further afield.

Also, the model attempts to describe the way teachers use graphics calculators and has not really been tested against teachers' use of CAS type calculators, nor even scientific calculators.

The log books were used only in the final stages of data collecting. Retrospectively, their use would have given a valuable insight into the work of all the other participants in this study. Corroboration with teachers' planners and departmental schemes of work would have provided further data and given greater insight into teachers' use of all types of calculators and technology.

10.5 Suggestions for further research

The process of researching for this thesis has raised more questions than it has answered. One of the most interesting questions for me has been to consider pupils' behaviour. The teachers in this study have often commented that pupils' behaviour prevents them from using graphics calculators. Studies (for instance Guskey, 2002; Sam and Kee, 2004) have shown that the use of technology changes the atmosphere and dynamics in the classroom. This leads me to ask:

- **Why do teachers feel 'threatened' by this change in atmosphere?**
- **How can teachers be encouraged to harness the energy that pupils generate whenever graphics calculators are brought into the classroom?**

The longitudinal study of Mark seems to suggest that he adopts the cultural norms of the department in which he works. I wonder if he would make more and better use of graphics calculators if he were working in a technology-orientated school. Further study of a novice teacher's use of graphics calculators in a school with a strongly positive stance towards technology would help to understand the use of graphics calculators as part of the wider school context.

- **What type of tasks and activities would be used by a novice teacher working in this type of school?**

More data need to be collected to further validate the proposed model, and to test it against other types of technology.

- **Does the model still hold for CAS type calculators?**
- **Does the proposed model hold for the use of interactive whiteboards?**
- **How does the way teachers use scientific calculators differ from the way they use graphics calculators?**

Much of the work in this thesis has been predicated on the assumption that graphics calculators should be integrated into mathematics lessons. However, several authors have questioned this assumption. Scott and Dinham (2002) comment that teachers are encouraged to take up new initiatives because they are told that education is in crisis. Guskey (2002) suggests that professional development is all about improving the learning outcomes of students, yet the media constantly report that mathematics education has been "dumbed down". Olson (2000) calls technology the '*Trojan horse in our midst*' and warns us of being swept away by it promises.

Ahmed et al (2004) summarize the conflicting views about whether to use graphics calculators or not:

'*How materials and tools are used is the most important factor, since teachers can use: good materials well; good materials badly; bad materials well and bad materials badly. Hence, the effective use of didactical materials used in the classroom will depend on the nature of classroom tasks, role of the teacher and the climate and social culture of the classroom.*'

My own position on the use of graphics calculators in mathematics classrooms has changed considerably over the period of this study. Previously, I used graphics calculators at every opportunity, normally at the rudimentary level. The technology was used predominantly as a novelty and very little mathematics was being learnt by the pupils. Now, I put the learning of the mathematics as the highest priority and the use of technology needs to fit in with that attitude. This has resulted in a better experience for my pupils, as they are more proficient at using graphics calculators for doing mathematics.

Appendices

Appendix A: Mark's Completed Pre-test Questionnaire

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Questionnaire 1 (PGCE)
Each statement numbered 1 to 20 expresses an opinion about using graphics calculators to teach mathematics. Please tick the extent to which you agree or disagree with the opinion stated using the 5 point scale:

1: strongly agree 2: agree 3: no opinion 4: disagree 5: strongly disagree

		1	2	3	4	5
1	Students should not be allowed to use a graphics calculator while taking maths tests				✓	
2	Graphics calculator use will cause a decline in basic arithmetic skills				✓	
3	Graphics calculators make mathematics fun		✓			
4	It is easier to solve maths problems using a graphics calculator				✓	
5	More interesting problems can be done when students have access to a graphics calculator	✓				
6	Students understand maths better if they solve problems using paper and pencil methods				✓	
7	All students should learn to use a graphics calculator		✓			
8	Students should not be allowed to use a graphics calculator until they have mastered the concept or procedure					✓
9	Using graphics calculators means students can do harder maths			✓		
10	Students should learn how to use a graphics calculator as part of their maths lessons		✓			
11	Teachers should know how to use graphics calculators	✓				
12	Graphics calculators should only be used to check work once a problem has been worked out on paper				✓	
13	Using graphics calculators makes students better mathematicians			✓		
14	Graphics calculators are good for checking solutions			✓		
15	Using graphics calculators with young pupils makes them better at maths later on			✓		
16	Teachers should teach student how to use graphics calculators	✓				
17	Graphics calculators are only good for doing calculations more quickly					✓
18	Graphics calculators can be used for investigations	✓				
19	Graphics calculators are too complicated to be used by younger pupils					✓
20	Money spent on graphics calculators would be better spent on textbooks.				✓	

21 I own	make/model (If known)	date of purchase (approx)
A 4-function calculator	Mobile Phone	'98
A Scientific calculator	Casio fx-570S	'98
A Graphics calculator	Caso -Cfx-6000?	'95
A CAS calculator		
I do not own any calculators		

will be getting a Texas TI-83 (School uses these).

22. Have you been shown how to use a graphics calculator as a part of your PGCE course?

No	Yes, an introduction
Yes, integrated into some topics ✓	Yes, integrated into all topic areas

23. Have you observed any lessons where graphics calculators were used in a maths lesson? YES/NO If YES, please give details (e.g. year group, topic, number of calculators available etc.)

NO

24. Have you used graphics calculators on your teaching practice? YES/NO
If YES, please give details (e.g. year group, topic, etc.)

25. How would you rate your personal use of graphics calculator for the following topics

Topic	Very Confident	Some knowledge	No knowledge
Programming		✓	
Plotting graphs	✓		
Transformations of functions		✓	
Equation solving	✓		
Tables		✓	
Iterative methods	✓		
Descriptive statistics		✓	
Statistical tests	✓		
Motion detector			✓

Thank you very much for taking the time to complete this questionnaire. Your responses will be treated in the strictest confidence. If you would be willing to take part in follow-up interviews or would like to be informed of my findings please include your name/contact details.

Appendix B: Mark's Completed Post-test Questionnaire

Questionnaire 1 (PGCE)
Each statement numbered 1 to 20 expresses an opinion about using graphics calculators to teach mathematics. Please tick the extent to which you agree or disagree with the opinion stated using the 5 point scale:

1: strongly agree 2: agree 3: no opinion 4: disagree 5: strongly disagree

		1	2	3	4	5
1	Students should not be allowed to use a graphics calculator while taking maths tests				✓	
2	Graphics calculator use will cause a decline in basic arithmetic skills				✓	
3	Graphics calculators make mathematics fun		✓			
4	It is easier to solve maths problems using a graphics calculator				✓	
5	More interesting problems can be done when students have access to a graphics calculator	✓				
6	Students understand maths better if they solve problems using paper and pencil methods				✓	
7	All students should learn to use a graphics calculator		✓			
8	Students should not be allowed to use a graphics calculator until they have mastered the concept or procedure					✓
9	Using graphics calculators means students can do harder maths			✓		
10	Students should learn how to use a graphics calculator as part of their maths lessons		✓			
11	Teachers should know how to use graphics calculators	✓				
12	Graphics calculators should only be used to check work once a problem has been worked out on paper				✓	
13	Using graphics calculators makes students better mathematicians			✓		
14	Graphics calculators are good for checking solutions			✓		
15	Using graphics calculators with young pupils makes them better at maths later on			✓		
16	Teachers should teach students how to use graphics calculators	✓				
17	Graphics calculators are only good for doing calculations more quickly					✓
18	Graphics calculators can be used for investigations	✓				
19	Graphics calculators are too complicated to be used by younger pupils					✓
20	Money spent on graphics calculators would be better spent on textbooks.				✓	

Space to comment on any of the statements above:

Number	Comment:
	Please continue overleaf if necessary.

Appendix C: Completed HoD Questionnaire

Questionnaire: HOD

1. How long have you been teaching? [illegible]

2. How long have you been a Head of Department in your current school? [illegible]

3. What is the make-up of your department?

Number of F/T	11
Number of P/T	2
How many hold positions of responsibility outside of the maths department? 3	

4. How many class sets of graphics calculators are there within your department?

0	1	2	3	4+

5. What make and model would you or have you purchased? [illegible]

6. Why did you choose this make/model? [illegible]

7. How many LCD calculator projection panels are there within your department?

0	1	2	3	4+

8. Have students purchased their own graphics calculators?

	KS3	KS4	Post -16
Number on roll(approx)	1100	700	
Approximately, how many have purchased their own graphics calc?	0	0	[illegible]

9. Describe, briefly, your department's policy on graphics calculator usage.

To use graphical calculators [illegible] to enhance pupils understanding [illegible] mathematics

10. Describe the type and quality of training that has been provided for your department on graphics calculators, in particular and ICT in general, over the last two years. (Continue on separate page if necessary.)

Topic	Venue (in-school, LEA site, etc)	Duration	No of dept that attended	The training was stimulating and has had an impact in the classroom	The training was stimulating, but has had limited impact in the classroom	The training was stimulating, but has had no impact in the classroom	The training was poor, but has had an impact in the classroom	The training was poor and has had no impact in the classroom	Space for your own comment
ICT				Tick columns and/or add own comment					
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]				[illegible]
[illegible]									[illegible]
[illegible]	[illegible]	[illegible]							[illegible]
									[illegible]
									[illegible]
Graphics calculators									[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
									[illegible]
									[illegible]
									[illegible]

11. To what extent has the KS3 Framework for Teaching Mathematics influenced the use of graphics calculators within your department?

No influence	Limited influence	some influence	Heavily influenced
		✓	

Space to add comment:

Many teachers [illegible]

[illegible]

and [illegible]

12. If you have class set(s) of graphics calculators, estimate how often they are used during an average week

	Regularly (once a week)	Occasionally (half-termly)	Rarely (termly)	Never
Post-16	[illegible]	[illegible]	[illegible]	
KS4		✓		
KS3		✓		

13. How many teachers within your department use graphics calculators regularly, as part of their teaching? [illegible]

14. How many teachers within your department use the LCD calculator projection screen regularly, if you have one? [illegible]

15. Does anyone have specific responsibility for developing resources for graphics calculators within your department? If so, how are these resources disseminated?

16. Describe any systems that are in place within your department/school that actively encourage the use of graphics calculators.

[illegible]

17. Describe any systems that are in place within your department/school that inhibit the use of graphics calculators

18. How would you rate your personal use of graphics calculator for the following topics?

Topic	Very Confident	Some knowledge	No knowledge
Programming		✓	
Plotting graphs	✓		
Equation solving	✓		
Tables of values	✓		
Iterative methods and sequences			
Statistics	✓		

19. Describe your thoughts and feelings about using graphics calculators in maths lessons

Thank you very much for taking the time to complete this questionnaire; your comments are strictly confidential and will only be used for my research project.
If you would be willing to take part in the next stage of my research project please contact me (shoneV@plymouth.ac.uk) or include your name and contact details here:

Name: ontact details:

Appendix D: Sample Page from Log Book

Date: 19/11/02 **Class: Year** 7 **Set** 1/3

Objectives for Lesson:

[illegible]

Who used the graphic calculator in this lesson? (tick one box)

Teacher only ☑ Pupils only ☐ Teacher and pupils ☐

Was the Viewscreen used? yes ☑ no ☐

What part of the lesson was the calculator used in? (tick all that apply)

Starter ☑ Main teaching activity ☑ Plenary ☐

Which calculator facilities were used?

Numerical ☐ Graphical ☐ Tabular ☐ Statistical ☐ Data logging ☐

Programs ☑ please give details........ STUCTRIP [illegible] ....

APPS ☐ please give details..

Other ☐ please give details..

What Teaching approaches were used?

As a mathematical tool ☐ As a visualisation tool ☐

As an exploratory environment ☐ As an investigational environment ☐

Other ☐ please give details..

Did you or your pupils have any difficulties with the calculator or the lesson as a result of using the calculators? yes ☐ no ☑

If yes please give details:

How did you solve any problem?

Were the learning Objectives fulfilled?: (1 = fully, 5 = not at all) 1 2 3 4 5 (Please circle)

Thinking about next time you have to teach this lesson would you:-

Teaching Approach: make no changes ☑ make minor changes ☐ make major changes ☐

Calculator Use: Increase calculator use ☐ Decrease calculator use ☐ Make no change in calculator use ☑

Were there any benefits of using the graphic calculator as opposed to not using it in this lesson?
Please give details.

Students using negative numbers without [illegible]

Were there any disadvantages of using the graphic calculator as opposed to not using it in this lesson?
Please give details.

As [illegible] at front + taking it in turns [illegible] ~~[illegible]~~ [illegible]

Please use this page to make any other comments about the lesson.

students
Extension were out and some others were away
so I had a small group to do some games with.

I had a slight theme of negative numbers
our current topic.

Appendix E: Summary of Pre-test Questionnaire Responses by PGCE Students from Institute 1

student	qn1	qn2	qn3	qn4	qn5	qn6	qn7	qn8	qn9	qn10	qn11	qn12	qn13	qn14	qn15	qn16	qn17	qn18	qn19	qn20
1	4	2	2	3	2	2	2	2	4	2	2	4	4	2	3	2	2	2	3	3
2	4	3	2	2	2	4	2	3	2	2	2	3	3	2	4	2	2	2	3	3
3	3	2	3	3	2	4	4	2	3	2	2	2	4	1	4	3	1	2	2	2
4	4	1	1	3	1	2	1	2	3	1	1	2	3	2	3	1	1	1	1	1
5	2	3	2	3	2	2	2	2	2	2	1	3	3	2	2	2	2	2	1	3
6	2	1	2	2	1	4	1	4	1	1	1	1	1	1	1	1	1	1	4	5
7	5	5	2	3	2	5	3	5	5	3	4	4	5	2	5	3	4	3	5	5
8	2	2	2	4	1	2	2	1	3	2	1	2	3	3	3	1	1	1	1	2
9	2	3	2	2	4	4	.	4	2	2	1	2	4	2	4	2	2	3	2	3
10	2	2	2	2	2	4	1	2	4	1	1	2	2	2	3	1	2	2	2	2
11	2	2	2	2	2	4	2	4	2	2	2	2	2	3	2	2	2	1	2	1
12	2	1	5	4	5	2	2	2	5	2	2	2	5	2	5	2	2	3	4	3
13	1	1	2	4	1	1	1	1	4	1	1	2	3	2	2	2	1	1	2	1
14	1	1	4	4	4	1	1	1	5	1	1	1	5	1	5	1	1	1	2	1
15	2	2	2	4	2	2	1	1	4	1	1	2	3	1	4	2	1	1	2	1
16	4	2	1	3	2	3	2	4	2	2	1	2	3	1	3	1	2	4	3	2
17	1	1	1	1	1	5	1	3	3	1	1	1	2	2	3	1	1	2	2	2
18	2	2	2	2	2	4	3	3	2	3	2	3	5	3	3	3	2	2	2	2
19	5	3	3	2	2	2	2	2	4	1	1	2	3	2	3	2	2	2	2	3
20	3	3	2	3	3	3	2	3	3	2	2	3	4	2	3	2	2	3	3	3
21	4	2	1	4	3	2	1	2	4	2	2	2	4	2	3	2	2	2	2	2
22	4	2	2	2	1	2	2	2	4	2	2	2	4	2	3	3	2	2	2	3

Appendix E: Summary of Post-test Questionnaire Responses by PGCE Students from Institute 1

Student	qn1	qn2	qn3	qn4	qn5	qn6	qn7	qn8	qn9	qn10	qn11	qn12	qn13	qn14	qn15	qn16	qn17	qn18	qn19	qn20
1	4	2	2	4	2	2	2	2	4	2	2	2	3	3	3	3	2	2	2	2
2	4	2	2	2	2	4	2	2	2	2	2	2	3	2	4	2	2	2	3	3
3	3	2	3	3	2	4	4	2	3	2	2	2	4	2	4	2	1	2	2	2
4	4	1	2	3	1	2	1	2	4	1	1	3	3	2	4	1	1	1	1	1
5	2	3	2	3	2	2	2	2	2	2	1	2	3	2	2	2	2	2	1	2
6	2	1	2	2	1	4	1	4	2	2	1	1	2	2	2	1	1	1	2	5
7	5	5	2	4	4	5	4	5	3	3	4	5	5	2	5	2	4	2	5	5
8	2	2	2	4	1	2	2	1	3	2	1	2	3	3	3	1	1	1	1	2
9	2	3	2	2	4	4	2	4	2	2	1	2	3	2	4	2	2	3	2	3
10	2	2	2	2	2	4	2	2	4	2	1	2	3	2	2	1	2	2	2	2
11	3	3	2	2	2	4	2	4	2	2	2	2	4	2	2	2	2	2	2	1
12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
13	1	2	2	3	1	1	1	1	2	1	1	2	4	2	2	2	1	2	1	1
14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
15	2	2	2	4	2	2	1	1	4	1	1	2	3	1	4	2	1	2	2	2
16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
17	1	1	1	1	1	5	1	2	2	1	1	2	2	2	2	1	2	2	2	2
18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
19	5	4	4	2	2	2	2	2	4	1	1	2	4	2	4	2	2	2	2	4
20	3	3	2	2	2	3	2	2	2	2	2	2	4	2	3	2	2	2	3	3
21	4	2	2	4	2	2	1	2	4	2	2	2	4	2	3	2	2	2	2	2
22	4	2	2	2	1	2	2	2	4	2	2	2	4	2	4	3	2	2	2	2

Students should not be allowed to use a graphics calculator while taking maths tests

Qn1	1 (SD)	2	3	4	5(SA)
inst1	18%	45%	11%	20%	5%
inst2	14%	64%	14%	7%	0%
inst3	10%	20%	40%	10%	20%

Graphics calculators use will cause a decline in basic arithmetic

Qn2	1(SD)	2	3	4	5(SA)
inst1	25%	45%	16%	11%	2%
inst2	21%	79%	0%	0%	0%
inst3	30%	40%	20%	10%	0%

Graphics calculators make mathematics fun

Qn3	1(SA)	2	3	4	5(SD)
inst1	18%	57%	18%	5%	2%
inst2	29%	43%	7%	14%	7%
inst3	20%	60%	20%	0%	0%

