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Technology use and the teaching of mathematics in the secondary classroom

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This project was far reaching in that it attempted to survey all secondary schools in New Zealand and follow this up with interviews and classroom investigations analysing the work of 32 teachers in 22 schools. I would like to thank all the teachers whose classrooms we visited for expressing their willingness to be involved and for their assistance with the study. In addition, I must mention the management within the schools who allowed the research to take place. Schools are increasingly under great pressure to produce improved student achievement, and some are finding it more difficult than in the past to allow researchers access to their classrooms—this was experienced in this study. Hence, we owe a great debt to the principals and teachers in the schools that we were able to visit for their full co-operation.

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Table of Contents

Tables

Figures

Appendices

1. Introduction

Mathematics teaching and learning is crucial to the future of New Zealand's knowledge economy and deserves a special focus in education. This has been recognised by Professor Smith who, in a major report in the United Kingdom (Smith, 2004), recognised that:

> Mathematics is of central importance to modern society. It provides the vital underpinning of the knowledge economy [and that] mathematics has a claim to an inherently different status from most other disciplines … [it] is fundamentally important in an all-pervasive way, both for the workplace and for the individual citizen. (p. 14).

However, Smith adds that "there is insufficient recognition, in many quarters, of the fact that mathematics is in many respects 'special' and that we must be prepared to consider, particularly in terms of organisation, structures, and investment, that different approaches and prioritisation may be required for mathematics" (p. 14).

One of the key synergisms of mathematics is with technology. As technology has advanced it has inevitably influenced what happens in the mathematics classroom. For example, in recent memory, slide rules and logarithm tables have given way to scientific calculators. However, in spite of recent government initiatives, such as the promotion of laptops in schools and the Computer Algebraic Systems (CAS) project (Neill & Maguire, 2006; Smith, 2006), there is evidence (e.g., Thomas, 1996; Thomas & Vela, 2003) that the use of technology in New Zealand schools has fallen well behind the learning possibilities demonstrated by international research studies (Doerr & Zangor, 2000; Drijvers, 2000; Guin & Trouche, 1999; Hong & Thomas, 2000; Lagrange, 2000; Pierce, 1999; Pierce & Stacey, 2001; Thomas & Holton, 2003; Thomas, Monaghan, & Pierce, 2004; Trouche, 2000). The disparity is true both in terms of the levels of use, and the types of use to which the technology is put. There have even been doubts raised about whether computers have any real value in learning (Cuban, 2001) and whether current teacher use is qualitatively and quantitatively sufficient to promote any benefits that might exist. In addition, since technology is advancing rapidly, and teachers in New Zealand may be unprepared to take full advantage of new technology, such as CAS calculators, for example, the Casio FX2 and the Texas Instruments TI-89 (Kaput, 2000; Lesh, 2000), once they are allowed into examinations. A new ministry initiative, titled Use of Symbolic Algebraic Manipulators (SAM)/Computer Algebraic Systems (CAS) Technology in Learning, and Assessment for Qualifications (Ministry of Education, [2005 on]), is a recognition of the need for professional development in this area.

The National Certificate of Educational Achievement (NCEA) assessment standards for New Zealand students have presented some challenges for teachers in terms of the use of technology (Hong, Thomas, & Kiernan, 2001; Kissane, 1999; Stacey, Asp, & McRae, 2000). This is particularly true of assessments at Levels 2 and 3 for standards such as:

2.5 Data sampling and analysis

2.6 Simulate probability situations, and apply the normal distribution; 2.8 Solve practical trigonometry problems

2.9 Solve straightforward trigonometric equations

C3.2 Integrate functions and solve problems by integration, differential equations or numerical methods

C3.3 Solve problems and equations involving trigonometric functions

S3.1 Analysing time series data

S3.5 Statistical investigations

S3.7 Solving problems with mathematical models.

The general explanatory notes to these standards include statements such as: appropriate technology should be used, but justified working may be required; and appropriate technology (such as spreadsheets) should be used to aid simulation.

This research study sought to explore both the qualitative and quantitative aspects of technology use in the classroom under NCEA Levels 2 and 3 assessment standards and their relationship to theoretical perspectives in the research literature and quality learning. It also considered how mathematics learning may be improved through better implementation and integration of this technology into teaching. It was a collaborative research study between university researchers and secondary-school teachers, working alongside teachers in schools to analyse current practice.

2. Research aims and objectives

Originally, the project was, rather optimistically on reflection, set up to study teaching and learning during implementation of the Levels 2 and 3 NCEA internal and external standards focusing on the standards:

2.6 Simulate probability situations, and apply the normal distribution

2.8 Solve practical trigonometry problems

3.1 Differentiate and use derivatives to solve problems

3.3 Solve problems and equations involving trigonometric functions.

These standards were chosen to include internal and external assessment, statistics, and the area of trigonometry, which many students find difficult. However, this was too wide a brief, even for a two-year study, and so we had to focus our attention on the teacher and teaching rather than on learning as well. Further, as will be clear below, the standards selected needed to be modified in light of school practice.

The key aims of the study were to:

- analyse, in light of international theories of learning, the current role of technology in mathematics teaching in the above NCEA standards
- identify, support, and extend best teaching practice in the use of technology for learning mathematics.

Similarly, the objectives of the research were to:

- identify the value of technology in the teaching and learning of some aspects of mathematics in schools
- identify how often and where technology is currently employed in the learning of mathematics in schools
- analyse, in light of current theories, the nature of the qualitatively different types of use of the technology in teaching
- identify any equity or cultural issues arising in the use of the technology
- examine the role of teacher attitude to technology and recent professional development on pedagogical practice with the technology
- investigate the ways in which teachers integrate the technologies into their teaching, especially in terms of their instrumentation of the tool, and the partnership they form with it (Drijvers, 2000; Guin & Trouche, 1999; Lagrange, 1999, 2000; Trouche, 2000)
- disseminate widely the research findings for the benefit of all teachers and learners.

Some of the key research questions we attempted to answer were as follows:

- Can technology use assist the learning of calculus, trigonometry, and statistics? If so, how?
- How can teachers interact with appropriate technology to improve mathematics learning?
- What is the current pattern of technology use in schools for internally and externally assessed NCEA standards?
- What demographic, social, attitudinal, cultural, and equity issues (if any) are identifiable in this pattern of use?
- What is the nature of the didactic contract that teachers form with students when teaching mathematics with technology? (Brousseau, 1997; delos Santos & Thomas, 2003)

3. Research design and methodology

This research project involved a partnership between the principal researcher, Associate Professor Mike Thomas, members of his research team at The University of Auckland, Dr Ye Yoon Hong and Dr Alan delos Santos, and three school teachers, Rosheen Gray of Kristin School, Jared Loh of Pakuranga College, and Jenny Bosley of St Cuthberts College, who are all very experienced in technology implementation in the mathematics classroom. The teachers all contributed to the design of the study as well as its implementation and analysis phases.