It is easier to solve maths problems using a graphics calculator

Qn4	1(SA)	2	3	4	5(SD)
inst1	9%	43%	23%	20%	5%
inst2	14%	57%	21%	7%	0%
inst3	10%	50%	10%	30%	0%

More interesting problems can be done when students have access to a graphics calculator

Qn5	1(SA)	2	3	4	5(SD)
inst1	27%	52%	9%	7%	5%
inst2	21%	71%	0%	0%	7%
inst3	40%	40%	0%	20%	0%

Students understand maths better if they solve problems using paper and pencil methods

Qn6	1(SD)	2	3	4	5(SA)
inst1	27%	36%	11%	20%	5%
inst2	0%	29%	21%	43%	0%
inst3	10%	50%	0%	40%	0%

All students should learn to use a graphics calculator

Qn7	1(SA)	2	3	4	5(SD)
inst1	41%	39%	11%	7%	0%
inst2	36%	14%	21%	21%	7%
inst3	10%	30%	40%	20%	0%

Students should not be allowed to use a graphics calculator until they have mastered the concept or procedure

Qn8	1(SD)	2	3	4	5(SA)
inst1	18%	34%	18%	18%	11%
inst2	0%	29%	36%	29%	7%

inst3	10%	40%	20%	0%	30%

Using graphics calculators means students can do harder maths

Qn9	1(SA)	2	3	4	5(SD)
inst1	11%	30%	18%	30%	11%
inst2	14%	57%	14%	7%	7%
inst3	30%	30%	10%	30%	0%

Students should learn how to use a graphics calculator as part of their maths lessons

Qn10	1(SA)	2	3	4	5(SD)
inst1	34%	55%	7%	5%	0%
inst2	36%	43%	14%	7%	0%
inst3	10%	40%	30%	20%	0%

Teachers should know how to use a graphics calculator

Qn11	1(SA)	2	3	4	5(SD)
inst1	59%	36%	0%	5%	0%
inst2	57%	36%	7%	0%	0%
inst3	40%	60%	0%	0%	0%

Graphics calculators should only be used to check work once a problem has been worked out on paper

Qn12	1(SD)	2	3	4	5(SA)
inst1	16%	50%	25%	7%	2%
inst2	21%	64%	7%	7%	0%
inst3	10%	70%	10%	0%	10%

Using graphics calculators makes students better mathematicians

Qn13	1(SA)	2	3	4	5(SD)
inst1	5%	27%	36%	18%	14%
inst2	0%	29%	50%	7%	21%
inst3	0%	40%	10%	30%	20%

Graphics calculators are good for checking solutions

Qn14	1(SA)	2	3	4	5(SD)
inst1	25%	59%	11%	5%	0%
inst2	43%	57%	0%	0%	0%
inst3	30%	70%	0%	0%	0%

Using graphics calculators with young pupils makes them better at maths later on

Qn15	1(SA)	2	3	4	5SD)
inst1	7%	18%	52%	14%	9%
inst2	0%	21%	64%	14%	0%
inst3	0%	20%	40%	20%	20%

Teachers should teach students how to use graphics calculators

Qn16	1SA)	2	3	4	5(SD)
inst1	30%	52%	14%	5%	0%
inst2	7%	79%	14%	0%	0%
Inst3	10%	50%	30%	10%	0%

Graphics calculators are only good for doing calculations more quickly

Qn17	1(SD)	2	3	4	5(SA)
inst1	27%	57%	2%	11%	2%
inst2	36%	43%	7%	14%	0%
inst3	20%	70%	0%	10%	0%

Graphics calculators can be used for investigations

Qn18	1(SA)	2	3	4	5(SD)
inst1	36%	45%	14%	2%	0%
inst2	57%	36%	7%	0%	0%
inst3	30%	50%	20%	0%	0%

Graphics calculators are too complicated to be used by younger pupils

Qn19	1(SD)	2	3	4	5(SA)
inst1	14%	57%	9%	16%	5%
inst2	21%	36%	21%	14%	7%
inst3	30%	40%	0%	30%	0%

Money spent on graphics calculators would be better spent on textbooks

Qn20	1(SD)	2	3	4	5(SA)
inst1	20%	45%	27%	2%	5%
inst2	21%	43%	21%	0%	14%
inst3	20%	40%	30%	10%	0%

Appendix G: Summary of all the HoD Questionnaires

	hod1	hod2	hod3	hod4	hod5	hod6	hod7	hod8	hod9	hod10	hod11	hod12	hod13	hod14	hod15
1. teaching years	10	26	23	19	21	15	8	11	12	13	25	9	25+	7	35
2. years as HoD	3	10	1	2	9	9	1	2	8	3	12	0.25	4	1	14
3a No of F/T staff	7	7	5	13	8	11	8	7	2	6	10	6	4	7	8
3b No of P/T staff	4	2	1	2	1	2	3	1	5	5	1	2	1	1	1
4.Class sets of GCs	0	1	2	3	1	1	1	1	1	0	1	1	1	1	1
5. Make/model	0	TI-83	Texas	casio	TI-81	TI 83	casio	TI 80	TI 73		TI-83	TI-83	TI-83	TI-83	sharp
6. reason for make	0	inset	familiar	familiarity	inset	familiar	price	inherited	uni		uni	inset	press	familiar	uni
7. No LCD panels	2	4	2	4	1	1	1	1	1	0	4	1	1	3	1
8a No of KS3 with GC	0	0	0	0	0	0		0	1/180	0	0	0	0	0	0
8b. No of KS4 with GC	0	0	0	0	0	0		10/400	1/120	2/370	0	0	0	0	10
8c. No of 16+ with GC	0	65/160	15/240	0	0	40	most/30	10/100		0	0	20/200	0	3/180	10
9. dept policy on GC	0	0	sow 16+	sow all ks	ma1, s/d/t	enc'rage	discretion	embryonic	Intro	T's only	starters	ad hoc	0	0	enc'rage
10a ICT inset	1	0	1	1	3	2	0	0	2	2	1	3	0	2	2
10b. GC inset	0	0	0	1	1	0	2	0	1	2	2	1	0	1	2
11. influence of NNS	0	0	1	1	0/cmmnt	2/cmmnt	1/cmmnt	1/cmmnt	1/cmmnt	1	0/cmmnt	1	0	3	1
12a. Use of GC, 16+	0	1	2	3	1	3		1		1	2	3	2	1	3
12b. Use of GC, KS4	0	2	0	2	1	2	2	0	0	1	2	3	2	1	0
12c. Use of GC, KS3	0	2	0	2	1	2	2	0	0	1	2	3	2	3	0
13. No reg users, GC	0	8	2	5	1	10	4	2	0		6	2	1	3	2
14. No reg users, LCD	0	2	2	2	1	5	4	2	0		6	1	1	3	1
15. staff respnsble, GC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16. affordances	0	sow	0	0	0	sow	resources	0	0	CBR	0	0	0	NNS	exams
17. hinderances	0	0	0	access	time	time		access	0	money	0	0	SATs	0	access
18. personal use	2	1	2	3	3	3	2	3	2	3	2	2	2	3	2
19. feelings abt GCs	n	p	p	n	n	p	p	n	n	n	n	n			n

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Date	Class	Lesson objectives	T/P	VS	S/M/P	Calculator facility	Comments
9/9	12/13		T	Yes	Plenary	Program Prob Sim	I was using it to illustrate theoretical probability versus experimental. Unfortunately the experimental prob was the same as the theoretical very quickly. In future maybe I could set it up beforehand and store some results.Using prob sim is easier than using a pack of cards
16/9	7(1).	Develop problem solving skills	T	Yes	Starter	Program STUGRID	motivation, first time they've seen it, very keen to join in.
16/9	9(6)	Problem solving skills (get their attention after lunch)	T	Yes	Starter	Program STUGRID	Motivation
16/9	11(7)	Problem solving (motivation at end of school day)	T	Yes	Starter	Program STUGRID	Motivation
17/9	10(2)	Recap basic algebra	T	?	Starter	Program BEARS	A very difficult group, poor behaviour, only 50% participating; decided to stop.(I have tried this approach before with a difficult yr 9 group in another school – they loved it, full participation and excellent behaviour).I don't think using the GC made any difference.
23/9	11(7)	Recap Coordinates	T	Yes	Starter	Program Battleships	Didn't finish game as behaviour deteriorated. Other students were disappointed
23/9	9(6)	Recap coordinates	T	Yes	main	Program battleships	Students keeping track of coords used on a grid in exercise book. As a whole class activity with a small group it works well. All involved and motivated. Last lesson of the day.Whole class participating, some reluctant at first, growing in confidence as lesson progressed.
27/9	12(re-sit)	Understand and use y=mx+c	T	Yes	Main	Graphical facility	Students were impressed and found it helpful, it speeded up the investigation of parallel lines. As we zoomed in to the graph, the line became fragmented. Added more grid points to solve this.
	Open Evening	Presentation	T & P			Programs Bears/boxed/stugrid	
1/10	8(2)	Use 4 operations	T	Yes	Starter	Program Countdown	I could have just written it on the board, but they were pleased to see the 'magical calculator' coming out. The timer was incorrect, so I gave them more time.
2/19	8(2)	Introduce probability	T	Yes	Starter & Main	Program Countdown Prob Sim	I used it show tossing a coin and rolling a die, what did we expect as we did more experiments. How did our results compare with what we predict using equally likely outcomes. GC quickly shows lots of trials

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Date	Class	Lesson objectives	T/P	VS	S/M/P	Calculator facility	Comments
4/10	12(re-sit)	Plotting non-linear graphs	T	Yes	Main	Numerical & Graphical	I could show them what to enter for particular calculations, quick and easy to show lots of different graphs, I showed the general shapes of quadratics, cubics and reciprocals. Showed using a calculator to work out 5/x and similar. I could have set up all the curves beforehand.
7/10	9(6)	Revision of co-ordinates	T	Yes	Main	Program Battleships	Last lesson of the day
Date	**Class**	**Lesson objectives**	**T/P**	**VS**	**S/M/P**	**Calculator facility**	**Comments**
8/10	7(10)	Revision of multiplication	T	Yes	Starter	Program Countdown	
14/10	11(7)	Efficient use of calculator	T	Yes	Main	Numerical	Problem-most didn't have their own calculators, so I had to hand out spares, different symbols and sequences for diff. calcs. Luckily it's a small group as I had to give a lot of individual instruction. I used the OHT of the calculator to show what some of the buttons looked like.
17/10	11(7)	Revision of co-ordinates	T	Yes	?	Programs Battleships STUGRID	Worst lesson of the week for this class, wanted something easy. They did well for 40 minutes.
19/10	7(1)	Revision of basic numeracy	T	Yes	Main	program STUGRID & BOXED	Extension students were out and some others were away so I had a small group to do some games with. I had a slight theme of negative numbers (our current topic). Students were using negative numbers without realising it. I was working from the front, students taking it in turns, a few students switched off at times after they had had their turn.
20/11	9(6)	Numeracy, problem solving	T	Yes	Starter	Program Countdown	I should have done it a couple of times to 'fix' the numbers so that they were easier for this group.
21/11	8(2)	Numeracy	T	Yes	Starter	Program Countdown	
22/11	12(re-sit)	Understand and use y=mx+c	T	Yes	Main	Graphical	I did a graph on the board and they said they would rather see it on the calculator-neater/clearer/quicker especially when there are several there at the same time.
2/12	7(1)	Solving equations	T	Yes	Starter	Program Equation	The program has scales with barrels and numbers on-the object is to discover the numerical value of 1 barrel, by balancing equations- same to both sides. Could be done just as well with a set of scales and a set of blocks or similar, but requires less setting up.
3/12	7(1)	Solving equations	P(?)	Yes	Main	Program Equation	Extension pupils out, so bottom 2/3 of class only present. Lesson same as yesterday, but by group of students who had completed work from the textbook as reward and as extension activity.
13/12	12(re-sit)	Probability	T	Yes	Main	Program Prob Sim	Can quickly show lots of trials. The graph showed relative numbers of the outcomes of rolls of die rather than frequency-confusing-had to show table and explain. I would like to use the class set and let students investigate events individually.

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16/12	12/13	Investigate st line graphs	T & P	Yes	Main	Graphical	Another group had been playing games on them and there were all sorts of things to clear before we could start on some of them. I gave the students different calcs then I sorted them out while they worked. Quick and easy to see variety of graphs, they can try things out, motivational. Some students very quickly abandoned the task in favour of playing with Prob Sim-needed refocusing. I will put the 'defaults' program onto the class set of calculators when I get a chance.
Date	**Class**	**Lesson objectives**	**T/P**	**VS**	**S/M/P**	**Calculator facility**	**Comments**
14/1	7(1)	Familiarisation with TI-83s	T & P	Yes	Main	Programs Bears, stugrid etc	Students exiting programs so that things like split-screens were still in the display. We used the 'defaults' program. The ext'n group were out so only 23 in the class.
21/1	7(1)	Familiarisation with TI-83s	T & P	Yes	Main	Program Caletter (uses coords to draw letters)	Extension group out, like last week. Weaker students were forced to think it through for themselves rather than asking their friends. Program does not allow for correcting errors-have to start again.
28/1	7(1)	Same as last week	T & P	Yes	Main	Program Creative	All the same as last week, but they had been asked to come up with their own design to input this week. We had some excellent pictures-boats, a die, a face etc. One or two of the students had difficulty in remembering to input both ends of each line each time and only found out when they had finished and lines were missing-they weren't motivated to do it all again. When doing coordinate pictures on paper students often get away with just drawing a picture and not really thinking about the way the lines are defined by points at either end. The program forces them to do this and they are also more motivated to work through all points as it is their design. But unlike when doing their design on paper, all the points must be accurate.
?	12/13	Familiarisation	T & P	Yes	Main	Graphical	I showed students how to produce line graphs on the calculator and then encouraged them to investigate gradient and parallel/perpendicular lines and intercepts by giving them some equations to start with and then just letting them get on with it. Some students made more use of the calculators than others.
6/2	12/13	Curves and asymptotes	T & P	Yes	Main	Graphical	Students investigated curves of the form $y = x^n$and then $y = \frac{1}{x^n}$ finding equations of asymptotes, then two particular curves$y = \frac{1}{(x-1)} + 2$ and $y = \frac{1}{(x-1)^2} + 2$. This is an

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							activity from Pure 1 MEI book.
6/2	11(7)	Interpreting graphs	T	Yes	Main	Using CBR	First we looked at some graphs on OHT and interpreted. Then we did a simple worksheet, then we used CBR distance time graph matching. A fun lesson for end of the day. Students could correctly interpret the graphs but could not think quickly enough to adjust what they had planned to do to adapt to the feedback on the screen. So they just carried on with their planned moves, even when it was clearly incorrect. They still enjoyed it-I just had to let them have 2 or 3 goes at each graph to try and improve results.
Date	**Class**	**Lesson objectives**	**T/ P**	**VS**	**S/M/P**	**Calculator facility**	**Comments**
7/2	10(2)	Reciprocal graphs	T & P	Yes	Main	Graphical (games at the end)	I demonstrated while students followed and copied how to produce the graphs, and we discussed asymptotes etc. then I gave them a list of equations to try. They had to produce the graphs and sketch them in their books. Students were then free to play games.
12/3	7(1)	Interpret st line graphs	T	Yes	Main	Using CBR	We discussed distance time graph from the textbook of a boy's journey to a shop and home again. We then looked at a distance time graph on the calculator and discussed what the volunteer should do to match it. This all went well. Then the CBR failed to function due o low batteries-no spares anywhere so we had to abandon it and do interpreting graphs from the textbook. Discussed with Carol afterwards, she had had a problem with flat batteries too, we said we must order in a stock of spares.
1/4	7(10	Same as last time	T	Yes	Main	Using CBR	Extension pupils out, small group left. Batteries sorted out, no problems this time. The instant feedback allowed students to see errors straight away and correct from them.
1/4	9(6)	Multiply/divide decimals by powers of 10	T & P	Yes	Main	Program Decimal Defender	All students fully engaged (last lesson of the day, bottom set, so this is good)
8/4	9(6)	Estimating by rounding	P	No	Plenary	Programs Battleships, etc	2 or 3 students who completed the work set were allowed to play on the calculators.
3/6	7(1)	Find coords of intercept points	T & P	Yes	Main	Graphical	I had planned the lesson for the smaller group that I have when the extension students are out. This group is quite used to using the calculators. I found out 5 mins before the lesson that I would have all 34 of them! I wrote on the board groups of 3 equations of st. lines. The students were to draw the lines and zoom in to find the intersections (vertices of a triangle constructed). I intended to finish with a discussion about the significance of the

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							points being on two lines, substituting values into equations. Difficulties: not enough for all to have 1. Several had low batteries and died during the lesson, leading to students' (and teacher's) frustration. I had to provide alternative activity. The students in the extension group have not used the calculators to draw graphs before and even pairing them with students who have used them, I still had to explain things in greater depth and at greater length than I had planned for.
15/7	Year 7	Three activities	P	Yes	Main	CBR and CBL	Year 7 cross-curricular activity. 20 selected able and talented science and maths students. The activities were arranged so that groups of 5 rotated round them. Students had instruction sheet telling them how to use the APP, which buttons to press. At least I student in each group had used the calculator before. It was up to them how they used it. The science teacher who set up the day gave them a couple of questions to answer and the challenge of walking the graph in such a way that a sine graph was produced. They found the activity easy and enjoyable. Activity 2:this activity students were using the bouncing ball part of the APP. They were testing squash balls at different temperatures to see if they bounced at different heights. They found it difficult to get good graphs, taking several attempts each time. Very pleased when they got a good graph. They did find a link between the temp and the height. Used arrow keys to move the cursor to the peak to find the maximum height of bounce. Activity 3:investigating free-fall using Photogate APP. I had a program on disc that I had used at Marjons with a picket fence to measure acceleration due to gravity. But I couldn't get it to work. We tried other things and gave up. Very frustrating.