The method used in the study comprised a national survey followed by a series of cases comprising a case study. An initial survey by questionnaire (see Appendix A) of mathematics teachers in all secondary schools across New Zealand was conducted at the start of 2005. The questionnaire comprised two sections: Part A was addressed to the head of the mathematics department in each school and contained questions about the school and the mathematics department; Part B was addressed to individual mathematics teachers about their practice. Both parts employed both open-ended and closed questions to elicit valuable data on issues such as: the number of calculators and computers in each school; the level of access to the technology; available software; the pattern of use in mathematics teaching; and teachers' perceived obstacles to use. The survey also included a set of 14 attitude questions (see Figure 3.1). The questionnaire data was analysed qualitatively, quantitatively, and compared with data on technology in schools gathered by Thomas in 1995 (Jones & Thomas, 1995; Thomas, 1995, 1996). Part B of the questionnaire included a response slip whereby teachers could volunteer to participate in the follow-up interviews and observations. From the positive responses to this, the research team identified a sample of 32 teachers in 22 schools who were relatively easily accessible. Hence, they were primarily in the greater Auckland area, although some were further afield.

Figure 1 **The attitude scales**

Mathematics Attitude Questionnaire

Name: ____________________________ **School:** ____________________________

Levels of Teaching (Circle): Y7 Y8 Y9 Y10 Y11 Y12 Y13 Years of Teaching: __________

Please circle the numbers on the right below corresponding to which of the following indicates your level of agreement with each statement.

5 – I STRONGLY AGREE (SA) with the statement 4 – I AGREE (A) with the statement 3 – NEUTRAL (N)
2 – I DISAGREE (D) with the statement 1 – I STRONGLY DISAGREE (SD) with the statement

	SA	A	N	D	SD
1. More interesting mathematics problems can be done when students have access to technology.	5	4	3	2	1
2. Students understand mathematics better if they solve problems using paper and pencil.	5	4	3	2	1
3. I have lots of ideas about how I can make use of technology in mathematics.	5	4	3	2	1
4. Students should not be allowed to use technology during mathematics tests or examinations.	5	4	3	2	1
5. I think technology is a very important tool for learning mathematics.	5	4	3	2	1
6. Technology can be used as a tool to solve problems students could not solve without it.	5	4	3	2	1
7. Technology is only a tool for doing calculations more quickly.	5	4	3	2	1
8. Technology can make mathematics more fun.	5	4	3	2	1
9. Students should use technology less often in mathematics.	5	4	3	2	1
10. Using technology will cause students to lose basic computational skills.	5	4	3	2	1
11. I want to improve my ability to teach with technology.	5	4	3	2	1
12. Students rely on technology too much when solving problems.	5	4	3	2	1
13. Technology should only be used to check work once the problem has been worked out on paper.	5	4	3	2	1
14. Mathematics students need to know how to use technology.	5	4	3	2	1
15. Students should not be allowed to use technology until they have mastered the idea or the method.	5	4	3	2	1
16. Mathematics is easier if technology is used to solve problems.	5	4	3	2	1
17. Learning how to use technology is difficult for me.	5	4	3	2	1
18. Using technology makes students better problem solvers.	5	4	3	2	1
19. I lack the confidence to use technology to solve mathematical problems.	5	4	3	2	1
20. Learning mathematics is mostly memorising a set of facts and rules.	5	4	3	2	1
21. When doing mathematics it is more important to know how to do a process than to understand why it works.	5	4	3	2	1
22. Learning mathematics means exploring problems to discover patterns and make generalisations.	5	4	3	2	1
23. Students would be better motivated in maths if they could use a graphic calculator.	5	4	3	2	1
24. Using a graphic calculator removes some learning opportunities for students.	5	4	3	2	1
25. Students would understand maths better if they had a graphic calculator.	5	4	3	2	1
26. Using a graphic calculator would make the management of data easier.	5	4	3	2	1
27. Students would be more confident in maths if they had a graphic calculator.	5	4	3	2	1
28. Since students can use a graphic calculator, they do not need to learn to draw graphs by hand.	5	4	3	2	1
29. I feel that computer algebra system calculators should be allowed in mathematics tests and examinations.	5	4	3	2	1
30. Using a graphic calculator to solve statistics makes the problems easier to understand.	5	4	3	2	1

Survey questions:

5 – I STRONGLY AGREE (SA) with the statement 4 – I AGREE (A) with the statement 3 – NEUTRAL (N)
2 – I DISAGREE (D) with the statement 1 – I STRONGLY DISAGREE (SD) with the statement

		SA	A	N	D	SD
1.	Technology is of little benefit in mathematics teaching.	5	4	3	2	1
2.	Calculators are often detrimental to students' mathematical understanding.	5	4	3	2	1
3.	A major obstacle to teachers using technology is a lack of good classroom resources.	5	4	3	2	1
4.	NCEA has too much emphasis on technology.	5	4	3	2	1
5.	A major obstacle to teachers using technology is classroom organisation or management.	5	4	3	2	1
6.	A major obstacle to teachers using technology in the classroom is a lack of teacher confidence.	5	4	3	2	1
7.	A major obstacle to teachers using computers in the classroom is the lack of good software appropriate to the mathematics.	5	4	3	2	1
8.	A major factor inhibiting teacher use of technology in the classroom is that its use in external assessment is not compulsory.	5	4	3	2	1
9.	Technology use is expected in all NCEA standards.	5	4	3	2	1
10.	Computers will be used much more in the mathematics classroom of the future.	5	4	3	2	1
11.	NCEA has too little emphasis on technology.	5	4	3	2	1
12.	All types of calculators should be allowed in examinations.	5	4	3	2	1
13.	Lack of student access to technology is the major obstacle to effective use.	5	4	3	2	1
14.	Best practice occurs when students own their own technology.	5	4	3	2	1

Members of the research team conducted in-depth case studies of technology use by these teachers, observing their classroom teaching practice and interviewing them about their technology use. Lessons were recorded on videotape, extensive field notes were also made from the observations, and the interviews were all recorded for later transcription and analysis. In addition, teachers were asked to fill in an attitude scale (see Figure 3.1), that comprised five subscales, on attitudes to: mathematics (Q's 2, 20, 21, 22); technology (Q's 7, 13, 15, 18); using technology to learn mathematics (Qs 1, 4, 5, 6, 8, 9, 10, 12, 14, 16); using the graphic calculator (GC) to learn mathematics (Qs 23–30); and personal learning (Qs 3, 11, 17, 19). The internal consistency of the scale, measured using Cronbach's Alpha reliability coefficient, was 0.898, suggesting that it is reliable.