Examples of lessons where graphics calculators could have been used but did not (when you used computers or no technology at all)

21/11	10(2)	Drawing quadratic graphs and finding roots	No technology used	It was last lesson of the day-couldn't be sure of sensible behaviour. I would use graphic calculator for this lesson in future

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A Case Study of the Issues Arising When Teachers Adopt the Use of a New Form of Technology in their Teaching for the First Time

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Introducing any new initiative into teaching involves professional development and training. This paper investigates the reactions of three teachers to the introduction of graphics calculators into their department. Each teacher was followed through one academic year. They were interviewed formally on two occasions and also met informally with the researchers to discuss how they were using the calculators. The interviews were used to develop profiles of the three teachers. From these profiles a set of recommendations was developed that could guide other schools who were introducing graphics calculators for the first time. These recommendations were (i) that the department should have an action plan which describes where and why the calculators are to be used (ii) both initial and on-going training is necessary (iii) appropriate support in the form of both teaching resources and hardware should be readily available.

1 INTRODUCTION

Recent years have seen the introduction of many forms of new technologies in schools across the UK. These technologies have allowed the development of innovative approaches to teaching in all subject areas.. In addition they also provide new challenges for teachers, particularly those with well established classroom practices. This paper looks at the issues that arose when a new technology was introduced into the mathematics teaching at one school.

A survey into the integration of ICT by Williams, Coles, Richardson and Tuson (2000) found that teachers' needs could be categorised into three interrelated areas: Access, Training and Support. Access covered the lack of availability of equipment as well as readily available resource material. Teachers reported that having to book the computer room had implications for effective classroom planning. They also reported that they needed more support in solving technical problems and trouble-shooting. The study showed that there was a high motivation to learn, but that the training should meet specific needs:

- be appropriate to classroom use
- have a hands-on practical element
- provide on-the-spot help
- provide opportunities to work and share ideas with other teachers.

Although Williams et al's survey looked at the use of computers and PCs within schools, one of the outcomes of the research in this paper is that their findings have strong resonance with teachers' needs and the integration of graphic calculators.

Williams et al (2000) identified that training was needed in technical skills in order to use applications specific to their professional context. They also found that improvements in access and training were only likely to be successful if there was ongoing support, 'this appears to be the most complex area of needs, encompassing technical support, evaluation of resources, and organisational culture'.

Many studies (Fullan, 1987 and in particular Craft, 1996) have reported on the inefficacy of the half-day in-service training offered to many teachers as a model of professional development. This is particularly so with ICT training, where many teachers feel they need more contact time and technical support.

Other studies (Moonen and Voogt, 1998, Marx, 1998, Putnam and Borko, 2000, amongst others) have shown that teachers need training to meet specific needs and this is even more relevant to ICT training. More than in any other area of in-service training, teachers feel insecure about their knowledge base when it comes to the use of ICT within their teaching. However, in order to address the training needs of teachers Craft (1996) suggests that there should be a 'greater emphasis on what happens before an in-service training event (identification of needs) and afterwards (evaluation and follow-up)'.

Bright and Prokosh (1994) note that in-service training on calculator use often forms part of the larger picture of in-service training on technology. He describes teachers' concerns as falling into two categories: 'low-level concerns....calculator skill, understanding relevant mathematics, knowledge of pedagogy specific to the incorporation of calculators in instruction' and more 'sophisticated' concerns which he describes as 'high-level concerns....interaction between calculator use and testing and more importantly teachers' beliefs about the role of calculators in learning mathematics.'

Bright and Prokosh go on to suggest that concerns about testing can be met by offering teachers opportunities to discuss assessment issues and furthermore the venue for such discussions could be through in-service programmes that take place over several sessions.

Bridging this concern and the other low-level concerns, Bright and Prokosh suggest that the most important elements are the teachers' beliefs about calculator use. He recommends that for any change to be successful, 'a necessary part of the process is having teachers learn mathematics with the assistance of calculators'.

These themes are supported by Guskey's (2002) work on professional development. He writes that teachers define their effectiveness in terms of their pupils' behaviours and activities and that 'what they hope to gain through professional development are specific, concrete and practical ideas that directly relate to the day-to-day operation of their classrooms'. However, Leach and Moon (2000) comment that 'the success of information and communications technology is dependent upon the way in which a variety of discrete classroom strategies are integrated into the teacher's overall pedagogy.' Yet, when it comes to ICT, the style of professional development often puts pedagogy aside. Professional development in ICT becomes a training session on how to use the technology because, often, that meets teachers' immediate needs. Watson (2001) argues that this type of professional development serves to 'augment' the existing system by 'providing specific skills and competencies focused on specific types of applications'.

Watson goes on to suggest that 'if the use of information technology in teaching and learning is to result in any fundamental or lasting educational change, a different model of professional development is required' (Watson, 2001). She calls this a 're-forming' model, and identifies five stages: orientation, adoption, evaluation, innovation, and institutionalisation. The hardest part of this process is having to adopt a new teaching style, moving away from 'sage on the stage' to 'guide on the side' (Watson, 2001).

This change in classroom dynamics shifts the role of the teacher to a facilitator and guide, 'a role that may be uncomfortable or even undesirable for teachers who enjoy directing teacher-centred classrooms' (Simonsen and Dick, 1997).

They carried out an investigation into teachers' perceptions of the impact of graphics calculators and found that teachers reported several 'major trends'. They cited logistical difficulties, lack of access and problems with security as their main concerns. They also found that teachers expressed concerns about students becoming calculator dependent and the time element in learning how to use a calculator.

One of the main barriers is the change in classroom dynamics. Teachers find that using graphics calculators means that their classroom becomes less teacher-centred. Whereas some teachers find this to be an advantage of integrating technology into their teaching, others feel threatened. Norton, McRobbie and Cooper (2000) reported that 'teachers with transmission/absorption images of teaching and learning and teacher-centred, content focused pedagogy had a restricted image of the potential of computers in mathematics teaching and learning.' This is reiterated by Reynolds, Treharne and Tripp (2003), who argue that 'teaching with ICT is not suited to the traditional pedagogical styles.'

Teachers have differing views about the effectiveness of graphical calculators. Fleener (1995) found that there were teachers who believed that using calculators hindered pupils' mastery of concepts. If teachers believe that using calculators will hinder their pupils' learning they are less likely to include graphical calculators in their teaching. A study by Graham, Headlam, Honey, Sharp and Smith (2003) of A-level students taking a statistics examination found that the students were aware of examiners' marking criteria when answering examination questions. These marking criteria give credit for the written methods of more traditional teaching styles. Consequently, both teachers and students may be reluctant to make use of technology, preferring instead the written methods. Teachers may feel that discouraging traditional written methods in favour of ICT could hinder the attainment of students in external examinations.

Demetriadis, Barbas, Molohides, Palaigeorgiou, Psillos, Vlahavas, Tsoukalas and Pombortis (2003), in a study of Greek schools, found that the use of ICT hinged around the external examination system. The teachers in that study used ICT when it was 'compatible to the established teaching and learning methodologies (which are valued as better accommodating the already set instructional target)'.

Recent initiatives in the UK such as the Key Stage 3 Framework for teaching mathematics (DfEE, 2001) and the revised subject criteria for A-level mathematics (16-18 years) have elements that promote the increased use of graphics calculators. (The national curriculum for school education in England and Wales has five Key Stages. Key Stages 1, 2, 3, 4 and 5 (KS1, KS2, KS3, KS4 and KS5) are for children aged 5 – 7, 7 – 11, 11 – 14, 14 – 16 and 16 -19 respectively.)

The Key Stage 3 document contains a number of examples of problems and tasks that can be used by teachers. In a number of these examples the use of graphics calculators is suggested and the exemplar materials include illustrations of graphics calculator screens. The new A-level criteria contained revised rules for calculator use in examinations. These rules remove the need for students to have to use a scientific calculator in some examinations and permit the use of graphics calculators in a greater number of the examination papers. Graphics calculators can now be used in 75% of the assessment of Pure Mathematics compared to 33.3% in most of the previous A-level specifications. Graphics calculators are still permitted in the application modules. The subject criteria also make reference to encouraging the use of new technologies.

In view of these initiatives, it was decided to look at how a school, that did not have a history of using graphics calculators, would cope with the introduction of this form of technology. In particular the researchers wanted to follow a number of teachers over a period of time to see how their use of the new technology was supported and how it developed, and whether issues that have been identified in other research projects would emerge in this context.

2 METHODOLOGY

In order to take forward the idea of following teachers who were new to graphics calculators it was necessary to identify a school or schools where there had not previously been significant use of graphics calculators, but where the desire existed to introduce them into the teaching within the school. The researchers were able to identify a local school which was in the process of purchasing a class set of graphics calculators for the first time. Some of the teachers in the school did own graphics calculators and in the past some had encouraged A-level students to purchase graphics calculators to support their studies, but the overall picture in the school was of virtually zero use. The school had just placed an order for a class set of graphics calculators, two teacher calculators with view-screens and the CBL equipment for producing motion graphs.

The school itself was a well established comprehensive school located in a residential area on the edge of a city. It covered the full 11-18 age range and had a good uptake for A-level mathematics, with a small number of students taking Further Mathematics A-level.

The researchers met with the head of department to discuss the plans for the research and to establish the school's intentions regarding the purchase and use of the graphics calculators. The outcome of this meeting was very positive. Three teachers were identified who were willing to take part in the project. These three teachers had varied levels of experience with graphics calculators and different amounts of teaching experience. The researchers felt that this mix would provide a range of responses. A first meeting with all three teachers took place at the start of the academic year to brief them on the requirements of the researchers.

The project has essentially two phases. During the first term a number of informal meetings took place between the researchers and the three teachers. The purpose of these meetings was to allow the teachers to describe what they were doing with the graphics calculators. This allowed a limited exchange of information between the teachers and also allowed the researchers to begin to see how the teachers' use of the calculators was developing. At the end of the first term a formal interview took place with each of the teachers. These interviews were recorded and transcribed for analysis. During this first phase there were no interventions from the researchers in the form of ICT training i.e. the teachers were left alone.

At this stage it became apparent that the teachers' use of the calculators was not developing, so during the second phase of the project (i.e. the second term of the school year), two interventions took place in which the teachers were given guidance on the use of the graphics calculators. On one occasion ideas for use in teaching sequences were demonstrated and discussed and on another occasion a demonstration lesson was given by one of the researchers, using a motion detector linked to a graphics calculator. At the end of the academic year a second interview took place. Again these interviews were recorded and transcribed for analysis.

The data were analysed using a grounded approach. The particular approach taken here was for two of the researchers to read through the interview transcripts and highlight the significant comments made by the teachers. They then compared their annotations and produced a list of comments on which they agreed. These lists were then used to produce profiles of each teacher. These consisted of an initial profile, a first interview profile and a second interview profile. These profiles were then given to two other researchers who were asked to confirm that they were accurate representations of the interview data. Confirmation was given in all cases.

Once the profiles had been completed and confirmed it was possible to begin to identify the issues for each teacher and to examine the extent to which these were also issues for the other teachers. A consideration of these issues led to a list of recommendations for schools who are considering the purchase and implementation of graphics calculators for the first time. It is also hoped that these recommendations will be of assistance to both users who are still relatively new to graphics calculators and to trainers who are working with teachers.

3 RESULTS

The profiles are presented for each of the three teachers and followed by a discussion of the significant emerging factors and issues. The three teachers are denoted by NQT (NQT – a newly qualified teacher usually refers to a teacher in their first year of teaching which is essentially a probationary year), No Experience (the teacher with no graphics calculator experience) and ICT (the teacher who had experience of using other forms of ICT in his teaching).

3.1 Initial Profiles

NQT

This teacher had a mathematics degree and had worked in industry for a few years before training as a teacher. She had not used a graphics calculator until she began training as a teacher on her postgraduate certificate of education (PGCE) programme, in this case a one year course of teacher training after graduation with a first degree. During her PGCE course she was exposed to extensive graphics calculator use and was issued with a calculator to use while engaged in her studies. Part-way through the PGCE programme, she took advantage of a discount purchase scheme to buy her own calculator and view-screen package. This purchase was stimulated by the reactions of pupils with whom she worked on teaching practice. The teacher felt that this purchase had been a good investment. She had joined the school at the start of the academic year as a newly qualified teacher (NQT).

No Experience

This teacher had many years experience as a teacher of mathematics at the school. She had a number of responsibilities within the school as well as a role as a teacher of mathematics. Before the school purchased the set of graphics calculators, she had no experience of using graphics calculators and had not had any training in their use.

ICT

This teacher had been employed at this school for a number of years as a mathematics teacher. He had departmental responsibilities as the second in department at the time of the study. He was an enthusiastic user of ICT in his mathematics teaching. He had been to a one day promotional event run by a calculator manufacturer, where he had been given a graphics calculator. As a consequence of this event the school had purchased six calculators, but these had not been used very much. He had also attended a more hands-on training course, which he found helpful. These courses had been fairly recent, but he felt that graphics calculators had "passed him by" for most of his career.

Summary of Initial Profiles

The initial profiles show that the three teachers have very different backgrounds and experience of graphics calculators. It was hoped that this variety would yield a range of different issues as the teachers introduced the graphics calculators into their teaching.

3.2 First Interview Profiles

NQT

When interviewed at the end of the first term this teacher felt that she was confident in her use of the graphics calculator. She had made use of the graphics calculators during the first term, but her use had been to provide lesson starters and for demonstrations to the whole class. She had enjoyed using a graphics calculator in this way and sensed that the pupils had done so too. She had found it a particularly useful tool for teaching work on graphs, but had found that the fact that the graphs were not smooth was a problem for some students. She had recognised that there were other times when she could have used a graphics calculator, but didn't. She had an overhead projector in her classroom and so found it very easy to make use of the view-screen in her lessons.

This teacher felt that using the view-screen was a good way to get her pupils' attention, but felt that if it was used too often their interest would wane. She does feel that using graphics calculators motivates the pupils.

She had found it quite time consuming to prepare graphics calculator activities while she was a PGCE student, but did not have time to spend preparing new graphics calculator activities now that she was working full-time in a school. She felt that with the help of some resources, such as a book or the internet, she could prepare lessons, but did not feel the need for the help of an expert to make more use of the graphics calculators. She had down loaded some games / starters from the internet.

She had made no use of other ICT, but would have been prepared to if she had been required to do so.

No Experience

This teacher had made some limited use of graphics calculators during the first term, but felt that she had no confidence in her own ability to use them. She had used some games and starters with a few groups and some of these had produced positive reactions from her pupils. The graphics calculators seemed to have been most successful when she had used the calculators with a smaller teaching group.

While this teacher can see some value in using the graphics calculators for pupils to check their answers, she still does not really appreciate the ways in which they can be used to support and enhance her teaching of mathematics. For example she stated that she "did not see the academic applications of the calculators". However she did want to move forward with the graphic calculators. She identified that she needed to learn more about how to operate the graphics calculators, how to apply them in a classroom setting and to see the full potential of using them. She did say that she had not yet achieved what she wanted to achieve with the graphics calculators. With a year 11 group she felt that no use of the graphics calculators was possible because of the pressure to prepare her pupils for their GCSE examination.

This teacher had no access to any resources during this term, other than a few programs given to her by the newly qualified teacher.

This teacher did use ICT, but in a limited way. She was confident with some applications, such as LOGO, which she used every year and where she was able to use prescribed tasks and had technical backup available. She felt that there was poor access to computers in the school.

She declared that she was aware that there were some suggestions for using graphics calculators in the Year 8 section of the Mathematics Framework document (DfEE, 2001).

ICT

This teacher had made some use of the graphics calculators during the first term. He said that he did not feel completely confident with the graphics calculators, but stressed that teachers need to be confident with new technology before they use it in the classroom. He attributed his low level of use with pupils to his lack of training, and that he had needed to have more training before starting to use the graphics calculators. He did say that he would like to learn how to use the graphics calculators and would prefer to do this, rather than carry out some of the administrative tasks that he was required to do.

He described a positive experience that he had with one group, when he did use the graphics calculators. He felt that the pupils could tire of starter type programs, but noted that it is sometimes difficult to know what "sparks" pupils. He had seen pupils be responsive and felt that the graphics calculators could provide a good change of environment.

He described a number of barriers to his use of the graphics calculators. These included an overhead projector that did not work, the distribution and collection of calculators in the classroom and time taken in setting things up. But perhaps more significant to this teacher was the time taken to prepare to use the graphics calculator, as he felt that he had to sit and work through all of his ideas before he could use them with a class.

This teacher had continued to use other forms of ICT. He has used a number of packages and is very confident with spreadsheets. He has "picked up" the use of mathematical packages that operate in a Windows environment, and feels that it is easy to learn how to use new software. However he sees the graphics calculator in a different light and feels that it is not as intuitive as working with a computer.

3.3 Second Interview Profiles

NQT

This teacher had received a positive reaction from a year 7 class, which had encouraged her to make more use of the graphics calculators. She had also had positive reactions from other classes, although one class had shown a particularly negative reaction. This negative reaction made her question whether or not to use the graphics calculators again with that class.

Her usage had changed. Initially she had used the graphics calculators mainly to provide starters for KS 3 classes to more in depth applications with KS 4 and KS 5. For example, encouraging students to ask some "What if?" questions. She felt that her use was fairly balanced between the use of the class set and the view-screen only. It had been easy for her to use the view-screen as she had an overhead projector available in her room. She had found the calculators particularly useful for graphing activities. Some of this work had been with a small group of A-level students and she felt that they had found this beneficial.

Her use of graphics calculators had been planned in advance of the lesson, in which they were to be used. She had not made impulsive use of graphics calculators during lessons.

She identified a number of barriers to the use of graphics calculators. These included problems with batteries, the difficulties of working with large classes, preparation time and the fact that using graphics calculators seemed to be a low priority. She also identified as a problem the lack of communication between herself and another teacher with whom she shared a class. She did not encounter any difficulties accessing the calculators as no two teachers ever wanted to use them at the same time.

The training sessions that had taken place with the researchers had raised her enthusiasm and refreshed her memory of things that she had done while training on her PGCE programme. She had found that other members of staff had expected her to be able to help them with graphics calculator issues.

She stated that there had been no changes to the scheme of work to include references to graphics calculators and that no one person in the department was responsible for the graphics calculators. The only resources that she had available were some worksheets that she had brought from college and some "APPS" that she had downloaded from the internet.