Thus, data including teacher attitudes and pedagogical practices, and department and school processes and practices, were collected, using video, teacher diaries, copies of lesson plans and questionnaires, and interviews, as appropriate. During the carrying out of the research, the methodology was critiqued by two overseas international experts, Professors David Tall of Warwick University, UK, and Carolyn Kieran of the University of Quebec in Montreal, who made valuable comments.

3.1 Theoretical framework

Thomas and Hong (Hong & Thomas, 2006; Thomas & Hong, 2005a) have previously described the concept of teachers' pedagogical technology knowledge (PTK) as a useful way to think about what teachers need to know in order to teach effectively with technology. PTK includes not simply being a proficient user of the technology, but more importantly, understanding the principles and techniques required to teach *mathematics* through the technology. This requires a new way of thinking, a change in focus from the technology to the mathematics, and a shift of mathematical focus. Developing PTK comprises the teacher's perspective on technology and its use and their instrumentation of it. Constituent parts of developing PTK involve the teacher in the transformation of the technological tool into an instrument (Guin & Trouche, 1999), and differentiation of qualitatively diverse ways of employing technological tools in teaching mathematics, such as direct procedural calculation, computational check, or building conceptual knowledge of mathematics (Thomas & Hong, 2005b). Teacher instrumentation and instrumentalisation of the tool engage the teacher in the actions and decisions required to adapt it to a particular mathematical task. They must consider what it can do and how, as well as organise their mental faculties to carry it out. More is involved than simply the mechanics of the syntax, the semantics of the input/output, the algebraic expectation, and coping with the difficulties of navigating between screens and menu operations. It means seeing possibilities for epistemic mediation of the technology between the user and the mathematics, and focusing the technological activity on specific conceptions (Guin & Trouche, 1999).

Another key factor in effective teacher use of technology is the relationship between the teacher and the environment they seek to interact with, as described by Gibson's (1977) theory of *affordances* and *constraints*. Hence, one of the key theoretical ideas employed in this research was the identification of the role of affordances, constraints, and obstacles in the use of technology in the mathematics classroom. Affordances refer to whatever it is about the environment that contributes, or has potential to contribute, to the interactions that occur, while constraints are characteristics of the affordance providing structure and guidance for the interaction (Greeno, 1994). In this mix, according to Greeno, "An affordance relates attributes of something in the environment to an interactive activity by an agent who has some ability" (p. 338). Thus, an example of an affordance, given by Gibson, is the provision of mailboxes for posting letters. In a classroom setting, the presence of technology, such as the GC, is an affordance, with student or teacher instrumentation, professional development, types of graphic calculators (Graphic calculators), technical support, time available to use the technology the limitations of the Graphic calculators (e.g., direct control over algebraic or numerical representations of a function but not its graphical one), precision of syntax when entering commands (Brown, 2004, 2005a, b; Brown, Stillman, & Herbert, 2004) and the content of curriculum, as examples of constraints. The role of the teacher in this theoretical model, according to Kennewell (2001), is to manage or orchestrate the affordances and constraints so that learning takes place (see also Drijvers, 2000, 2002). Forgasz (2006) talks about encouraging and inhibiting factors, while Thomas (1996) uses the terminology of obstacles to technology use. However, there is a difference between a constraint, which implies the presence of an affordance, and a factor that inhibits the presence of an entity with its potential for affordance in the environment. That is, obstacle is something that prevents the presence of an affordance-producing entity in the classroom situation. For example, a school or department that cannot or will not buy graphic calculators or viewscreens, a head of department (HOD) or teachers who have antitechnology attitudes, and a lack of software are obstacles to the formation of technology affordances.

This research considered this issue of the potential affordances, constraints, and obstacles for secondary mathematics teachers using technology in Years 12 and 13 (age 17 or 18 years) teaching. Three major areas where such factors are found are: those emanating from the individual teacher themselves; the school mathematics department, and especially the HOD; and the wider school policy and attitudes to technology use.

4. Results

Teacher and school demographics

A copy of the questionnaire (see Appendix A) was mailed to the mathematics HOD of each secondary school in New Zealand. Having learned some lessons from Thomas's 1995 survey (Thomas, 1996), on this occasion stamped, addressed envelopes were enclosed with the questionnaire for all the schools. Also, the posted questionnaire was followed up several weeks later by sending a faxed copy to schools that had not by then responded. Using this approach, we achieved a response from 193 of the 336 secondary schools (57.4 percent) in New Zealand, usually from the mathematics HOD, with the likelihood of a representative sample of school data (although this has not been tested statistically). We also received completed section B questionnaires from a total of 465 teachers in the schools, mostly from the 193 schools. It was interesting that of the respondents, 68.4 percent had used computers in their lessons and 31.6 percent had not. Thus, nearly a third of responses were from teachers who had not used technology, and we felt that this gave us a balanced view in terms of the results. Some of the demographics of the teachers responding to the survey and their schools are given in Tables 1–6 below.

Teacher profiles

The 193 HODs responding were 56 percent male and 44 percent female, with a mean age of 46.6 years, and their age distribution is given in Table 1. The 445 teachers who responded were 52.6 percent male and 47.4 percent female, with a mean of 44.9 years, and their age distribution can be seen in Table 2. Only 16 of the teachers and six of the HODs who responded were 61 or older. If this is representative, then it seems to imply that many teachers retire or leave teaching before this age.

Table 1 **Age distribution of HODs responding to the survey**

Age group	Frequency (n=193)	Percentage (%)
21–30	9	4.7
31–40	36	18.7
41–50	78	40.4
51–60	64	33.2
61+	6	3.1

Table 2 **Age distribution of the teachers responding to the survey**

Age group	Frequency (n=465)	Percentage (%)
21–30	45	9.7
31–40	101	21.7
41–50	152	32.7
51–60	131	28.2
61+	16	3.4
No response	20	4.3

The survey targeted those teachers teaching at Levels 2 and 3 of NCEA, and Table 3 shows the distribution of the teaching they were involved in during 2005. Use of technology in Year 13 calculus is somewhat less than that in statistics, which in turn is less than that in Year 12. During this teaching, 68.7 percent of the teachers said that they used computers in their teaching, and 31.3 percent did not. Thus, nearly a third of those replying to the questionnaire did not use technology, ensuring that the voice of such teachers is well represented in the results.

Table 3 **Teaching levels of teachers responding to the survey**

Currently teaching	Frequency (n=465)	Percentage (%)
Year 12 maths	310	66.6
Year 13 calculus	122	26.2
Year 13 statistics	189	40.6

NB: Teachers could make more than one response, hence, percentages add up to more than 100.

HODs were asked to estimate how many of their mathematics teachers would not feel confident using technology in their teaching. The mean response was, compared with a total mean number of mathematics teachers in the schools, 7.22 full-time and 3.09 part-time. This enables us to say that around 30 percent of teachers are probably not confident enough to use technology, which is, interestingly, roughly the proportion in our survey who did not use it.

School profiles

The demographics of the schools that the 193 HODs were from are contained in Tables 4–6. Table 4 shows that most, 68.4 percent, were in coeducational schools, and 57 percent in state schools. The mean size of the schools was 748.4 students.

Table 4 **School type by gender of the teachers responding to the survey**

Type of school	Frequency (*n*=193)	Percentage (%)
Boys	22	11.4
Girls	32	16.6
Coeducational	132	68.4
No response	7	3.6

Table 5 **School type of the teachers responding to the survey**

Type of school	Frequency (*n*=193)	Percentage (%)
State	110	57.0
Private	6	3.1
Independent	9	4.7
Integrated	35	18.1
No response	33	17.1

Table 6 **Numbers of students in school for the teachers responding to the survey**

Number of students Years 9–13	Frequency (*n*=193)	Percentage (%)
<300	39	20.2
300–400	16	8.3
401–500	17	8.8
501–600	12	6.2
601–700	17	8.8
701–800	11	5.7
801–900	8	4.1
901–1000	8	4.1
1001–1100	13	6.7
1101–1200	10	5.2
1201–1300	8	4.1
>1300	34	17.6

The data in these tables are an indication that the sample was reasonably representative of the populations of secondary schools and mathematics teachers in general, although this has not been tested statistically.

Computer use in mathematics teaching

Around 10 years ago, Askew and Wiliam (1995) reported on a review of research in mathematics education in the 5- to 16-year-old age range, and found that "Although computers have been in use in mathematics education in this country [UK] for well over twenty-five years, the pattern of usage is still very varied and very sparse" (p. 34). A UK Department of Education (DFE) report (1995) also noted a low level of usage of computers in mathematics, with an average of 15.6 minutes of lesson time per week spent using the computer, and in the United States (US) the position was very similar (Ely, 1993). While some might hope that this position has changed in more recent years, a survey by Ruthven and Hennessey (2002) on school computer use concluded that "Typically then, computer use remains low, and its growth slow" (p. 48).

There are a number of possible reasons for a low level of computer use in mathematics teaching and learning. Some, described by Thomas, Tyrrell, and Bullock (1996), include the upheaval resulting from the computer's presence; an unwillingness to change classroom management techniques; not wanting to lessen teacher control in the classroom; and an inability to focus on the mathematics and its implications rather than the computer. To this we must add the obvious reason: that many teachers still may not believe that the computer has real value for their students' learning. Certainly, Veen (1993) has argued that teacher factors outweigh school factors in the promotion of computer use, and Maddux (1994) thinks that computers will play a minor role until more teachers incorporate them into their teaching. More recently, Becker (2000a) reported on a national US survey of over 4000 teachers and concluded that "… in a certain sense Cuban is correct—computers have *not* transformed the teaching practices of a majority of teachers" (p. 29). However, he noted that for certain teachers, namely those with a more student-centred philosophy, who had sufficient resources in their classroom (five or more computers), and who had a reasonable background experience of using computers, a majority of them made "active and regular use of computers" in teaching. Becker (2000b) added a description of some characteristics of such an 'exemplary' computer-using teacher, but concluded that extending these to other teachers would be expensive. With specific reference to mathematics teaching, Ruthven and Hennessey (2002) outlined a model, comprising twelve themes, that "… highlights key processes and critical states which require active—and reactive—planning and management on the part of the teacher for ICT use to successfully support teaching and learning" (p. 83), in the hope that this might assist teachers to make more effective use of technology in the classroom.

It was against this background that we sought to use the questionnaire data to describe the changing pattern of computer use in the mathematics classroom in New Zealand. This longitudinal comparison was made possible by using the data collected by Thomas in 1996.

Computer use statistics

In 1995, 67.2 percent of the teachers said that they used computers in their mathematics teaching, and this remained steady at 68.4 percent in 2005. One change has been the increase in the number of information and communication technology (ICT) rooms, up from 71 percent of schools in 1995 to 96 percent, with a mean of 2.46 rooms per school, up from 1.79 in 1995. However, while in 1995, 89.1 percent of teachers usually using computers in labs for mathematics teaching, this had dropped to 59.1 percent in 2005, with 10.7 percent using them mostly in their classroom. When HODs were asked how many computers teachers have access to in their classrooms, 35.2 percent indicated none, 51.8 percent chose one and the rest said two or more. While not all teachers have access to computers in their classrooms, there are other places where they can have access to computers, including: ICT room (87 percent), staffroom (68.4 percent), library (73.1 percent), and offices (56 percent). When we look at how often the teachers are using the computer in teaching, in 1995 5.9 percent said they used them at least once a week, but in 2005 this had risen to 13.3 percent. In 1995, the schools had a reported mean of 40.0 computers per school, with a mean of 1.7 computers in the mathematics department. By 2005, there had been a huge jump in these numbers, with an average of 101.6 computers per school, 21.9 of which are laptops (one school reported 1800 laptops), with mathematics departments having 6.5 computers on average (4.2 of which are laptops), and 26.9 percent of the schools now have over 100 computers. One possible reason for the growth in the numbers of computers in schools is the support of the New Zealand government, which has pushed a considerable amount of funding into getting computers into schools. We also asked who assumed responsibility for the computers in the school. Table 7 shows that the vast majority of schools have an IT director who takes on this role.

Table 7 **Responsibility for computers in schools**

Responsibility for computers	Frequency (*n*=193)	Percentage (%)
HOD maths	3	1.6
IT director	167	87.0
Other	36	18.8

NB: Some respondents selected more than one option, hence percentages add up to more than 100.

In Table 8 we see a breakdown of the numbers of computers in the schools by type. They are, not surprisingly, predominantly IBM compatible computers, what have become known as PCs, with a mean of 10.6 Apple Macintosh computers.

Table 8 **Numbers of computers in schools by type**

Computer type	Mean number	Percentage (%)
PC	88.3	86.9
Macintosh	10.6	10.5
Other	2.7	2.6
Total	101.6	100.0

Although there are often large numbers of computers in schools, they are mostly not in the mathematics classroom. However, Table 9 shows that mathematics departments do, on average, have a total of 6.47 computers available, of which 4.21 are laptops (teachers were asked how many of the computers were laptops).