When asked to compare graphics calculators with other ICT, she said that the comparisons would depend on the criteria, but that it is the actual software that is more important than the hardware.

No Experience

This teacher still did not feel very confident with the graphics calculator. She did feel more confident working with small and with more able groups. When an expert was present to support her, this teacher felt very much more confident. She had some very positive experiences with a year 8 class and also did something that went well with year 7. One class however, did not like using the graphics calculators at all. This last experience, evidenced by poor student behaviour and little interest in the lesson, was quite discouraging. Although she would be happy to repeat her work on sequences, she still felt that she was not proficient with graphing. She was not able to identify a topic where she thought that the graphics calculator would be the ideal teaching tool. This teacher stated that she felt that she needed a lot more help and instruction, in particular to resolve unexpected problems, such as pupils getting the calculator into the wrong mode. She had really enjoyed the demonstration lesson and would like to do more work alongside a proficient user. She emphasised that she needed instructions that would enable her to start from scratch and that time lapses would cause her to forget what she had learned. She said that in the first term when she had no support, she had floundered. She did find that matching activities to pupils' level of ability was quite difficult.

Although she had been given some training her level of use had not increased during the second term and she still felt that she could have done most things without the graphics calculator, but that the calculators provided a backup and a more interesting delivery. The pupils had liked the puzzles and games that she had obtained from the NQT.

Things that acted as barriers for this teacher included large classes, a lack of time to prepare and the discouragement that she experienced due to her initial lack of knowledge with respect to graphic calculators.

She stated that there had been no changes to the department's plan to include references to graphics calculators and that no one person in the department was responsible for the graphics calculators. She commented that looking ahead may help the department to prepare resources for the pupils to use. She felt that she needed more resources to give her instructions on how to use the graphics calculators.

ICT

This teacher feels that he has fallen by the wayside and there is little evidence of any change in his use or attitude to using graphical calculators. However the limited use led to positive feedback. A Year 8 class was enthusiastic but the teacher asks "was this due to novelty value that could wear off?" He enjoyed using the viewscreen in a demonstration lesson on trigonometry with a small group of sixth formers but commented that none of them said "can we use it again?".

He did enjoy the training session with the motion detector which he found engaging. It was one activity that he felt he could use in the future – but had not done so during the year.

He described several barriers to his use of graphic calculators: the personal investment of time for training, the screen output looks dated compared to PC's and the logistics of pupils sharing one calculator between two. Overall this teacher prefers computers to calculators and would tend to use software such as Autograph instead of a graphic calculator for topics such as graphs.

3.4 Final Profiles

NQT

This teacher has moved forward during the year with the input from the researchers raising her motivation and refreshing her memory (from her PGCE course in College) of some of the applications of graphics calculators to learning. Her personal competence with the technology was good at the beginning of the year and gradually through the year her use of the technology changed from demonstration lessons and starter activities with the view-screen to include using the class set. This teacher still sees that there are barriers to using the technology more widely: e.g. large classes, the lack of time to prepare or develop good resources, negative experiences when working with pupils and the low priority of the use of calculators compared with other ICT.

No Experience

Although there is not much evidence of change in level of usage, this teacher has moved forward from the initial profile at the start of the academic year, gaining some confidence when working with small groups and more able pupils. Her use was mainly with the view-screen and applications for starters and puzzles. She recognises the need for more training, feeling more comfortable in using the class set when 'an expert' person is available to support the students who have problems with the functionality of the calculator. She did have one topic, sequences, that she had delivered with some success, after a short training session, and was confident to use again. For this teacher, the barriers to using the technology more widely are discouragement due lack of personal competence, large classes and the lack of time to prepare or develop good resources.

ICT

This teacher admits that his main reason for using the graphic calculators was because of the research project with the researchers. He retains a lack of personal confidence with this particular technology feeling that other ICT can do all that he needs in his teaching. The main barriers to moving forward with the graphic calculators are a lack of time and a feeling that the "cons outweigh the pros". For this teacher there is the additional issue that the "pros and cons" are not based on his own experiences of working extensively with graphic calculators, he has a natural desire to use computer software only.

4 DISCUSSION OF PROFILES

A consideration of the teachers' responses allowed the majority of their comments to be placed into five categories:

- The Place of the Graphics Calculators in the Institution
- Hurdles to Developing Use of Graphics Calculators
- Logistical Hurdles to the Use of Graphics calculators
- Positive Reactions of Pupils to the Graphics Calculators
- Negative Reactions of the Pupils to the Graphics Calculators

Each of these categories is now considered in turn.

4.1 The Place of the Graphics Calculators in the Institution

A major issue that emerged from the interviews was the "Institutional" view of the graphics calculators. The department had taken the decision to purchase a set of graphics calculators, but had done very little more than this. This was evident in a number of ways. The interviews revealed that there had been no attempt to incorporate references to the graphics calculators in the department's schemes of work and that no other documentation had been produced that attempted to define a policy for the department with respect to the use of graphics calculators. This was at variance with the department's policy on the use of computers. For example specific topics were linked to computers in the scheme of work and resources, including technical assistance, had been made available to the teachers. At the end of the year, the teacher identified as No Experience stated:

> "*I think ...there needs to be mapped specific topics and instructions, this is what we are going to use them for, this is how you use them and here are the materials.*

Not too restrictive once you get into the flow, but perhaps a little more organisation within the department, in the same way that we know whether we are going to use Logo or something like that."

In fact the decision to purchase the graphics calculators did not seem to have any supporting rationale. The use of graphics calculators was certainly not embedded into the curriculum. It was also very interesting that only the teachers who were involved in the study actually used the graphics calculators.

Further there had been no investment in resources or training to support the teachers in the department as they introduced the graphics calculators into their teaching. The teachers had very much been given the calculators and left to their own devices. The researchers suspect that if the teachers had not been involved in this study, even less use would have been made by the two teachers identified as ICT and No Experience. When asked if she felt she had just been given the calculators and told to get on with it, one of teachers actually stated:

"No, that is not quite right, it was more, here are the graphic calculators and we are going to be part of a research project for the University."

The teachers were in no doubt that they needed both resources and training. This became very apparent to the researchers during the first term. The interventions made by the researchers who conducted some short training sessions did seem to provide the knowledge and confidence for the less experienced teachers to use the graphics calculators in their teaching, but only in the very specific areas covered in the sessions. While describing the limited training received from the researchers, No Experience stated:

"Starting right from scratch, I needed a lot more."

She also associated her minimal use of the graphics calculators with her lack of training.

"I think that I could have done with a lot more help and instruction at the beginning."

She also stated:

"I would have liked a lot more instruction."

The teacher identified as ICT made the following statement about the need for training:

"Personally, I think that what you need to do with teachers, is take them off timetable and have a dedicated INSET day."

As well as a lack of training there was a very significant shortage of resources for the teachers to use. It was evident from the interviews that the teachers were only making use of the resources that they had access to as a group and that most of these were ones that the NQT had gathered together while on her PGCE. No Experience commented on this fact.

"...NQT had a few activities and puzzles that she had gained from her course and we used them."

The teacher identified as ICT mentioned resources several times in his interviews. For example he said that:

"A step by step guide would be useful."

And

"If there was something that they could work through, a starter pack might be quite useful."

In summary the teachers' approach to the use of the calculators seemed to be reactive, rather than proactive, in the sense that they used what limited resources they had available with a "what can I do with this now that I have got it" approach, rather than with a strategic plan for how they would incorporate the graphics calculators into their teaching. The vague or complete lack of policy for the use of graphics calculators within the department effectively placed the use of graphics calculators in a low position on the agendas of the staff working in the department. The lack of training and resources also made it very difficult for the teachers to develop the use of graphics calculators as a part of their teaching. These observations are very interesting when looked at in the light of the work of Doerr and Zangor (1999), who found that for effective use teachers needed to believe in the value of the graphics calculator, be confident in its use and be aware of its limitations.

4.2 Hurdles to Developing Use of Graphics Calculators

The issues discussed in the previous section were also significant hurdles to the use of the graphics calculators. Clearly the lack of training and resources were hurdles to use as well as factors that contributed to the low status of graphics calculators within the department. However there were additional hurdles that seemed to discourage the use of graphics calculators; five such hurdles are considered below.

Probably the most significant was the time that the teachers felt that they needed to prepare activities and tasks for their pupils to work with in lessons. For example, the NQT stated that:

"There are things that I am not using it for which I know it can do, but I haven't got the time to prepare for it."

She expands further on this point later in the interview, describing where the preparation of graphics calculator activities comes in her list of work priorities:

"It is at the bottom of the pile."

If the teachers had been able to participate in a training programme or been better resourced, they may have needed less time to prepare graphics calculator lessons, but the issue of the time needed to prepare for these lessons would still be an issue.

The second issue was the lack of communication between the teachers involved in the study. There was an awareness that the teachers could learn from each other, especially from the NQT who had more experience, but the principle of sharing fell by the wayside because the teachers had too many other things to do. The teacher identified as No Experience realised that she could have gained quite a lot from the more proficient NQT. She stated:

"I think I could have done more with them if the facility had been there to work alongside someone who was proficient..."

Although there was one lesson each week when all three of the teachers were free at the same time, they never used it to meet and talk about the graphics calculators, unless one of the researchers was visiting the school to meet with them. Perhaps this follows as a consequence of the lack of a clear graphical calculator policy in schemes of work and hence their perceived status within the Department.

Third was the lack of awareness of the potential benefits of the graphics calculators. This was really most significant with the teacher identified as No Experience. The other two had more awareness, ICT due to his experience of working with computers and NQT because of the training she had experienced during her PGCE. At one stage in the interview No Experience stated:

"I didn't see the academic applications of it. I only saw the games."

Her limited view of the potential was again illustrated when she stated:

"..they could use the graphics calculator to see if their answers were correct..."

Further this teacher did not seem to view the calculators as tools to support her teaching, but as something extra that had to be fitted in. For this teacher there was a real tension between preparing her pupils for their examinations and finding time for using the calculators. She did not see that the calculators could contribute to the preparation for the examinations. During the first interview she said:

"The trouble with using it at this stage with year 11 is that you are under great pressure."

This issue again relates back to the status of the graphics calculators in the department and the lack of training.

The fourth issue cited was concerned with troubleshooting potential problems that arose when the students used the calculators. There was a fear among the three teachers that their pupils might do things to the calculators that they would then be unable to resolve. On one occasion No Experience had a problem with a pupil who had put his calculator into a different "mode" from which neither he nor the teacher could escape. Her solution to this problem was simple:

"I just took it off him and told him to share with someone else."

This emerged as quite a big issue for both this teacher and for ICT. In one interview he stated:

"I can sit at home and work it out, but you know what kids are like, they just press the buttons and they have the screen in a certain mode."

The real concern of these teachers was that when they did prepare an activity for the graphics calculators, the pupils could create problems that they as teachers could not resolve. This did not seem to be an issue for the NQT as she was more confident with the calculators. This fear is compounded by the lack of training.

The final hurdle was due to the different user interface compared with most modern computer applications. The fact that most modern software applications run in a Windows environment means that once you have mastered one software application, starting to work in a new one is not too daunting because the environment and some of the commands will be familiar. When talking about using computers in preference to graphics calculators ICT said:

"There is so much cross compatibility with it, you just sit them in front of it, you don't even have to tell them how to do it."

The fact that the graphics calculator has an unfamiliar user interface does seem to present a hurdle to some potential users. There was also a feeling expressed by ICT that the actual technology seemed very dated in comparison to some of the other modern technology that the pupils are regularly using:

"When you think what the kids deal with these days, the hand held games, mobile phones etc. The multi coloured screens are much finer and they look at the graphics calculator ... and it is a bit dated."

4.3 Logistical Hurdles to the use of Graphics Calculators

There were also some logistical hurdles that restricted the use of the graphics calculators. These were all things that could be resolved with some forethought and expenditure that was not large in comparison to the cost of a class set of graphics calculators. The logistical issues were to do with security and distribution, the time it took to set up the view-screen and problems with batteries. The issue of distribution and security took the school some time to resolve and did initially prevent any of the teachers using the class set of graphics calculators for some time. Even when this had been overcome there was still an issue about security. ICT made the following comment in one interview.

"But when there's twenty £50 calculators in a box, it's like well, sit down, no one move we're having them back and that sort of thing."

Using the view-screen was also an issue for some of the teachers when they did not have easy access to an overhead projector. This then made setting up the equipment very time consuming and made the teachers question whether the effort involved was justified. ICT commented:

"There's a ten minute setting up. In the end you tend to do something else."

The issue of batteries was significant for the teachers who made the most use of the calculators. NQT commented in one of her interviews:

"It is frustrating when you get them out and the spare batteries aren't there. The spare batteries should be in the box with them."

4.4 Positive Reactions of Pupils to the Graphics Calculators

There was considerable evidence that the reactions of the students to the graphics calculators had an impact on the teachers' use of the graphics calculators. While a negative response often resulted in a negative impact there was evidence from all three teachers that positive feedback from their pupils encouraged the teachers to make more use of the graphics calculators. NQT had first experienced this while doing teaching practice as part of her PGCE. When asked why she had purchased her own calculator she replied:

"The reaction I got from the students, I thought it is something I would like to continue with."

ICT also described a positive impact:

"A very positive feedback from a year 8 class."

Similarly, No Experience stated:

"They enjoyed it and certainly said, when can we do this again."

Having described this reaction to a lesson on sequences, she went on to say:

"I would probably use it for sequences again."

Exploring these positive reactions further with the teachers revealed that many of the responses seemed to be associated with the motivation of the pupils. NQT summed this up in her statement:

"If you get a good reaction from using them that encourages you to use them again."

Interestingly NQT made a comment about the pupils exceeding her expectations when working with the graphics calculators:

"I was impressed by how they took what little they had done and extended it."

No Experience also felt that the interactive nature of the calculators was positive:

"They like interactive things."

It seemed that seeing the pupils motivated or achieving more then motivated the teachers to consider further use of the graphics calculators with that group of students. However as this further use often did not materialise, the researchers suspect that the teachers were uncertain about how to actually extend their use. There was also a feeling expressed by both ICT and NQT that with too much use of the graphics calculators this enthusiasm could fade. ICT talked about the graphics calculators "*grabbing their interest*" but followed this with the statement:

"If I used it every lesson, that would wane."

When talking about the positive feedback from one class ICT qualified this with the statement:

"What I haven't done is use it long enough to find out whether it is novelty value."

4.5 Negative Reactions of the Pupils to the Graphics Calculators

As much as positive reactions seemed to encourage the teachers, bad experiences seemed to have the opposite effect. NQT, who was the most proficient with the graphics calculators stated:

"If it goes wrong, you try and analyse why it goes wrong and think, well do I want to use them again with that group or for that activity."

Note that in this statement there is a strong suggestion that the reason for the activity going wrong could be associated with the activity or with the group of pupils. No Experience also felt that a poor reaction could be associated with the class of students:

"One class didn't like it at all."

5 RECOMMENDATIONS

The overall experience of the teachers with these calculators could not be described as successful. The discussion above has considered the place of some individual factors, but when describing their whole experience, ICT talked of "*falling by the wayside*" and No Experience said "*and we floundered*". In contrast NQT had made much more use of the calculators, but she still made the following comment in her final interview:

"It would have been nicer to have used them more, but there just isn't the time to."

She went on to talk about the time needed to prepare activities for the graphics calculators and concluded that doing this was a very low priority.

"It is at the bottom of the pile."

Through the analysis of the interview data, this study has identified factors that inhibited the successful use of graphics calculators in the school. The authors have therefore produced a number of recommendations for schools adopting graphics calculator technology for the first time. These recommendations would have helped the teachers who took part in this study, but in themselves cannot guarantee success.

1. The department needs to have a reason for introducing the calculators and to have considered how they are to be integrated into the work of the department. The reason needs to be enshrined in a departmental policy through, for example, the schemes of work.
2. There needs to be sufficient initial training so that the teachers have some confidence when they first begin to work with the calculators. This training should include "troubleshooting" so that teachers have experience of resolving problems that the students accidentally create while working with the calculators.
3. There should be on-going training. There should be time set aside, so that the teachers can meet together to share ideas, experiences and resources.
4. The department should acquire or develop resources to support the use of graphics calculators.
5. Departments should implement security procedures that are simple to use.
6. Make overhead / data projectors available in all mathematics classrooms, so that teachers can easily produce view-screen images for their pupils.
7. Ideally mathematics departments need to have access to experienced practitioners to whom they can turn for advice and demonstration lessons.

6 SUMMARY

The authors feel that this study has provided a number of insights into the reasons why teachers do not make good use of graphics calculators in their class rooms. Previous studies, such as Rodd and Monaghan (2002) which was based on the collection of questionnaire data, have identified some of the barriers to use. This study has gone deeper by using interviews to gather detailed information about the experiences of a small number of teachers and confirmed that the well known obstacles still exist over ten years after the introduction of graphical calculator technology in mathematics teaching and learning.

Putnam and Borko (2000) found that 'situated learning' was one way of supporting teachers when working with new technologies. They found that 'ground[ing] teachers' learning experiences in their own practice by conducting activities at school sites' helped them to 'enact these ideas in their classroom'. This theme of using situated learning did emerge in this study as the need for training became very evident. The small number of sessions that were conducted with the teachers during the second phase of the study, had a positive effect, because they related so closely to the classroom needs at that time. However a more substantial programme of situated learning / training would be needed to provide the level of support required to bring about a significant change in practice.

The researchers hope to take this work further by trying to locate a department where the recommendations of this study can be implemented in a school introducing graphics calculators for the first time. The benefits of these recommendations can then be evaluated in that environment.

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BIOGRAPHICAL NOTES

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To use or not to use Graphic Calculators on Teaching Practice: a Case Study of Three Trainee-Teachers' Beliefs and Attitudes.

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This paper reports on a pilot study involving three PGCE (Post-Graduate Certificate in Education) students' initial beliefs and attitudes towards graphic calculators, and their subsequent classroom practice whilst on their school-based training. This case study investigates whether the trainee-teachers modify their behaviour to meet the 'ideal' expected of them by their university tutors whilst on teaching practice, or do they revert to teaching the way they were taught? Are their beliefs and attitudes about mathematics and mathematics education evident from their classroom practice? These questions are considered with respect to the use of graphics calculators in mathematics classrooms. The initial questionnaire suggested three differing viewpoints, but the lesson observations and interviews suggest that the student with the positive attitude was almost as reticent to use graphics calculators as the one with the negative attitude.