Table 9 **Numbers of computers in mathematics departments by type**

Number of computers per maths department	Mean number	Percentage (%)
PC	5.79	89.5
Macintosh	0.58	8.9
Other	0.10	1.6
Total	6.47	100.0
Laptops*	4.21	–

NB: Laptops are included in the total above.

We were also interested in the question of where teachers have access to computers in schools. Table 10 shows us that there are computers in many classrooms, with 61.1 percent of the teachers claiming to have access to them there. In addition 87 percent can access them in ICT rooms and only 0.5 percent, or about nine teachers, have no access at all to a computer.

Table 10 **Teacher access to computers in schools**

Where teachers have access to computers at school	Frequency (*n*=193)	Percentage (%)
In their classroom	118	61.1
ICT room	168	87.0
Staffroom	132	68.4
Library	141	73.1
Office	108	56.0
Nowhere	1	0.5
Other	66	34.2

NB: Teachers could make more than one response, hence, percentages add up to more than 100.

When we asked another question on how many computers individual teachers have in their mathematics classroom, Table 11 shows that the most likely number is just one, with 51.8 percent giving this response, and 35.2 percent having none, which does not quite agree with the 61.1 percent having access in Table 10, but is close. Hence, the reality of using a computer in the mathematics classroom is that management of a relatively scarce resource will pose problems for most teachers. However, a little surprisingly, 11 teachers appear to have more than four computers in their classroom, although precise numbers of computers above four were not asked for.

Table 11 **Numbers of computers in mathematics classrooms**

Number of computers in classroom	Frequency (n=193)	Percentage (%)
None	68	35.2
One	100	51.8
Two	8	4.1
Three	4	2.1
Four	2	1.0
Other	11	5.7

One of the features of computer access that was new to this research compared with that conducted in 1995 was the use of the Internet. In Tables 12–15 we describe some of the features on Internet access that the teachers reported on. We asked how many of the computers in the classroom were connected to the Internet. 76.5 percent said that most or all were connected, and only 11.4 percent replied that none were. Hence, most classrooms that have a computer have one connected to the Internet. When we looked wider in the school to ascertain how many of the school's computers were Internet connected, we see a similar pattern. Table 12 shows that from the 179 school responses, 96.1 percent said that most or all of the computers were on the Internet and only two teachers said that none were.

Table 12 **Computers with Internet connections in schools**

Computers with Internet connection	Frequency (n=179)	Percentage (%)
None	2	1.1
Some	5	2.8
Most	38	21.2
All	134	74.9

Since most of the computers are connected, as we anticipated, we thought it would be good to know where the teachers could access the Internet themselves. Only one teacher had no access anywhere, and most teachers could go online in their classroom, an ICT room, staffroom, library, and office (see Table 13). One problem we noted was that there were more respondents indicating that they had access to the Internet than they had access to computers. This may be because they interpreted access to computers to mean access for teaching, rather than for Internet use only.

Table 13 **Computers with Internet connections in schools**

Where teachers can access the Internet	Frequency (n=193)	Percentage (%)
In their classroom	114	59.1
ICT room	166	86.0
Staffroom	141	73.1
Library	145	75.1
Office	114	59.1
Nowhere	1	0.5
Other	47	24.4

NB: Teachers could make more than one response.

When we looked at where students have access to the Internet (see Table 14) we note that, while 59.1 percent of teachers have access in their classroom, only 26.4 percent of students are able to take advantage of this. They are restricted to ICT rooms (95.9 percent) and libraries (85.0 percent) for their access. This may well be because it is easier to exercise some monitoring or control of access in these situations, where computers are more likely to be networked.

Table 14 **Student access to the Internet in schools**

Place of student access to the Internet	Frequency (n=193)	Percentage (%)
In their classroom	51	26.4
ICT room(s)	185	95.9
Library	164	85.0
Nowhere	2	1.0
Other	16	8.3

NB: Teachers could make more than one response, hence total is more than 100 percent.

Teaching with computers

The next question addressed was whether the increased numbers of computers had changed the pattern of use in the teaching of mathematics. While approximately a third of the teachers said that they *sometimes* used the computer in their teaching of Years 12 and 13 statistics and modelling, and 14.3 percent use them for Year 12 calculus, when they were asked whether they *regularly* use computers, there was a drop in number in all of the three areas (see Table 15), especially in Year 12. As we will see below, the teaching of Level 3 statistics was the primary usage area.

Table 15 **Use of computers in Years 12 and 13 statistics and calculus (*n* = 465)**

	Sometimes (%)	Regularly (%)
Year 12	35.2	9.3
Year 13 calculus	14.3	5.7
Year 13 statistics and modelling	38.1	29.7

Only the 318 teachers who used the computer in their teaching responded to the next 12 questions on the survey, and Tables 16 to 21 refer to their responses. For example, they were asked which of the remaining curriculum areas (along with specific topics of graphs, trigonometry, and calculus) they used the computer in (see Table 16).

Table 16 **Curriculum areas where secondary teachers are using computers**

	Percent of 1995 teachers (n=229)		Percent of 2005 teachers (n=318)	
Area of use	Some use	Most often used	Some use	Most often used
Geometry	34.1	4.8	28.2	3.9
Statistics	75.1	38.0	85.4	59.5
Graphical work	74.2	35.4	75.5	28.0
Algebra	32.3	4.8	33.4	3.5
Trigonometry	22.7	3.1	22.5	2.3
Calculus	24.0	3.9	22.5	2.6

NB: 2005 results based on replies to Q10 in Figure 1.

These figures show a significant increase in the use of computers for the learning of statistics, both as first choice curriculum area (χ^2=24.5, p<0.001), and for some use (χ^2=9.47, p<0.01). This not surprising since there is a strong emphasis on statistics in schools, and it lends itself to an approach where the computer can perform routine calculations, as well as graphical and investigational work. It is surprising, in view of the excellent packages Cabri Géomètre and Geometers SketchPad, that there has been a fall (although not a significant one, χ^2=2.07) in the use of geometry packages. Cost may be a factor in this. Of the 193 schools in the 2005 survey, only 20 mathematics departments had a technology budget, ranging from NZ$200 to $NZ15000, with a mean of NZ$2762.50, and one HOD commented that "Annual [software] fees also take up a lot of the allocated budgets".

It is sometimes thought that technology is a male oriented domain, but as Table 17 shows, there were a few differences between male and female use of computers in any of these curriculum areas, with the main one being a significantly lower use by females in trigonometry (χ^2=4.44, p<0.05), calculus (χ^2=4.89, p<0.05), and algebra (χ^2=7.68, p<0.01). Possible reasons for these differences are not easy to deduce.