1 INTRODUCTION

There is considerable evidence (see Thompson, 1992, for a comprehensive review of the literature) that the beliefs and attitudes of teachers impact on their classroom practice; but how do beliefs and attitudes affect the classroom behaviour and practice of trainee-teachers, and where do they get them from?

Ball (1988) suggests that prospective teachers arrive at teacher-training with pre-conceived ideas about mathematics, mathematics education and mathematics teaching. She writes that student teachers 'do not arrive at formal teacher education 'empty-headed'; instead they bring with them a host of ideas and ways of thinking and feeling related to math and the teaching of math, *drawn largely from their personal experiences of schooling*' (authors' italics). This is reiterated by Virta (2001), who notes that 'the models and beliefs adopted during early school years had obviously had a strong influence on their [pre-service History teachers] attitudes towards teaching and the teacher's role'.

Hill (2000) comments that trainee-teachers rely on familiar teaching methods, methods which can be 'implemented without much conscious effort and thought'

and instead of teaching the way they were encouraged at teacher-training college they 'revert to teaching the way they were taught at school'. She suggests that one reason for this reversion may be that 'the former [school] experience lasted longer and took place during their formative years'.
It would appear, then, that trainee-teachers may be trapped in a self-perpetuating cycle that begins at school; they teach the way they were taught at school, and their pupils, who later become trainee-teachers, repeat the process.

Pehkonen and Torner, (1996) define [mathematical] beliefs as 'the compound of his subjective (experience-based) implicit knowledge (and feelings) concerning mathematics and its teaching/learning'. Daskalogianni and Simpson (2001) put forward the argument that students have a number of different beliefs which are developed during their school years, they suggest that these beliefs are 'shaped by endogenous factors (such as students' mathematical skills, students' preferences of mathematical topics, students' confidence and intrinsic motivation) and exogenous factors (such as teaching practices, curriculum style and assessment requirements)'. Daskalogianni and Simpson (2001) go onto define 'beliefs overhang' as the 'beliefs developed in schools, which are preserved at least for the first three weeks in the course...and result in a problematic move from school to university'. This 'beliefs overhang' also exists between school and teacher-training and lasts much longer than three weeks.
Rufell et al (1998) describe attitude as 'a mental orientation' a 'something...that is a multi-dimensional construct with three inter-woven components:

- Cognitive: expressions of beliefs about an attitude object
- Affective: expressions of feelings towards an attitude object and
- Conative: expressions of behavioural intention.

They go on to say that they 'regard beliefs as part of the cognitive component of attitude'. (Rufell et al, 1998)

In this paper the definition of attitude put forward by Rufell et al (1998) as being a 'mental orientation' that leads to a 'posture' or a stance or position is adopted. Beliefs are defined as a person's subjective and experiential or emotional response as given by Pehkonen and Torner (1996).

As well as beliefs and attitudes as personal constructs there is the issue of beliefs and attitudes about mathematics. Thompson's (1992) review indicates that teachers' beliefs play a 'significant role in shaping the teachers' characteristic patterns of instructional behaviour'. In the same way the trainee's views on the nature of mathematics, the nature of mathematics teaching, and the process of learning mathematics form Ernest's 'key belief components' (1989). Within this belief system Ernest proposes 'three philosophies' of mathematics: the instrumentalist view, the Platonist view, and the problem-solving view. He goes on to suggest that the trainee's view of mathematics can be associated with beliefs about teaching and learning and gives the example that an instrumentalist view of mathematics 'is likely to be associated with the instructor model of teaching and with the strict following of a text or scheme. It is also likely to be associated with the child's compliant behaviour and mastery of skills model of learning' (Ernest, 1989). He goes on to conclude that 'the teacher's mental or espoused models of teaching and learning mathematics, subject to the constraints and contingencies of the school context, are transformed into classroom practice'.

In their study into attitudes towards mathematics Rufell et al (1998) asked 26 PGCE secondary students to describe positive and negative experiences of mathematics. They found that the majority of positive experiences were related to 'the self', ('clicking into place', 'seeing the light') whereas the negative experiences were related to teachers ('giving wrong answers on the board and hence confusing pupils'). In a study of young pupils' images of mathematicians, Picker and Berry (2000) found that the pupils had stereotypical, negative impressions of their mathematics teachers and that these formed part of a cycle that perpetuates the myths of mathematics and mathematics teachers. Pupils saw their teachers as being coercive, foolish, overwrought, unable to teach, and disparaging. Contrast this with Jaworski's 'teaching triad' (1992) which includes 'student sensitivity' as one of the three elements of mathematics teaching. In her study Jaworski (1992) describes Clare's 'intense interest in and caring for the student'. Mathematics teachers' perception of themselves as caring professionals seems at odds with the pupils' perceptions of their teachers. Addressing this dichotomy may go some way towards improving attitudes towards mathematics.

The student-teachers in Virta's (2002) study describe good and bad models of teachers; they saw bad teachers as being inefficient, using boring methodologies, having poor communication skills and classroom management, whilst good teachers encouraged critical thinking, were creative and well informed. One of the students in this study describes how his school experience shaped his image of a good teacher:

'There was a teacher who was an absolute authority for me, he kept his classes silent and interested during the whole lesson. He transmitted his knowledge...and will certainly remain in the minds of all his students for the rest of our lives' (Virta, 2002). Another student praised his [History] teacher but added that 'in these days his methodology would certainly be out of date'.

Flores (2001) found that, even when trainee-teachers reported negative episodes from their own school days, they stressed the impact of those experiences in shaping their current practice. One student-teacher comments that s(h)e avoids interacting the same way as her teachers, another student-teacher says that s(h)e behaves in exactly the same way; yet both are influenced by their past experience which shapes their current practice as a consequence.

The four mathematics PGCE students in Smith (2001) view teaching as either 'transmission orientated' or 'learning by discovery'. One particular trainee believes that teachers 'should explain to their classes rather than provide learning opportunities' because that was his preferred learning style.

On the whole, trainee-teachers are successful school-students and it would seem that they appreciate the teaching methodologies they encountered at school. However, as Virta (2002) notes 'the model of the apprenticeship of observation seems to function as a source of contradictory messages, possibly supporting conservative or indifferent attitudes on teaching'.

Despite these entrenched beliefs and attitudes at the beginning of a teacher training course, student-teachers are in a period of transition. McNamara et al (2002) describe teacher training as a 'ritual ceremony', a 'rite of passage' from a trainee towards a novice teacher. In this study student-teachers comment that they perform 'symbolic rituals' such as wearing smarter clothes, adopting a new title (Sir/Miss), and acquiring the new knowledge of the professional community; but they also recognise that teaching practice is a 'performance', that they need to 'demonstrate to tutors, class teachers, parents and pupils their ability to behave in a 'teacherly' way' (McNamara et al, 2002).

These student-teachers exist between two worlds; McNamara et al (2002) note that 'many of the students valued and privileged the 'real' world of the classroom in preference to the 'idealised' world of university', whilst realising that their performance was being measured against an ideal. The difficulty, they say, with this notion of 'ideal' is that different institutions (school, university, government, colleagues and so on) have different expectations and views of what this 'ideal' entails.

This paper looks at this dilemma; do trainee-teachers modify their behaviour to meet the 'ideal' expected of them by their university tutors whilst on teaching practice, or do they revert to teaching the way they were taught? Are their beliefs and attitudes about mathematics and mathematics education evident from their classroom practice? These questions are considered with respect to the use of graphics calculators in mathematics classrooms.

2 METHODOLOGY

This paper presents a case study of three PGCE students. They were chosen from a cohort of 21 mathematics graduates and represent three different attitude and belief systems. The whole cohort completed an initial attitude and beliefs questionnaire (based on a questionnaire designed by Fleener, 1995), and from this three student teachers were selected as potential candidates for the pilot study. They agreed to be interviewed and observed during their teaching practice. They were reassured that the interviews/observations were confidential and would have no bearing on their course assessment. They were also aware that the study was looking at teaching styles.

The questionnaire was adapted from the questionnaire designed by Fleener (1995) to include questions on graphics calculators. The statements were designed to investigate the students' beliefs and attitudes about mathematics and about teaching and learning mathematics using graphics calculators. The first part of the questionnaire consisted of 20 statements about mathematics and graphics calculators and respondents were asked to choose from a 5-point Likert scale, ranging from 'strongly agree' (SA), 'agree' (A), 'no opinion' (N), to 'disagree' (D) and 'strongly disagree' (SD). The second part of the questionnaire consisted of open-response questions. The questionnaire was administered in the first term of a three-term (one year) PGCE course during a group seminar; consequently the response rate was very high (100%). The first part of the questionnaire (only the Likert-scale questions) was re-administered at the end of the course.
The questionnaire responses were scrutinised to find one student that seemed to have a positive attitude towards graphics calculators, one that seemed to have a negative attitude towards graphics calculators and one that seemed to be neutral.
This was done by taking each of the Likert-scale statements corresponding to 'Beliefs about Graphics calculators' and assigning a 'typically' negative/positive/neutral response and then comparing the actual responses that were given by individual students. A student that matched most closely the typical negative responses was labelled as having a negative attitude towards graphics calculators; one that closely matched positive responses was labelled as positive and students that expressed 'no opinion' on several items were labelled as neutral. For instance, agreeing or strongly agreeing with the second statement would suggest that the respondent has a negative attitude towards graphics calculators.

The lessons delivered by each student were observed on four occasions; three times as part of their teacher-training assessment and once as part of this pilot study. They were reassured that the lesson observed for this study would not influence their assessment in any way. Detailed field notes were taken during the lesson observations and a copy given to the student. These notes were available during the interviews.

The interviews were semi-structured and each student was asked the same questions, but their responses may have led to different follow-on questions. Detailed field notes were taken. The first interview followed up the responses to the questionnaire and second interview took place after the lesson observation. The trainees were also given detailed feedback for the lesson observations that formed part of their course assessment, and any relevant comments were noted for later discussion.

Research question	Data collection methodology
What are the beliefs and attitudes of PGCE students towards mathematics and Graphic calculators?	Questionnaire Interview
Do their beliefs and attitudes affect their classroom behaviour whilst on teaching practice?	Lesson observations
Which has greater influence on student-teachers' classroom behaviour, expectations of university or expectations of school?	Comparison of Lesson observations Interview

Table 1: Summary of the Research Questions Linked to Methodology.

The questionnaire, lesson observations and interview go some way towards providing validity and reliability in the data. Yin (1994) suggests that the most important advantage of using multiple sources of evidence is the development of 'converging lines of enquiry'. Cohen et al (2001) call this 'methodological triangulation'; 'using different methods on the same object of study'. To ensure validity in the data, the PGCE students were given copies of the field notes, and these were corroborated during the feedback sessions.

3 ANALYSIS OF DATA

Table 2 shows an overview of the questionnaire data: the individual responses to the Likert-scale statements by the three PGCE students (Nigel, Polly and Nina: pseudonyms) are given, as well as the overall frequencies for each statement for the whole cohort.

From these responses it appeared that Nigel had mostly 'negative' beliefs and attitudes towards graphics calculators, Polly had mostly 'positive' beliefs and attitudes, and Nina was mostly neutral. Nina responded 'no opinion' on twelve statements, whereas other students in the survey chose 'no opinion' at most six times. It would appear that the whole cohort had feelings about graphics calculators and were either positive or negative in their beliefs or attitudes; only Nina was highlighted as being predominantly neutral.

The overall frequencies record the number of responses for each question; total frequencies of less than 22 reflect a missing response by one or more students to that statement.

	Likert-scale questions on the initial questionnaire	Nigel	Polly	Nina	Overall frequencies				
					SA	A	N	D	SD
1	Students should not be allowed to use a graphics calculator while taking maths tests	SA	SD	N	2	6	2	9	3
2	Graphics calculator use will cause a decline in basic arithmetic skills	SA	SD	N	1	0	5	10	6
3	Graphics calculators make mathematics fun	A	A	A	4	14	2	1	1
4	It is easier to solve maths problems using a graphics calculator	N	D	N	1	8	7	6	0
5	More interesting problems can be done when students have access to a graphics calculator	A	SA	N	6	11	2	2	1
6	Students understand maths better if they solve problems using paper and pencil methods	SA	SD	N	2	7	2	9	2
7	All students should learn to use a graphics calculator	N	SA	A	8	10	2	1	0
8	Students should not be allowed to use a graphics calculator until they have mastered the concept or procedure	SA	SD	N	1	4	4	9	4
9	Using graphics calculators means students can do harder maths	SD	D	N	1	6	6	7	3
10	Students should learn how to use a graphics calculator as part of their maths lessons	N	SA	A	8	12	1	1	0
11	Teachers should know how to use graphics calculators	D	SA	A	12	9	1	0	0
12	Graphics calculators should only be used to check work once a problem has been worked out on paper	A	D	N	0	3	3	13	3
13	Using graphics calculators makes students better mathematicians	SD	N	D	1	3	8	6	4
14	Graphics calculators are good for checking solutions	A	A	A	5	14	3	0	0
15	Using graphics calculators with young pupils makes them better at maths later on	SD	A	N	1	3	11	4	3
16	Teachers should teach students how to use graphics calculators	N	A	A	7	11	4	0	0
17	Graphics calculators are only good for doing calculations more quickly	A	SD	D	0	1	0	13	8
18	Graphics calculators can be used for investigations	N	SA	N	7	10	4	1	0
19	Graphics calculators are too complicated to be used by younger pupils	SA	D	N	1	2	4	12	3
20	Money spent on graphics calculators would be better spent on textbooks.	SA	SD	N	2	0	8	7	5

Table 2: Summary of the Initial Questionnaire Data for the Three Students.

Nigel (predominantly negative)

Nigel is a mature student, having graduated with a degree in Mathematics twenty years ago and then been self-employed. His questionnaire responses suggest a tendency to be negative towards graphics calculators and he confirmed this during the follow up interview:

> Researcher: How often do you use graphics calculators in your teaching?
>
> Nigel: Myself, I don't use them really. I don't see a need for them; most things are just as easy without. I use them for doing tedious calculations, but other than that I don't use them. I try to teach pupils how to do things mentally, or show them how to do things so that they can work it out without calculators. Also, the textbook doesn't use any graphics calculators, and the examples that the pupils see don't use anything, so they think that they can do it without, so that's how I show them. I do let them use an ordinary calculator if they need to do any arithmetic.

Nigel suggests that he 'doesn't see a need for them', he has become a successful mathematics graduate without needing to use a graphics calculator and consequently feels that all of his pupils can be successful without using them too.
Similar attitudes were reported in a paper by Quinn (1998), where Peter, a trainee says 'I don't agree with the use of calculators and computers in mathematics. The children use these items as thinking types of crutches...they become mentally lazy and no longer have to think or reason through a problem'.
Nigel's predominantly negative view of graphics calculators may stem from his lack of personal exposure and experience.

> Researcher: Have you ever used graphics calculators?
>
> Nigel: No, not really. We didn't actually use calculators at all, I didn't have one for my 'O' level, and I used a scientific for my 'A' level, I didn't use anything really for my degree. I occasionally used my scientific if wanted to check the value of a trig function in radians, so I haven't really ever used a graphic calculator.

His exposure to graphics calculators on his PGCE course has also been limited to two half days at university and none at all during his first teaching placement. His entire experience of graphics calculators has consisted of working on a piece of work on transformations of functions with his peers on the PGCE course. He is aware that many mathematics departments have access to graphics calculators in school, but they are rarely used. More significantly, their use has not been modelled for him during his training.

Observations of Nigel during his teaching practice confirmed that he makes very little use of technology. The first observation took place in the third week of his school-based placement and was part of his formal assessment. This was a lesson with year 12 on Polynomials: the Factor Theorem. He began the lesson by stating the Factor Theorem, then demonstrating how the theorem works by writing examples on the board; the students were asked to copy these examples in their note book. At no time during his exposition did he ask any questions. He then set an exercise of problems for the class to solve from the text book.
During the feedback he was asked why he had chosen such a (didactic) approach.

> 'I just did it the way that Carol [the class teacher] does it; I always check with her if my plan is okay before I teach it, and she gives me pointers if she thinks I need to do things differently. She prefers that I do things like the text book, so that was my reason behind doing it this way'.

Nigel's objective for this (assessed) observation was his subject knowledge and his lesson planning and he was able to meet the course criteria for those two aspects. As an aside he was asked if he had considered using technology at any stage during his preparation. Again, he responded that he didn't feel that the students would have benefited from using technology.

> 'I suppose I could have used Omnigraph [a graphing package], but to be honest, I don't think it would have added anything more to what I'd already told them'.

The last observation was not part of the assessment process and took place in his second teaching practice. Nigel was asked to plan a lesson using graphics calculators. He decided to do to straight line graphs with year 8.
Nigel asked pupils to investigate the affect of changing m and c in $y=mx+c$. Pupils were given a worksheet and they were asked to plot two straight lines by generating a table of values and plotting the coordinates on a set of axes. They were asked to write down the y-intercept. Then he distributed the graphics calculators (one between two) and gave explicit instructions to the class on how to use the graphing facility.
Pupils were then asked to plot several other straight lines and note down the intercept.

> Researcher: How did you feel that lesson went?

Nigel: I wasn't really very happy with it at all. The pupils don't know how to use the graphics calculators, so they can't really do the maths properly. And because I don't really understand them either the whole lesson was chaos.

Researcher: Did you have any help from the class teacher when you were preparing the lesson?

Nigel: Oh, yes, she suggested the topic and we chose the questions together, but she's never used the graphics calculators with that group before either.

Researcher: Did you use any ideas from your seminar on graphics calculators?

Nigel: Not really, I get most of my ideas from the school text book or the class teacher. The stuff we do at university doesn't seem to apply in real life.

In this last statement Nigel demonstrates that he experiences 'university and school as two distinct worlds' (McNamara et al, 2002), and also that he feels that the world at school is the real world. Since there are no teachers using graphics calculators in his 'real' world, then expecting him to include graphics calculators into his repertoire may be unreasonable. However, McNamara et al (2002) note that the 'rite of passage' that trainee-teachers go through is not a 'linear passage' but 'involves a back and forthness that repeatedly repositions the initiand in response to a complex, often contradictory, set of agendas.' It might be that, having taught one lesson using graphics calculators, Nigel might reconsider his experience.

For Nigel, as well Polly and Nina, the departmental scheme-of-work seems to predicate what the trainees teach (but this is equally true of experienced teachers). The school-based subject mentors appear to have greater influence on the way the trainees teach than their university-based tutors.

Polly (predominantly positive)

Although Polly's route onto the PGCE course was typical of others in the cohort (A-levels, mathematics degree straight onto teacher-training) her personal experience of graphic calculators was very similar to Nigel's.

'We didn't use one at school, I had my one, but we didn't really use it at all. We weren't allowed to use it on our university course at all, so I sort of got out of the habit. And on this [PGCE] course we did a bit as a group, and during my first school visit I observed an experienced teacher using graphics calculators with an A-Level class.'

She was asked to expand on the last point:

> 'They were doing trig equations, and the idea was to use the [graphics] calculator to show them the function so they could see how many solutions they should have...but it wasn't really helpful, because the teacher didn't really know much about the calculators; it was a bit like the blind-leading-the-blind in a way. The teacher was really good, because he knew his stuff and the students respected him, but with the calculators the students knew as much as he did, and if they got stuck he couldn't help them and they felt a bit disappointed in him, which was a shame.'

Despite Polly's positive responses to the questionnaire statements, her lack of exposure and personal experience as a student, followed by a 'disappointing' observation seemed to influence her choices as a trainee.

> Researcher: Have you used graphics calculators as part of your teaching?
>
> Polly: I haven't used them at all. I must admit I was put off by Mr W's experience, I don't think I'm confident enough to use them with a class unless I know that if anything cropped up, I could deal with it.

Polly's need to be able to 'deal with anything that cropped up' is evident from the lesson observations. All four of the observed lessons were planned in detail, resources were well prepared, and pupil tasks were differentiated thus enabling all pupils to take part in the lesson.

During the feedback for the first (assessed) lesson she was asked about her planning:

> Researcher: I notice that you have got all of the solutions to the exercise written out in full; that must have taken you ages.
>
> Polly: It did, but I needed to do all the questions to make sure there weren't any tricky bits in there. Also, I wanted to check my own understanding [of polynomials], when you do the work as a student you tend to do as you're told, but now it's me that's doing the telling, so I wanted to make sure I knew what I was talking about.

> Researcher: I noticed that you used some of your own examples, why didn't you follow the text book?
>
> Polly: I was going to, to start off with, then the more questions I did, the better I felt about it, more confident, then I thought, well I get this topic so I'll explain it my way.'

Prestage and Perks (2001) comment that 'the view of teaching for these pre-service teachers is to replicate the learner-knowledge they hold for others to learn.'
Furthermore, their subject knowledge is disjointed, and that they lack 'multiple and fluid conceptions'.
In the initial stages of their teaching practice the pre-service teachers are working within the confines of their subject knowledge and certain professional traditions, (government strategies, examination syllabus, school policies); these 'merge in the first instance to create classroom events for others to engage with learning mathematics' (Prestage and Perks, 2001). However, there appears to be little difference in the 'classroom events' when described by some experienced teachers. 'High on the list when justifying decisions about curriculum, were text books and other departmental resources, experiences of learning maths' (Prestage and Perks, 2001).

Polly is able to overcome her lack of confidence with her subject knowledge by 'rehearsing' the solutions to the exercise. But if the way that classroom events are modelled for the trainees does not include the use of graphics calculators, then they have few opportunities to visualise, rehearse and use graphics calculators within their own classroom.

The second observed lesson was a lesson on area of composite shapes with year 7 pupils.
Polly had prepared a sheet of shapes and pupils had to dissect each shape into a rectangle and two, congruent triangles. From this, pupils developed a method for working out the area of trapeziums.

> Researcher: Where did you get the idea for the practical activity?
>
> Polly: From Mrs S; she suggested that this group like to do this sort of work, so I had a look at her worksheet and used it to make up my own.
>
> Researcher: what was the pupils' learning experience from this lesson?
>
> Polly: I think they learnt that area isn't a difficult topic, that they can build up from what they already know. So even if they can't remember the formula for the area of a trapezium, they can work it out by splitting the

> shape into rectangles and triangles. I think that they can build up most things in maths like that, start from what you know, and build up.

Polly demonstrated that she was willing to experiment and try out new approaches, but she was still reticent to use technology in her classroom. This seemed at odds with her experimental style, but she attributes this to a lack of resources within the school.
However, she realises that she has to meet the course criteria regarding the use of ICT and comments:

> 'I suppose I would manage if I had to, if you said you were coming in to assess me and it had to be a lesson with graphics calculators, I would make myself learn the bits I needed, otherwise, the most useful thing would be to team teach with someone who knows about graphics calculators.'

Polly suggests that if she needed to, she would 'rehearse' the use of graphics calculators in her teaching, but only to meet set criteria.
She highlights the need for good role models and a collaborative approach during teaching practice. Unfortunately, this is often lacking in many schools with regard to the use of graphics calculators.

Nina (predominantly neutral)

Nina's responses to the questionnaire where predominantly 'no opinion'. This suggested that she had neither a positive nor a negative attitude towards graphics calculators. Interestingly, other respondents marked 'no opinion' at most six times.

Like the other two students in this case study, Nina has had very limited personal experience of graphics calculators.

> 'We didn't use them very much at school, some of us had them for our A-Levels, but because we didn't all have one, we didn't use them in lessons. We didn't use them on the BSc at all. We've done a little bit on this [PGCE] course, just a general introduction to graphing and so on. I'm teaching myself at the moment on the school one that I've borrowed.'

Nina was asked to expand on her last comment;

> Researcher: What sort of stuff are you doing with it?
>
> Nina: Nothing in particular, just trying to find what each of the buttons is for. I did think about using them [graphics calculators] for trail and

improvement last week, but I ended up using Excel because I needed to do that to complete Phase Two [course criteria].

Like the other two students, Nina is process driven; she recognises the need to meet assessment criteria and her planning is influenced by them. But unlike Polly and Nigel, Nina has considered using graphics calculators in her teaching.

Nina agreed to use graphics calculators for one lesson (not assessed). It was agreed that she would plan the lesson, whilst the researcher's role would become that of a 'classroom assistant'. This was an extension to the 'participant-observer' (Cohen et al, 2001) role that was the norm for other lesson observations. Acting as a classroom assistant allowed a level of flexibility in the classroom; there was more interaction and greater involvement with the pupils, yet allowing for moments when critical incidents could be recorded.

During the feedback session we discussed an incident where a group of pupils (year 7) were working on $x^2 + x - 6 = 0$:

> 'I was so excited; they were discussing whether they could have two solutions, whether the solutions could be negative, and so on. They were actually talking about difficult maths concepts. And when I showed them how to get the graph up, they were shouting out that the solutions were where the graph crossed the axes. They're a good group anyway, but I think they learnt so much more today.'
>
> 'Yes, I would use them [graphics calculators] again, but it took a lot of time to prepare. I spent ages making sure I knew how to use it myself. I thought about all the things that could go wrong, it took more planning than an ordinary lesson on trial and improvement.'

Despite Nina's positive and 'exciting' experience, she still has concerns about the time it takes to plan and prepare lessons using technology, but she comments that she is willing to make that commitment. Having support (although she didn't need any) in the classroom made her feel secure, and points to the need for a more collaborative, team teaching approach in schools.

Table 3 summarises the questions for the semi-structured interviews, which took place after the initial responses to the questionnaire. This table highlights their lack of experience with and exposure to graphics calculators, both as students and as trainees. It also shows that they had had very little training in teaching with graphics calculators during their first teaching placement.

	Nina	Polly	Nigel
Previous experience	None as a student limited on PGCE	None as a student Limited on PGCE	None as a student Limited on PGCE
Number/ type of calculators owned	1 scientific Graphics borrowed from school	1 scientific 1 graphics	1 scientific
Preference	Scientific	Graphics for graphing and functions Scientific for calculations	No calculators
Reason	Never needed to use GC Familiarity with functions	Scientific for ease of use Graphic for visual	Maths can be done without calculators
Used/ observed GCs on TP	Not used Not observed	Not used Observed 1 lesson on trig functions	Not used Not observed
GC facilities in current placement school	teacher calc and view screen 2 Class sets	Teacher calc and screen no class set of GCs	Unsure
Advantages	Less expensive than computers More accessible	Visual Efficient Motivational	Motivational Can be used in normal classroom
Disadvantages	Too complicated Intimidating for some pupils	Need to monitor each pupil Pupils might mess about	More expensive than scientific Time consuming to master

Table 3: summary of interview responses

4 DISCUSSION

Despite the high profile of ICT requirements by the TTA, National Numeracy Strategy and other LEA/Governmental policies, use of graphics calculators remains

limited in many schools. Reasons for poor take-up are many, complex and overlapping.
It is generally recognised that teachers' personal history certainly plays an important role: if they have had no experience of graphics calculators as pupils, students or trainees, they are unlikely to use them in their teaching. If they do not use graphics calculators in their teaching they are unable to model practice for the next generation of trainee-teachers.
Ball (1988) comments that 'teacher education is often a weak intervention' and that teachers 'in spite of courses and workshops, are most likely to teach math just as they were taught'. There is a strong need to break this cycle and it may be that the most accessible period is during Initial Teacher Training.

Chuene et al (1999) report that there is a marked contrast between the teaching strategies used by trainees and newly-qualified teachers; the trainees want to teach in a social constructivist, pupil-centred way, but the novices seem to abandon that philosophy and return to the didactic 'chalk-and-talk' style. They suggest that 'the view of mathematics teaching changes with exposure to school, or that teacher education programmes have lost touch with school practice and fail to prepare their candidates for the realities of schools.' Nina and Polly had similar teaching styles, both preferred to teach using a discovery approach, this was most likely based on their university work on constructivist theories. Nigel was much more transmission orientated, he preferred to 'tell' his class what he wanted them to know and then they would do exercises and problems based on that. He recognised that using technology required a shift in his teaching style, and he tried to adopt a more 'investigative' approach to the lesson on straight line graphs. However, he clearly felt uneasy with this way of working. Reynolds et al, (2003) argue that 'teaching with ICT is not suited to the traditional pedagogical styles'; this may account for the teaching styles observed and emulated by the three students in this report.

Nina's evaluations of her lessons during the feedback sessions often included the comment 'I could have used graphics calculators in this episode'. Her reasons for not including them in her teaching were mostly lack of resources ('not enough to go round') and behaviour management ('controlling disruptive pupils'). Capel (2001) found that student-teachers listed six items of concern; the main concerns were 'maintaining the appropriate degree of class control', 'getting a favourable evaluation of my teaching' and 'doing well when a supervisor is present'. Nigel and Nina recognise that using technology has an impact on classroom dynamics (shifting roles from instructor to facilitator; less teacher-centred and more pupil-centred). If they are concerned with behaviour management and they are being constantly monitored, they are less likely to include the use of graphics calculators in their lessons.

Although, all three of the students were encouraged to include graphics calculators into their teaching repertoire, none were willing to present it for assessed observation. It seems that the assessed observation is one of the 'hoops to jump through' (McNamara, 2002). The trainees see it as part of their 'rite of passage', becoming an aspect of teacher training that is 'performed-for-an-audience'. Both Nigel and Nina agreed to 'perform' a lesson with graphics calculators for this study as long as it did not influence their assessment for the course. Lessons presented by trainees contain elements of teaching that they have observed and then rehearsed, superimposed with layers of theory from university. When trainees present lessons for assessment, they attempt to blend all three aspects into their lesson plan.

Burn et al (2000) suggest that as trainees progress through their training year they move beyond concerns with the self and begin to consider pupil learning. When planning lessons the trainees rate pupil achievement as the main aim of their lesson. They note that the trainee-teachers use three different subcategories when discussing 'pupil achievement'; cognitive (learning a new skill or concept), coverage (getting through the syllabus) and product (producing a finished piece of work). Using graphics calculators does not fit neatly into this model of pupil achievement. In the early stages graphic calculators are time-consuming, so they can be a hindrance if speed is important. Also they do not produce a print-out, so there is no record of the work the pupils have done.

Polly and Nina suggest that they can increase their confidence by making sure they have 'rehearsed' their lesson, checking that they understand what they have to do before the lesson so that they can field 'awkward questions and strange answers'. Humphreys and Hyland (2002) extend the performance metaphor by suggesting that there needs to exist a 'critical dialogue between mentor and student in an environment of demonstration, rehearsal and practice.' Working with a mentor in a collaborative approach is one way to raise the profile of graphics calculators in schools; experienced teachers need to demonstrate good practice, and allow the student-teachers to rehearse and practice the use of graphics calculators in their lessons. Flores (2001) notes that there is a need for a 'more effective supervision and supportive climate'. She goes on to say that the trainees 'adopt a strategic compliance' and they follow their supervisor's behaviours even if they don't agree with them. This suggests the need for more training for the subject tutors, so that they become aware of the need to model best practice.

Da Ponte et al (2002) found that pre-service teachers wanted to use ICT in their teaching. The pre-service teachers in their study tended to agree that using technology would have a 'very strong role in the school of the future' but that they were concerned about the lack of resources. They also perceived a 'dominant opinion in teachers against the use of technology'. Da Ponte et al (2002) suggest that this attitude can be challenged when 'there is a group of teachers committed to put innovative activities into practice'.

> 'I'd like to use graphic calculators in my teaching, but there always seems to be something more important that I have to deal with. At the moment, I'm more concerned with completing all my Dimensions for Phase Two [ITT assessment criteria]. It's not that I don't think they're important, it's just not on the top of my priority list.' [Polly]

Burgess (2000) notes that the 'separation of subject and pedagogy' is of concern to ITT providers because the trainees (and their subject mentors) are more worried about meeting the QTS standards. Nigel, Nina and Polly all comment that they are influenced by these standards. On the one hand they have to teach a particular topic area and on the other they have to meet the ITT assessment criteria. The student-teachers in Flores' (2001) study refer to the 'gap between theory and practice and to the inadequate preparation for coping with the daily problems of the school and classroom'. Flores (2001) suggests that initial teacher education has a 'weak impact in determining beginning teachers' professional behaviour'. This is not unusual according to Maynard and Furlong's (1993) five stages of development. Student-teachers move sequentially through a period of 'early idealism' to 'survival' 'recognising difficulties' 'hitting the plateau' and 'moving on'. It is only in the final stage that student-teachers are able to experiment with their teaching, and this is most likely to occur during their first year as a newly-qualified teacher.

5 CONCLUSIONS:

The three student-teachers in this pilot study appeared to be more influenced by their school-based experience, which they call the 'real world', whilst recognising the 'idealised world' of the university as part of their 'rite of passage'. All three of the trainees recognised the difference between the role of the assessor and the researcher; they were willing to experiment with the use of graphics calculators only when they were not being assessed. For the assessed lesson observations they stuck closely to the teaching style of their subject mentor. They are able to rehearse and practice methods and teaching styles that are demonstrated by classroom teachers. Since no-one is modelling the use of graphics calculators in a classroom environment, they have to teach themselves. Unfortunately, this is not a high priority during their training.

This raises two, closely linked, issues. How does the university ensure that trainees are given the opportunity to observe teachers using graphics calculators in the classroom? What training is made available to the teacher to enable her to use graphics calculators in the classroom?

One way to overcome this difficulty may be for the university tutor to act as a mentor in a classroom environment. By working collaboratively with the classroom-teacher the university tutor would be able to demonstrate good practice and encouraging team-teaching and joint-planning. This will enable trainee to observe, then rehearse and practice using graphics calculators in their teaching.

This pilot study formed part of a longitudinal study, following a cohort of PGCE students as they complete their teacher-training, become newly-qualified and go into their first year as qualified-teachers of mathematics.
As a case study of three individuals, attempts to generalise from the data may be considered inappropriate, but this pilot attempts to present the 'complex dynamic and unfolding interactions of events in a unique instance' (Cohen et al, 2001). Efforts have been made at every stage to preserve the qualitative data in its original form, and lesson observation notes were cross-referenced with the student-teacher.

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BIOGRAPHICAL NOTES

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The use of graphics calculators by students in an examination: what do they really do?

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In many British schools, A-level Mathematics students are advised to purchase graphics calculators at the start of their Mathematics course, and there has been considerable research into the effectiveness of the use of graphics calculators in developing mathematical understanding. Recent UK examination regulations have prohibited the use of graphics calculators in certain module examinations but allowed them to be used in others. This study set out to investigate how a small group of students actually used their graphics calculators under examination conditions. The students sat an externally set practice examination paper for a statistics module. The examination paper was analysed by the research team in order to identify the potential use that the students could have made of the graphics calculators in each question. When they took the examination the students were provided with specially adapted calculators; these calculators were virtually identical to the students' own calculators but contained specially written software which enabled the students' keystrokes to be captured and saved. After the examination the keystrokes were replayed and studied by the research team with reference to the students' examination scripts. Each of the students was interviewed. The interviews were based on the students' use of calculators on the examination paper and more generally in their study of mathematics. The research found that very little use was made of the graphics calculator in the examination, with most of the students using a scientific calculator in preference to their graphics calculator, unless a graph was specifically requested in the question.

1. Introduction

The introduction of graphics calculators into mainstream education has led to various studies on the use of hand-held technology as a tool for teaching and learning mathematics.

Many of these studies consider the impact on students' understanding of mathematical concepts and their performance in assessments. Early work by Hembree and Dessart [1] found that there were 'consistently positive effects on computational and problem-solving skills when tested with calculators available, and broadly neutral to positive effects when tested without'. Similarly, the study into graphics calculator use carried out by Ruthven [2] concluded that there is strong evidence that information technologies have an influence on students'

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mathematical attainment and on the mathematical approaches that they use. Ruthven goes on to note that regular use of graphics calculators enables students to develop a repertoire of solutions for problem solving. This is reaffirmed in later work by van Streun *et al.* [3], but they go on to note that 'the calculator has no additional advantage in interpreting the data'. The majority of these studies tend to focus on algebraic topics, with little, if any, mention of the graphics calculators' in-built statistical functions.