Table 17 **Curriculum areas by gender where secondary teachers are using computers**

	First mentioned (%)		Mentioned (%)	
Area	**Male**	**Female**	**Male**	**Female**
Statistics	57.1	61.1	86.5	84.1
Graphical work	28.2	27.4	76.3	75.1
Geometry	4.5	3.2	32.1	28.0
Trigonometry	5.1	1.9	39.1	29.5
Calculus	3.8	1.3	29.5	20.4
Algebra	3.2	1.3	30.3	19.1

NB: n=234 for males and 211 for females. Twenty teachers did not reveal their gender. There was a provision for an "other" response, which affects some percentage totals.

To gain some idea of the variety of uses that computers are being put to in schools, we asked the teachers to rank in order of regularity of use the types of software they employed in teaching mathematics. The results from each of the two surveys can be seen in Table 18. It appears that there has been a significant change in the kinds of software used in mathematics classrooms over the period, away from specific content-oriented graphical (χ^2=5.59, $p<0.05$), mathematical (χ^2=38.7, $p<0.001$), and statistical packages (χ^2=12.3, $p<0.001$), and towards generic software, especially the spreadsheet (χ^2=28.0, $p<0.001$), which often comes provided with the computer and may handle statistical work well enough for secondary schools. The trend away from specific graphical packages is a little more surprising since there are now some excellent programs, such as Autograph, available. It is also possible that the graphic calculator has made inroads into the use of the computer for graphing functions. Questions on the use of the Internet were new in 2005, and 46.1 percent of the teachers reported some use of it to teach mathematics. 61.1 percent of the teachers have access in their classroom (and 68.4 percent in a staff room). For the students, only 26.4 percent have classroom access, although 95.6 percent of schools have ICT rooms for computers.

Table 18 **Types of software used with computers**

	Percent of 1995 teachers (n=229)		Percent of 2005 teachers (n=318)	
Area of use	**Some use**	**Most often used**	**Some use**	**Most often used**
Spreadsheet	67.2	31.9	86.2	62.6
Mathematical programs	61.1	25.8	34.3	5.0
Graph drawing package	61.1	22.3	50.9	17.7
Statistics package	44.1	11.8	29.6	5.0
Internet	—	—	46.1	6.6

NB: In addition 7.4 percent of secondary teachers in 1995 said that they used desktop publishing software.

A breakdown of these uses by gender is given in Table 19. These results show that significantly fewer females mentioned using mathematics software (χ^2=4.00, $p<0.05$), or statistics packages (χ^2=7.85, $p<0.01$) in their teaching, with some evidence of a lower use of the Internet (χ^2=3.78, n.s.).

Table 19 **Types of software used with computers by gender**

	First mentioned (%)		Mentioned (%)	
Software	**Male**	**Female**	**Male**	**Female**
Spreadsheet	62.2	62.8	87.2	84.7
Graph drawing package	19.9	16.0	53.2	50.0
Internet	5.8	7.7	50.6	41.4
Mathematics software	4.5	5.1	39.1	29.9
Statistics package	7.7	2.6	35.9	23.7

NB: *n*=234 for males and 211 for females. Twenty teachers did not reveal their gender. There was a provision for an "other" response, which affects some percentage totals.

How do teachers organise their lessons around computer use? Since 1995, a number of student-centred constructivist perspectives on teaching very have been widely encouraged in mathematics education circles (e.g., Ernest, 1997; von Glasersfeld, 1991). Has this influenced how computers are used, as one might predict?

We can get some idea of what has happened in the classroom by looking at Table 20, which describes the methods that teachers employ when using the computer. The constructivist approach broadly encourages student-centred investigation and problem solving, rather than teacher-led instruction and enforcing of skills; so one might expect teachers to use the computer to do one or the other, but not both.

Table 20 **Teaching methods used with computers**

	Percent of 1995 teachers (n=229)		Percent of 2005 teachers (n=318)	
Method	**Some use**	**Most often used**	**Some use**	**Most often used**
Skill development	67.7	37.6	58.5	24.5
Free use	34.9	3.1	18.9	2.8
Investigations/PS	68.6	38.4	58.8	27.4
Demonstrations	40.6	10.9	59.6	29.7
Programming	8.7	1.3	6.9	1.6

However, in both 1995 and 2005 it appeared that a substantial proportion of teachers used both methods and did not see themselves on one side of a dichotomous ideological fence. This was shown by around 60 percent reporting computer use for skill development and demonstrations, as well as investigations. There was, however, a significant decline in the proportion of teachers using the computer for skill development (χ^2=4.79, p<0.05), and in those allowing free use of the computer (χ^2=18.0, p<0.001). However, the use of demonstrations significantly increased (χ^2=19.5, p<0.001), and so the data implies that while directed use and demonstration is more common in 2005, it is not as often skill directed. Again, this is not entirely what one might expect from a constructivist perspective. We note that the percentage of teachers who value computer programming, sufficiently to spend some time on it, has remained reasonably constant, if somewhat low. It may be that those who are convinced that programming may encourage the formation of mathematical thinking have strong convictions (Pea & Kurland, 1984). There are more recent ideas related to the value of programming that suggest that allowing students to interact with games where they are in control, programming attributes and functions in microworld-like games software may be beneficial for learning (Noss & Hoyles, 2000). Once again, we examined this pattern of usage by gender, as shown in Table 21.

Table 21 **Teaching methods used with computers by gender**

	First mentioned (%)		Mentioned (%)	
Type of use	**Male**	**Female**	**Male**	**Female**
Demonstrations	31.0	27.4	62.6	56.1
Investigations/problem solving	31.6	23.4	65.8	51.9
Skill development	20.6	28.5	61.9	55.1
Free use by students	3.9	1.9	23.2	15.8
Programming	2.6	0.6	10.3	4.4

The data in the table show that significantly more males than females used investigations or problem solving (χ^2=8.60, p<0.05). One possible explanation for this is that females may have been slightly lower in confidence levels (see Table 23).

Obstacles to computer use

In the original 1995 survey, 93.5 percent of the teachers responded that they would like to use computers more in their mathematics teaching, however, in the latest survey those agreeing with this sentiment had dropped to 75.1 percent. While this is a highly significant decrease (χ^2=47.0, p<0.001), one must take into account the increased rate of use of computers, and hence, some teachers may feel that they have reached their optimum usage level. In any case there is still a sizeable proportion of the teachers who would like to use them more, and so we are led to ask: "What factors do they perceive as preventing them from making greater use, or using them at all?" The results from the two surveys on this aspect are shown in Table 22, for the 229 and 349 teachers, in 1995 and 2005 respectively, who responded that they would like to use computers more.