Similar studies into students' attitudes towards calculator use suggest that they are positive in most cases, although any changes in attitude may be as a result of new teaching styles, which need to be adopted in order to integrate graphics calculators into the curriculum.

The study by Boers and Jones [4] found that students tended to use more exploration in solving problems. The students gave a list 15 positive aspects of using a graphics calculator while learning mathematics. Of these, the five most important ones were linked to algebraic/graphical topic areas. They also listed their concerns, of which over-dependency was cited as being the most important. Work by Dunham [5] noted similarities and found 'many students, especially females, were concerned about relying on the calculator, feeling that it as important to learn and be able to use algebraic techniques as a means of solution as well'. Penglase and Arnold [6] suggest that this may be attributed to 'curriculum demands [of] proficiency in algebraic skill'.

More recently the discussions have centred on permitting the use of graphics calculators during examinations. QCA (Qualifications and Curriculum Authority) [7], the body responsible for curriculum development and examinations in Britain, lists 'use contemporary calculator technology' as one of the five assessment objectives within its 'Subject Criteria for Mathematics'. The same document also stipulates that the assessment must include elements for which 'computers, graphics calculators and calculators with computer algebra functions are not permitted' and that this element must account for at least 25% of the overall award. In asking whether technology should be permitted in examinations, Ellis and Browne [8] suggest that assessment should match the curriculum, and if students are expected to use calculators within the course then any examination which excludes their use cannot be a valid assessment. Currently the situation in England and Wales is that students are permitted to use only a scientific calculator in some of their three pure mathematics module examinations, consequently many students are unwilling (or unable) to purchase a graphics calculator that they cannot use in their first examination. Monaghan [9] comments that the UK examining bodies are open to market forces and as such cater for the needs of schools/departments and teachers who are generally conservative in their outlook. His work is concerned with calculators that have facilities for algebraic manipulation, but his remarks are pertinent to the use of graphics calculators. He writes that the 'explicit desire to minimise possible advantage to candidates with algebraic calculators may partially arise from an implicit desire to keep the customers, most of which do not have algebraic calculators, happy'. The influence of the decision by QCA to prohibit graphics calculators in some A-level examinations affects the confidence and competence of graphics calculator use in modules where graphics calculators are permitted in the exam.

The impact of technology on the style of examination questions is discussed in detail by Drijvers [10], Kokol-Voljc [11], Malabar and Pountney [12], and Brown

[13], among others. Where graphics calculators have been used in public examinations, studies of those examinations have tended to focus on the 'pure' papers. However, there are two aspects pertinent to this paper; analysis of students' use of the graphics calculator, and the impact of the graphics calculator on the type of question posed in the examination.

Several authors (Forster and Mueller [14]; Monaghan [15]; Taylor, [16] and [17]) have commented that the graphics calculator is underutilized or used inappropriately. One reason suggested by Monaghan [15] is what he describes as 'the peculiar form of higher secondary mathematics examinations [which] restrict classroom activities to lower level tasks'. In his report on one 1994 A-level examination Taylor [16] noted that 'candidates made little use of the facilities of their machines and ... that it was doubtful whether candidates were fully aware of these facilities'. Until teachers are aware of 'teacher privileging' (Kendal and Stacey [18]) and able to integrate graphics calculator use into their teaching repertoire, it may be difficult to move away from this scenario. Forster and Mueller [14] suggest another reason for underutilization may be that students lack confidence that the calculator will yield the correct answer. However, as graphics calculator use becomes more prevalent in classrooms, they may be able to overcome their uncertainty. Furthermore, they suggest that when students do want to use a graphics calculator they have to make the decision about time effectiveness, they 'have to judge if the time used to enter equations into the calculator will be well spent' (Forster and Mueller [14]). One important conclusion from their study is that 'choosing to use a GC was not associated, in general, with higher (or lower) marks than traditional alternatives'.

The use of graphics calculators has been expected in examinations in Western Australia since 1998 and one of the outcomes and implications discussed by Forster and Mueller [14] is the acceptance of what constitutes 'adequate written working in answering examination questions'. There is a degree of uncertainty here, as what is acceptable to one examiner (or examining body) may not be considered sufficient by another. Similarly, Taylor [16] suggests that an instruction in the rubric to provide an explanation of how much working out is required will be of limited help as 'there would probably not be a consensus among examiners and it would be even less clear to students'.

There are many articles looking at the potential use of graphics/CAS calculator use in an examination: for instance Ellis and Browne [8] and Etchells [19] consider how a CAS calculator could be used to answer a calculus question. Drijvers [10] speculated about how a student might answer a question on functions. An analysis, of the actual use of graphics calculators in an examination, has been carried out based on scrutiny of students' scripts by Puga [20] and Malabar and Pountney [12]. In the Malabar and Pountney study, students were set examination questions and asked to comment on whether they used CAS technology and how. Although their results provide an insight into how students work, it is possible that students' responses do not match up with actual use. This idea is developed further in the Puga study in which students are required to provide the DERIVE input and output for their solutions. From this he is able to identify the types of mistakes and misconceptions made by the students. Each of these studies considers the use of CAS technology rather than graphics calculators. Recent work by Smith and Berry [21] using the TI-83 enables a record of keystrokes used by the student to be recorded and this can then be compared with students' scripts to analyse the use they make of the graphics calculators. They were able to observe students' working styles on a functions task. This work is an extension of that study and looks at the use students make of their graphics calculator in a statistics A-level examination.

2. Research method

The study involved seven students who were halfway through the second year of their Advanced Level Mathematics course (aged 17–18 years). All students were studying their third module in Statistics and this study focuses around the mock examination of that module. The teacher had used the graphics calculator extensively with the students in the teaching of the subject in this and both previous statistics modules. The students had owned a graphics calculator since the beginning of the course and so continuous access to the graphics calculators had been available for about 18 months. The study was conducted in three parts:

- Expert analysis of the examination paper, by members of the research team, prior to the examination being taken by the students.
- Recording of how the students used the graphics calculator during the examination.
- Interviews with the students after the examination.

2.1. *Expert analysis*

Prior to the examination the paper was worked through by researchers who were proficient in both the content and in the use of graphics calculators. The researchers identified opportunities to make use of the graphics calculator in tackling each of the four questions in the paper.

2.2. *Recording students' usage*

The students were each given a calculator for use in the examination, which was identical to the one that they had been using throughout their studies. However, this calculator contained a piece of software that enabled the researcher to capture exactly the students' use of the graphics calculator. The software records the key presses a student makes as they use the calculator and saves them within the calculator's internal memory [21]. At the end of the examination the information was extracted from the calculator and analysed.

2.3. *Interviews*

Follow-up interviews were held with all seven students in the group. The interviews were designed to elicit student attitudes to the calculator and use of calculators in examinations in general as well as asking specific questions about the use the student made or could have made in the Statistics examination. The interviews were all conducted on a one-to-one basis with the same researcher interviewing all seven students. There was a clear interview protocol that was followed each time.

3. Results

3.1. *Expert analysis*

The researchers worked through the paper and identified the opportunities for using a graphics calculator. In addition to identifying the opportunities the researchers also classified the ways in which the graphics calculator might be used. The three categories that were defined are described below.

- *Quasi-scientific.* Uses graphics calculator in the same way as a scientific calculator would be used. No use is made of those features of a graphics calculator that are not present on a scientific calculator. No advantage is gained from having a graphics as opposed to a scientific calculator. The user does not seem to be aware of the facilities that are available on the graphics calculator.
- *Semi-proficient.* Some use is made of the features of the graphics calculator and some benefit is derived from having the graphics calculator as opposed to the scientific calculator. However, the best or most efficient use is not made of the graphics calculator. The user is aware of some of the facilities on the graphics calculator, but does not know how to make the best use of them or is not aware of the feature that gives the most efficient solution to the problem.
- *Proficient.* Use is made of the appropriate features of the graphics calculator to obtain the most efficient solution to the task in hand. The user is aware of a wide range of the features available on the calculator and is able to select an appropriate method or features to reach the solution.

For each question the possible ways of using the graphics calculator were allocated to each of these categories. One example of this is now described. In one question the students were required to calculate a confidence interval. Table 1 shows the three possible approaches and the classifications that were made.

Quasi-scientific approach	48+1.645*20/√(50) 52.65276262 48-1.645*20/√(50) 43.34723738	In this approach the student uses their knowledge of the definition of a confidence interval in conjunction with a book of statistical tables to compute the confidence interval.
Semi-proficient approach	48+invNorm(0.95) *20/√(50) 52.65234861 48-invNorm(0.95) *20/√(50) 43.34765139 ■	In this approach the student uses their knowledge of the definition of a confidence interval, but obtains the required values from the calculator, and so does not need to use a book of statistical tables.
Proficient approach	ZInterval (43.348,52.652) x̄=48 n=50 ■ ZInterval Inpt:Data Stats σ:20 x̄:48 n:50 C-Level:.9 Calculate	The student uses the facility provided in the calculator to calculate the required confidence interval.

Table 1. Example of the classification of graphics calculator use.

3.2. *Recording of students' usage*

With permission from the students' teacher we decided that we would not make the students aware that their use of the graphics calculator was being recorded and so its use was as natural as possible. All the students usually used a TI-83 graphics calculator in their classes and previous examinations. For this examination they were given a TI83+ graphics calculator identical in every way except that it had the Key Recorder software installed and running. All the students took a scientific calculator into the examination as well as the graphics calculator. (This is normal practice for such students!)

After the examination the actual keystrokes that each student made were played back, giving the researchers an opportunity to see exactly what each student had done during the examination. It soon became apparent that none of the students used their graphics calculator in a manner that could be described as proficient or even semi-proficient as none of the statistical functions of the calculator were used at all by any student. What was even more of a surprise was that only one student (Student A) used the graphics calculator for calculations (figure 1). We can assume that the other students must have used their scientific calculator for these calculations.

A later question asked the students to derive a probability density function,

$$F'(x) = \frac{1.25}{x^2}$$

and illustrate it with a sketch. This was the only question that involved graphing and all of the students used the graphics calculator to obtain a graph (figure 2). A number took a couple of attempts to get the correct graph and one student (ironically Student A) entered the equation as $5/4x^2$ which produced the graph of a quadratic which she copied onto her answer script (figure 3). No student set the graphing window on the calculator to fit the requirements of the function before pressing the graph key. The calculators had been preset to the standard window and so the graph produced looked reasonable. We suspect, however, that on the

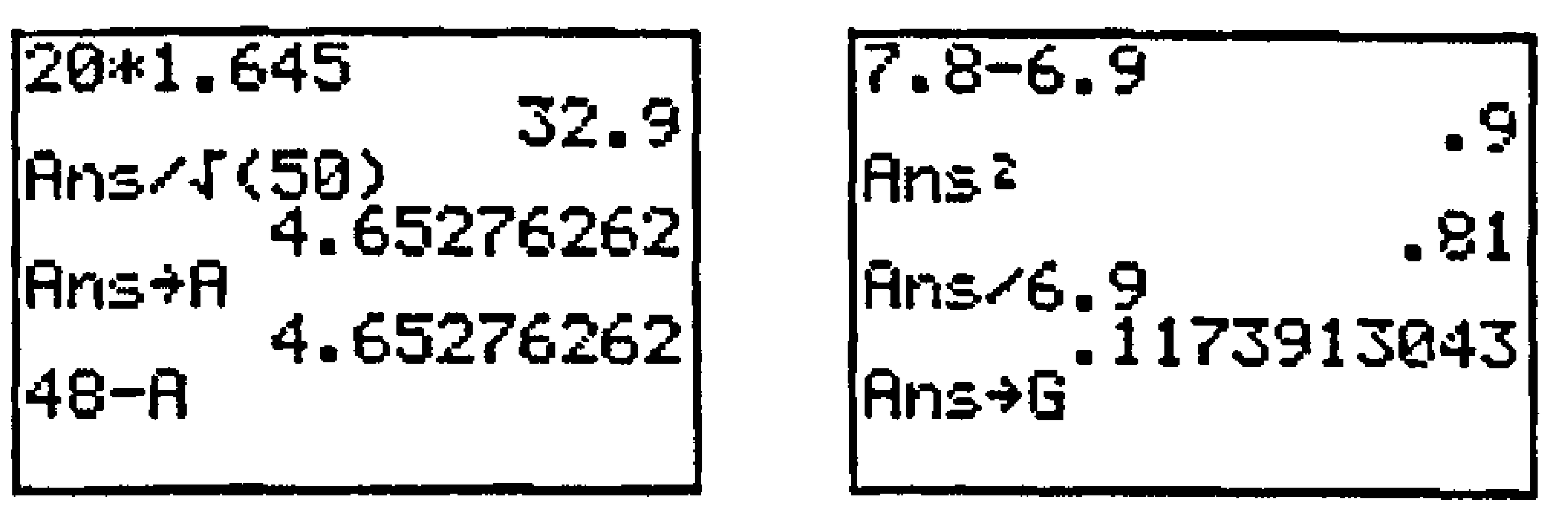

Figure 1. Student A's use of the graphic calculator for calculations.

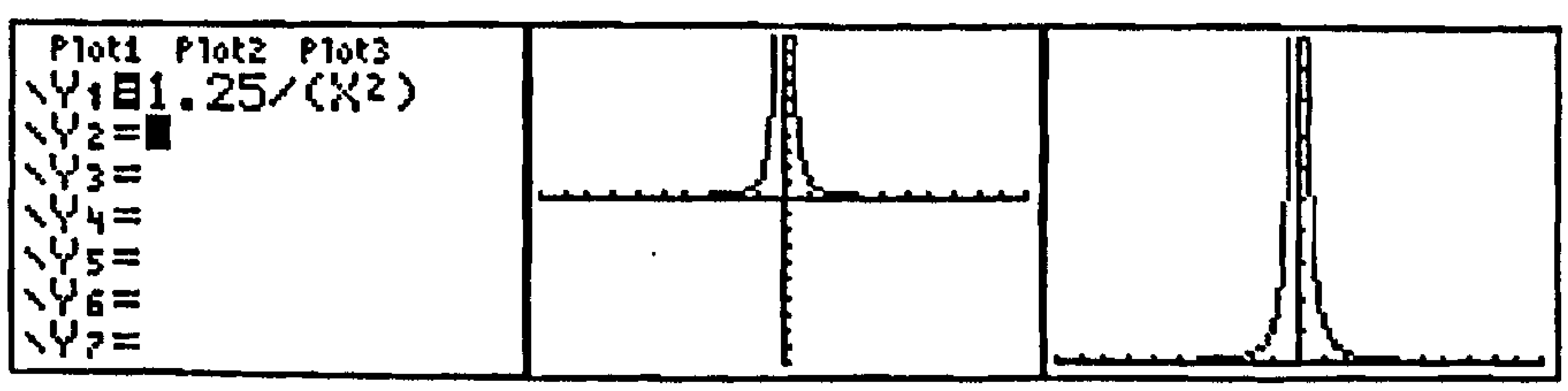

Figure 2. Use of the graphic calculator in question 3.

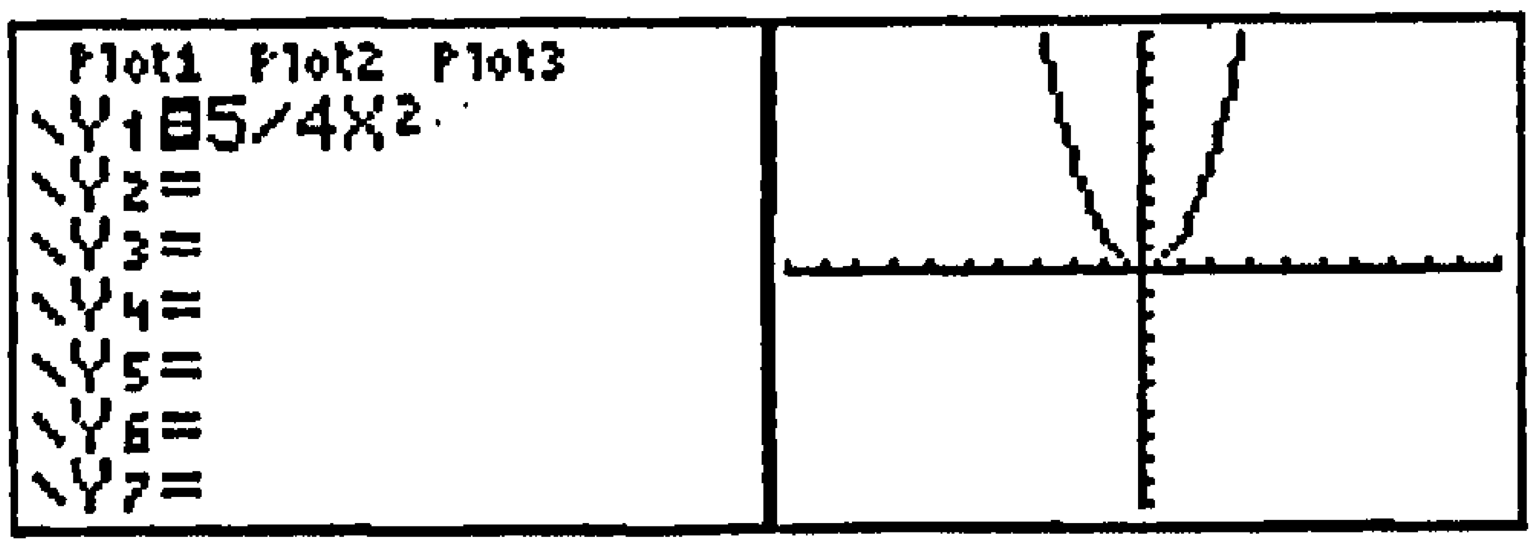

Figure 3. Student A's incorrect entry of the function in question 3.