Table 22 **Obstacles teachers perceive as preventing them using computers in their teaching**

	Percent of 1995 teachers (*n*=229)		Percent of 2005 teachers (*n*=349)	
Obstacle	**First mentioned**	**Mentioned**	**First mentioned**	**Mentioned**
Available software	17.4	52.5	14.0	51.0
Available computers	43.7	67.8	55.3	75.1
Lack of training	17.4	45.4	9.7	41.2
Lack of confidence	12.7	34.8	6.9	28.9
Government policy	4.1	12.4	—	—
School policy	0.6	8.0	0.6	12.0

NB: There was provision for an "other" response, which affects some percentage totals.

In 1995, there were two areas where the teachers wanted to see improvement in order to reach their goal of using computers more. They were the provision of resources, in terms of available hardware and software and the increasing of their confidence through satisfactory training. In 2005, we see that the lack of training may have been better addressed, with significantly fewer teachers mentioning it first (χ^2=7.39, p<0.01), although there was no significant change in the proportion mentioning it, and only 39.6 percent of the teachers had recently been on any kind of professional development covering use of technology to teach mathematics. Clearly, there is still a need for training, since when HODs were asked how many of their mathematics teachers would not feel confident using technology in their teaching, the mean response was 3.1, compared with a total of 7.2 full-time and 3.1 part-time mathematics teachers. In addition, there was no significant change in the number of teachers who feel that they lack confidence in computer use (χ^2=2.31, n.s.), in spite of greater penetration of computers in homes over the period. Further, the perceived need for software remains constant despite greater use of the spreadsheet, which is now provided with virtually all computers. However, the problem of the availability of computers remains the major issue with a significant increase in those mentioning it first (χ^2=7.49, p<0.01), and 75 percent thinking that it is an issue. Although the number of computers in schools is increasing, since they are primarily located in large ICT rooms, access to them by mathematics teachers is still the primary problem preventing greater use.

Examining the obstacles along teacher gender lines (Table 23) seemed to indicate that females felt confidence was a problem more than males did, but there was not a significant difference (χ^2=2.98, n.s.). Similarly, it looked like males thought lack of software was a problem more than females did, but again it was not significant (χ^2=2.09, n.s.).

Table 23 **Obstacles teachers perceive as preventing them using computers in their teaching by gender**

	First mentioned (%)		Mentioned (%)	
Obstacle	**Male**	**Female**	**Male**	**Female**
Computer availability	42.5	42.9	56.2	60.0
Availability of software	13.3	8.6	42.9	36.2
Lack of training	6.0	9.0	31.3	32.9
Lack of confidence	2.6	8.6	19.7	26.7
School policy	0.4	0.5	11.6	7.1

The 2005 survey asked teachers that if they seldom used the computer room what was the reason, and 38.7 percent said that it was because of the difficulty with booking the room, and a few said that it was too difficult to organise. There were very few other reasons of note given. Typical teacher comments were: "Access to computers at required time [of year and within school timetable blocks]" was difficult; there is a problem "… getting into overused computer suites"; and "Due to the increased demand for IT classes it is very difficult to book a computer room for a class of 20–30 students." In addition, in 1995, 13 percent of teachers mentioned some other obstacle, and in 2005 the figure was 18.4 percent. These included the time and effort needed by both students and teachers in order to become familiar with the technology. It appears that some teachers are concerned that this instrumentation phase would impact on time available for learning mathematics.

Good practice

In our sample of 32 teachers whose lessons we observed, 17 used the computer in their teaching. Of these, four used the spreadsheet Excel, six used PowerPoint, and three used interactive white boards (IAW—see below). In addition, one teacher used the Statdemo program, two used the Lanschool program, and two used the program Graphmatica. These lessons have shown that there are diverse ways in which computers can be used by the teachers in the classroom.

Affordances and constraints

In this report, we consider an affordance as the potential for action to eventuate, and constraint as the structure imposed for the action (see section 3.1). Using this description, we present a description of affordances and constraints in computer-based teaching based on teachers' responses to the survey and interviews and those that we perceived based on our classroom observations.

If the action to be satisfied is teaching and assessing using technology, it follows that the presence of computers and other kinds of technology is, by definition, an affordance. This affordance allows the teacher to introduce new ways of teaching, within certain constraints. For one, our teachers said that the presence and use of technology allows them to save time from tedious computation and to obtain more accurate results compared to using one-liner scientific calculators: “[It] speeds up the whole process once students have a basic conceptual understanding, computer handles the mechanical part of it”; and “It speeds up. It takes a lot of a drudgery, speeds a lot of stuff, like say for sketching graphs, say for learning transformation of graphs.” Further, the computer allows them to see the data and check incorrectly entered or inputted data. They are also able to use realistic data, improving real-world learning, as teacher B3 stated: “I think their learning is improved because they can deal with real data. Everything doesn’t have to be sanitised, clean and the numbers made easy to work with.” This aspect of realistic applications was also mentioned by teachers B2 and B4, who recognised that the Internet opens up a whole world of possible applications:

> B2: That could include going on the web and asking questions, looking everywhere…To improve their learning … is that to do with being self motivated, looking for answers to questions themselves?

> B4: With computers there are a lot of web sites and programs out there that can actually help them [students] with skills so its just a variety of the different ways of doing the skills … There are also a lot of places they can go and look at problems if they are interested in maths.

Hence, in this situation, the computer becomes more of a problem-solving tool, as teacher B1 explained: “I think that technology helps students be able to get onto the real reasons that we are doing the problems, think about the story behind the problem more and just use the technology to solve the problem.”

The ability of the computer to show graphs more accurately allows teachers to emphasise visual learning. Many of the teachers were pleased about this affordance since they appreciated the value of using a multirepresentational approach to learning since, as they say, it allows students “to make really strong links” between representations, and thus promote conceptual learning. This form of learning, according to them, “Gives students better understanding”; and “It exposes them to different ideas of mathematics … if we use technology in graphing, they actually see the graph.” Other teachers commented that: “I feel that visualising some things brings effective learning in place of me simply writing on the board. I think they understand better when you show them something, exactly what’s happening”; and “You can actually see the tangents and see that it’s moving and changing and see that they’re positive or negative or zero.”

Technological devices, such as computers, running software such as Excel offer the affordance of different ways of representing numerical data graphically. They also allow the students access to multiple representations and more time for discussion. This was observed in one of the classes where the students were asked to investigate how the measure of central tendency and the variance of the data change as the students provide different sets of data, and to describe the nature of data necessary to obtain a certain mean and standard deviation. With Excel’s ability to input data sets, the students were able to investigate these ideas based on data that they themselves had gathered.

With regard to the use of IAW, one of the researchers noted that the ability of the IAW to accept data and to communicate results in different representations “excited” the students, enticing them to gather round and discuss the technology.