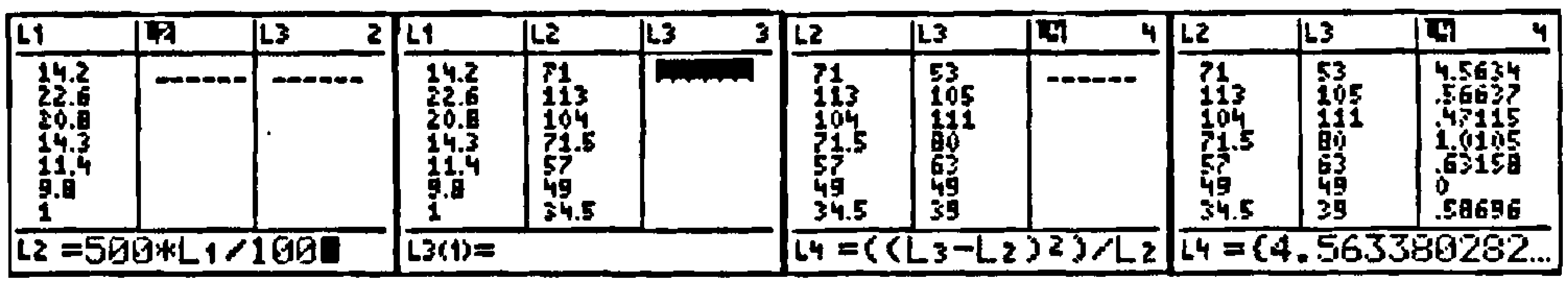

Figure 4. Students' use of List facilities for question 4.

students' own calculators the window settings would have been those for the last graph they had sketched and so could have produced some odd results. However, all the students (with the exception of Student A) sketched their graph in the context of the original question where only the positive quadrant needed to be shown. This was in contrast to work done by Smith and Berry [21] where students tended to copy exactly what was on the calculator screen and did not attempt to use their existing mathematical knowledge to interpret the calculator screen. This work included direct copying of the graphs as seen on the screen, including a thoughtless approach to the treatment of asymptotes.

Two of the students made use of the graphics calculator to carry out a chi-square test in question 4. Student B used the calculator's 'List' facility to calculate a whole series of values for the chi-squared test rather than calculate these values individually, as shown in figure 4. One other student made extensive use of the calculator memories in a quasi-scientific approach to this question. This was the only question where there was evidence of proficient calculator use.

3.3. *Interviews*

In order to analyse the interviews three tables were prepared to summarize the responses of the students to the questions posed. The three areas were the general use of calculators, the use of the graphics calculator in the practice examination and discussion of the screen dumps presented to the students. The tables were used to look for similar responses and to try to identify general trends in the responses. These tables were used as a basis for analysing the interviews and specific extracts from the interviews are used to further illustrate the findings from the interviews.

3.3.1. *General use of calculators*

The responses of the students to the general questions posed in the interviews have been summarized in table 2.

Student	A	B	C	D	E	F	G
Calculators owned	SC since year 7 plus GC since year 12	SC since year 7 plus GC since year 12	SC since year 7 plus GC since year 12	SC since year 7 plus GC since year 12	SC since year 7 plus GC since year 12	SC since year 7 plus GC since year 12	SC since year 7 plus GC since year 12
Calculator used most	Used to be SC but now use GC almost all of the time.	SC	SC	SC as I'm more used to it. I've had it longer.	SC	SC, because it has been with me so long.	SC. If we are doing calculations, it's easier, I understand it more.
Where/why SC used	Used to be more familiar, but now find GC easier.	Addition, formulas, trig, logs, easy statistics	Quicker to use than a GC. For easy sums.	Always, unless the SC won't do it.	For multiplication and fractions, and just normal sums.	Everything except graphs and programs.	Calculations
Where GC used	Now used all the time. Particular mention of memories, matrices and graphs.	Statistics if there is a lot of data, lists, functions, drawing graphs, numerical methods coursework	Graphs and functions, calculating means and standard deviations.	Just for drawing graphs, matrices and a little bit of statistics	Drawing graphs and matrices	Graphs, programs. matrices and statistics coursework.	Statistics, graphs and programs.
Comments on training	Mainly through trial and improvement and asking the teacher.	Initial introduction plus ongoing demonstrations and instruction.	Initial introduction plus ongoing instruction. Asks friends for help.	Instructions from staff, experiments and use of the manual.	Instructions from teachers and looking in the handbook.	On going teacher input, plus help from others in class.	Basic introduction, ongoing instruction, help from others.
Preference for statistical tables or calculator	Tables, but might use GC if more time to practice.	Tables, feels more confident with something that is printed.	Tables.	Tables, because it is what the examiner is going to refer your answers to.	Tables, we started with the tables and got used to them. If you make a mistake with the GC you could lose method marks.	Tables, because I can see where everything is coming from.	Tables, you turn to the page and there it is. With a GC you might press the wrong button.

Table 2. Summary of responses to general questions.

The seven students all possessed two calculators, one scientific, which they had used for the last nine years, and a graphics calculator that they had used alongside the scientific calculator for the last two years. All but one of the students stated that they used the scientific calculator more often than their graphics calculator. They often stated or implied that they would only use the graphics calculator for things that the scientific calculator could not do or when they felt that there was an advantage in using the graphics calculator. For example one student stated:

> *If the scientific calculator will do it I use that one. If it doesn't I use the graphics.*

Another student stated:

> *If it's straightforward number work I would use my scientific one. If it is a calculation involving lots of steps that I might need to remember, and things like that, then I would probably go for the graphics one. If it involved a graph I would probably use the graphics calculator.*

The reason that the students gave for this type of response was that they are more familiar with the scientific calculator. One student stated:

> *In the stats I use the scientific calculator, because I am more used to it. I know where all the buttons are. I am still not used to the graphics calculator.*

These types of remark were very common among the six students who used their scientific calculator more than their graphics calculator.

It is now interesting to consider the student who stated that she used the graphics calculator more than the scientific calculator. She clearly explained how she had shifted from the position of preferring the scientific calculator, to making the graphics calculator her preferred choice.

> *I used to use my scientific one, but now I use my graphics calculator almost all the time.... At the beginning it was just that I was used to the functions on the scientific one, I could do fractions, but now I am used to the memory on the graphics calculator and you can store so many things on it. I find it easier to store things on it and I don't have to keep going back and doing the calculations all over again. I just think that it is easier to use.*

Among the students there was a strong sense of familiarity with their scientific calculators and because of this a reluctance to replace their use with graphics calculators. The one student who had made the transition to the graphics calculator, clearly identified having been in a situation where she used the scientific calculator more due to her familiarity with it.

It is interesting to explore the possible reasons for this pattern of calculator use. Quite often the students made comments during the interviews that suggested reasons for this pattern of use. Four issues will now be discussed: instruction in the use of the graphics calculator; students' views of graphics calculators; calculator restrictions in examinations; and students' perceptions of what examiners need to see on examination scripts in order to award marks.

Instruction in the use of the graphics calculator. All of the students stated that they had received some instruction on how to use the graphics calculators from their teachers. Several of the students mentioned an initial introduction and also ongoing instruction as new topics were covered. For example, one student described the initial training session.

> *We had an introduction, things like how to go about drawing graphs and lists and things we had to know how to do. We were shown how to find things. Altering the windows in a way that was sensible. It was an exciting lesson when the calculators arrived and we played around with them.*

Another student listed some of the things that they had been taught to do with the calculator.

> *We were shown how to enter matrices and do the calculations and statistical tests and working out the normal.*

It was evident from the transcripts that the students had received instruction in how to use the calculators from their teachers and there was also some evidence of the students helping each other to use the graphics calculators.

Students' views of graphics calculators. The students all expressed a positive view of their graphics calculator, for example.

> *I think it is very useful. I like having it there. I don't use it as often as I could, but I feel happy using it. It is fairly easy to use, but I don't use every function.*

But these views were often expressed in the context of things that could only be done on the graphics calculator. For example, one student stated

> *I think it's really valuable, say in exams where you are not sure on graphs for example.*

Alongside these positive views there were a number of comments that suggested that the students were not as confident as they might be with the graphics calculators. They may have been aware of the potential of the graphics calculator to perform a calculation or task, but did not have the confidence to use it in that way. One student said:

> *We have been shown how to do it, but I am not too confident.*

Calculator restrictions in examinations. The current examination regulations in the UK prohibit the use of graphics calculators in some of the early examination papers taken by these students. The effect of this restriction was expressed by one of the students.

> *I think that one of the things that put me off using it is you can't take it into the first exams, so you get used to using the scientific one instead and stick with that.*

This comment illustrates how this type of restriction does not encourage the students to make use of their graphics calculators, which in turn contributes to their lack of confidence in their use of the graphics calculators.

Students' perceptions of what examiners need to see on examination scripts in order to award marks. We now examine the students' perceptions of what examiners need to see on examination scripts in order to award marks. There was a strong feeling expressed by a number of students that they had to show a significant amount of working to convince the examiner that they really knew what they were doing.

> *The only thing was if I made a mistake* [using the graphics calculator] *I might not have got so many marks.*

Another student stated this view with quite a strong degree of conviction.

> *Well if you get the answer wrong the examiner can look back and see how you did it and you may get method marks. If you have done it on the calculator and just written down the answer and got it wrong, the examiner won't know where you went wrong and just mark it with no marks.*

As well as the issue of method marks and showing working, one student also expressed the view that the tables book would be used by the examiner and so the students should also use the tables book, rather than a graphics calculator to obtain probabilities. This student stated:

> *... the tables book because that is what the examiner is going to refer your answers to. The calculator might have rounding errors.*

In summary the general discussion that took place in the interview suggested that the students found the calculators useful, but did not use them as much as they might have done and so lacked confidence in them. This lack of use is encouraged by examination regulations, expectancy that the examiners will not use graphics calculators and the need to show working to gain method marks. The approach of the series of textbooks (for example, [22]) that support the specification studied by these students places a great deal of emphasis on the use of tables and probably compounds this view.

3.3.2. *Use of calculators in the mock examination*

The students were asked to explain where and how they had used their graphics calculators in the mock examination. These responses supported the evidence gained through the monitoring of the graphics calculator use in the mock examination. The responses are summarised in table 3.

This part of the interviews confirmed that for the majority of the students the pattern of usage was only using the graphics calculator for things that the scientific cannot do or if there is a method that the student feels confident to use on the graphics calculator. Typical responses were from the students who performed calculations and used the tables book to obtain answers. For example one student described their calculator use in a question requiring the use of the chi-square test.

> *Because the actual calculations are quite simple here, I used the scientific one. It was just adding and multiplying.*

In the question that required a sketch of a function, there was widespread use of the graphics calculator. In this context the students were confident and ready to use their graphics calculators. One student stated:

> *Part four says derive the probability and illustrate it with a sketch. I derived the probability and drew the graph using the calculator.*

3.3.3. *Discussion of screen dumps presented to the students*

Some screen dumps that showed how the calculator could be used to obtain answers to some of the questions were shown to the students during the interview. The students were asked if they recognized these types of screen and if they could

Student	A	B	C	D	E	F	G
Question 1	SC	SC	SC	SC	SC	SC	SC
Comments	More confident in using tables than GC.	Used SC as prefer to put the formula down and do calculations. Could have used GC, but not sure how to.	SC quicker for calculating. Might have tried GC if there was more time.	SC was easier, especially the bit with the fractions. I could have used the GC, but it would have taken longer.	Even if I had used the GC I would have used the tables to check.	I used the tables because in an exam you have to make sure it's exactly the same numbers as the exam board is using.	Because they award marks for showing your working. I like to write down the equation.
Question 2	GC	SC	SC	SC	SC	SC	SC
Comments	Used for working with probabilities that had been looked up in the tables book.	Could have used GC, but probably would not have done this.	Might have used GC for checking if there was more time.	Because it's just adding numbers etc. SC is easier to use.	I could have used it to do the normal distribution, but I'm more confident with tables.	The SC was easier to use and in the most convenient place on the desk.	To know what I am doing I would rather draw the distribution and put the numbers in.
Question 3	GC	GC	GC	GC	GC	GC	GC
Comments	I used it to check the graph that I had drawn. I wouldn't have used it for integration.	I did use it as we needed to draw a graph.	I used it to draw the graph. As soon as I see a graph I use the GC.	Because the SC calculator does not do graphs.	For drawing the graph	I had to sketch the graph. It showed me that I had got the wrong answer.	Used for the graph.
Question 4	GC	GC	SC	SC	SC	SC	SC
Comments	I would have used the memories. Gives greater accuracy.	I used lists to do the calculations. I learned how to this on a biology field trip and got very familiar with this.	Easier to do quick sums on SC.	I could have done it more accurately on the GC as there is more memory.	Because the actual calculations here are quite simple I used the SC. We've been shown how to do it on the GC, but I'm not too confident.	Because there wasn't anything that I couldn't do on a SC.	I didn't use it here because they like to see the whole working.

Table 3. Summary of responses to questions on use of calculator in the mock examination.

Student	A	B	C	D	E	F	G
Screen dump 1	Explains screen correctly.	Thinks that two probabilities are being multiplied.	Recognises that two probabilities are being found and multiplied.	Explains screen correctly.	Explains the screen with a little help.	Recognises that two probabilities are being found and multiplied.	Thinks it's calculating a normal probability.
Screen dump 2	Remembers using this, but not how to use it or interpret result.	Have been shown screen, but unable to interpret.	Understands input, but cannot interpret output.	Explains screen correctly, with correct interpretation.	Explains screen correctly, with correct interpretation.	Knows it is do with some sort of test.	Very uncertain and unable to explain.
Screen dump 3	Explains confidence interval and adds we've done this quite recently.	Explains confidence interval, but not familiar.	Explains confidence interval and adds "I wouldn't do it that way".	Explains screen correctly, but not very confident.	Explains screen, I could do it that way with more practice.	That's the confidence interval, I prefer working them through.	Gives you the confidence interval, would be useful if I knew how to do it.

Table 4. Summary of responses to screen dumps used in interviews.

explain what was happening. A summary of the students' responses to these questions is given in table 4.

The discussion of the screen dumps that were shown to the students seemed to confirm the view that the students lacked confidence in using some of the more sophisticated functionality of a graphics calculator. The interviews identified that several of the students were aware that these screens could be produced and could explain them in some cases, but that none of them really had the knowledge or confidence to produce such screens for themselves. One student made the comment below, which seemed to sum up the feeling of most of the students.

I remember seeing this, but I cannot remember how to do it.

4. Conclusions and discussion

The most striking thing to have come out of this investigation is how limited the students' use of the graphics calculator was in the examination. During the interviews there emerged several reasons why this might be the case:

- familiarity;
- prohibition of graphics calculators in earlier examinations;
- the use of a textbook written by the examination board geared towards the use of tables and not graphics calculators;
- method marks.

4.1. *Familiarity*

All of these students had been using the graphics calculator for 18 months and had been shown how to use the statistical functions on it during the teaching of this subject. However they had all had their scientific calculator for over 6 years and during the interviews it was apparent that they were more comfortable with the scientific one for doing 'normal calculations'. The swapping between the graphics and scientific calculators during the examination confirms this. The graphics calculator was still relatively new to the students and during an examination they preferred something with which they were more familiar.

4.2. *Prohibition of graphics calculators in earlier examinations*

Despite having obtained the graphics calculator at the beginning of the previous year, the students were very reluctant to use it for this first year of their studies as two of their module examinations were 'scientific calculator only papers'. This was yet another reason they why were unfamiliar with the graphics calculator, especially in examination conditions.

4.3. *The use of textbooks written by the examination board*

The textbooks used by the students did not encourage (or discourage) the use of a graphics calculator. However, when examples similar to those in the examination were shown they all made use of the statistical tables for finding the probabilities and confidence intervals. It is easy to see how the students feel—if this is the way it is done in the textbook then this must be the correct way, despite the teacher having shown all the students how to use the graphics calculator to solve such problem.

4.4. *Method marks*

One of the main concerns of the students was obtaining method marks in the examination. They felt that if they had used the graphics calculator then the examination board might not be able to award them the marks as allocated to each part of the solution. The students were familiar with the marking schemes employed for such examinations and felt that if they did not reproduce exactly what was on the mark scheme they did not obtain the marks. For example when testing at the 5% significance level the mark scheme indicates a mark for the figure 1·96, obviously this figure would not appear when using the graphics calculator to carry out the hypothesis test. All published mark schemes fail to mention alternative marking methods for students who have used a graphics calculator. Teachers who see these mark schemes feel reluctant to encourage the use of the graphics calculator in case their students are penalized. The students often see mark schemes when using past papers for revision and so will tend to do what is expected.

These points explain why the students did not make full use of the technology available to them in the examination. Statistical analysis such as hypothesis testing and confidence intervals is only done using statistical tables during such courses. In commerce and industry the use of technology is taken for granted and this is what such courses should be preparing the students for. There are two ways to achieve this:

- more guidance from the examination boards;
- greater familiarity with the graphics calculator.

The main concern in the examination was getting the marks. The examination boards need to make schools more aware of how their marking schemes cater for a student who uses a graphics calculator. This will allow teachers who have been using the graphics calculator during the teaching of the course (as was the case here) to tell the students that that is how they can do it in the examination. The students will then use the calculator more during their learning. At present they are reluctant to do so in case they forget how to use the tables when in the examination for example.

If students are as familiar with the graphics calculator as they appear to be with their scientific calculators then the unease felt about using the graphics calculator even for simple calculations would disappear. These students had only had access to a graphics calculator for 18 months and had only really used it for part of that time. It is important to introduce the technology further down the school (as is happening at this school now). This was remarked on by one of the students:

> *One thing I would like to say about the graphics calculators is that they could be used when you were younger, my sister uses mine and she is two years younger. In class when you are trying to give an example of a graph everyone can see an image projected onto a board and for the teacher it is more manageable. If the students are younger they would be more confident in using it by my age.*

The authors feel that if students are to make effective use of graphics calculators in examinations, the students need to be encouraged to make more extensive use of graphics calculators throughout their mathematics studies, so that they become more familiar with them and confident to use them. It is interesting to note that the rules for the use of calculators in UK examinations are being reviewed currently and that it is possible that a new set of rules may do more to promote the use of graphics calculators.

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