The ability of a PowerPoint presentation to incorporate animation may also be considered an affordance in the sense that it can capture students’ attention and engage them to think about the presentation. It must be noted, however, that this may not be so in some cases. There were presentations that were simply offering mathematical topics in a “traditional” manner—direct lecture, but with the use of technology. However, a number of well thought out presentations were observed that demonstrated how PowerPoint can be very powerful in terms of capturing students’ attention and encouraging them to participate in class discussions. In addition, a teacher said that PowerPoint “makes review and revision easy and quick. It also meant that absent students receive the same information.”

Obstacles and constraints

As described in section 3, Theoretical framework, we follow Thomas (Thomas & Hong, 2005a) in describing an obstacle as something that prevents the presence of an affordance. Thus, the teacher commented that “there is shortage of computer rooms”. describes an obstacle, but the problem of booking the use of existing computer laboratories is a constraint. This constraint of difficulty in booking or scheduling was even mentioned as a problem even in a school with seven computer laboratories. A second obstacle was the lack of data projectors in the classrooms, but even for those schools where they existed there were constraints, such as the comment that “we don’t have a fixed projector so we’re always moving it and connecting it to everywhere and it takes a few minutes.”

Some HODs mentioned the lack of teacher confidence in using technology, and this is a constraint that could hinder the effective use of technology in teaching. Some teachers, on the other hand, lamented the lack of professional development (PD), which they said could help them learn more how to use the technologies and how to integrate them in their maths teaching. If no such PD exists in their area then this is an obstacle, however, if PD exists, but is not providing the required knowledge, then it’s a constraint. An obstacle mentioned by both HODs and teachers was the lack of finances or funds to support technology-based teaching. Again, if there are no funds then this is an obstacle, but if funds are available, but limited, then the funds are an affordance and their limited nature a constraint.

The requirements of external assessment, such as NCEA, is a constraint on teaching. Some teachers admitted to being exam-oriented in their teaching. One of them said: “Sadly I want them to pass their exams … so unfortunately, that’s the first focus. If we didn’t have to worry about that, I’d like to teach them about the big concepts of mathematics and the applications of that. The concept is important.” While this teacher believes in concept-oriented teaching, she laments that students must be trained to pass their examinations. Another lamented the change in teaching due to NCEA, saying that: “Before NCEA, all taught to [the] same level. With NCEA, [we] teach certain students up to a certain level that they want to aim for. Students just go to the basics." Clearly, students have used NCEA to give a clearer focus to the knowledge they are required to learn at each level of achievement, constraining teaching. It was interesting to see that even in the group who were happy to be observed using technology, the influence of external pressure to do so, in the form of the constraint of NCEA assessment, was commented on. Teachers said that:

"NCEA, you know. It's often in the explanatory notes, you know… "Incorporate technology." It's expected to be used. So you know, we've got a directive to do it."; "It's coming from NZQA, there is this expectation that technology will be used in a class, and from the curriculum document as well…so we are kind of expected to."; and "L1, L2, and L3 teachers must use technology because assessment was based on technology."

Clearly, the presence of computers is a vital affordance for teaching mathematics with computer assistance. Since it is rare for each student to have access to a computer in the mathematics classroom, and ICT rooms are difficult to access, it was a common observation that computers only become accessible for teaching if the teachers' computer screen can be projected onto a screen using a data projector. This lack of an affordance was one of the obstacles identified by some teachers, who welcome technology in teaching, but cannot use computers because their school is unable to provide them with a data projector.

For those teachers who use computers in teaching, the number of computers present in their classrooms is a differentiating factor in their practice, since it directly constrains the access students have to the computers. The options that we observed were: only one computer in the classroom; several computers in the classroom; and classes were held in a computer laboratory. We are able to summarise some of the key teaching differences in each of these cases as follows:

1. In the case where there is only one computer in the classroom, it was observed that the computer was used mostly for demonstration or for presentation. Many teachers use computers with PowerPoint or Excel, either to demonstrate an algorithm, to show how to solve problems using technology, or to present a lesson or the topic for the day in a teacher-directed manner. Most of these lessons using PowerPoint essentially employed it as an alternative to writing notes on the whiteboard (see examples in Figure 2). This has the advantage of having clearly presented notes available beforehand, and these can be supplemented with explanatory working on the board alongside, as some teachers did. However, it tended to lead to a rather procedural, skills-oriented type of lesson. And yet, we did observe an exception to this with one teacher using an animated presentation employing Java applets integrated into the PowerPoint presentation (see below).

Figure 2 **The PowerPoint work of two of the teachers**

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

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Where there was only one computer in the classroom, it was sometimes connected to the Internet and used to access demonstration or presentation programs. There were also cases where the only computer in the classroom was connected to another device, such as an interactive whiteboard (IAW), to good effect.

2. In one situation, where there were several computers in the classroom, it was observed that the five computers other than the teacher's were placed at the back of the classroom and were used by students who were assigned exercises to work on at the same time that the teacher gave the lesson to the rest of the class.
3. Some lessons observed were conducted in ICT computer laboratories, and the following differences were noted for these lessons:
   - In several classes, each student operated their own computer, but these were not connected through a local area network (LAN).
   - In two classes from the same school, each student operated a computer in a one-to-one ratio and they were connected to a LAN. In this situation, the teacher was observed to have control of student activities, and direct intervention was possible remotely (that is through the teacher accessing the student's computer from their own computer).
   - In other classes, the number of computers was not enough for one-to-one access and, thus, two or three students shared a computer.

Characteristics of good practice

Although the variety of numbers of computers used by teachers for teaching mathematics, and by students in learning, may be said to influence teaching outcomes, the dynamics in the classroom seem to be more dependent on the ways in which the teacher uses the computers and other technological tools available in the classroom than the number of such tools. In this research we have identified several aspects of what we consider to be good practice.

One aspect of good practice that was noted by the researchers with regard to the use of technology in teaching is the ability of the teachers to use the technology well. High levels of personal instrumentation and instrumentalisation (Rabardel, 1985) are a key factor in good technology use. In the case where there are other technological tools or instruments used with the computers, the teachers ability to use each of those tools or instruments efficiently, and to shift from the use of one to the other seamlessly, appear to contribute to good practice.

Another aspect is the teachers' ability the use of technology appropriately with the topic on hand during the lesson. For instance, in teacher C4's class, the teacher initially worked with data downloaded from the Internet (www.stats.auckland.ac.nz), discussed with the students what the data was about, and then eventually used the data in Excel. As the discussion progressed, the students were encouraged to use their graphic calculators with the same data, copying them and using their calculators to parallel the actions demonstrated by the teacher in Excel. In this instance, the teacher demonstrated fluency in her orchestrated use of technology without forgetting the mathematics (statistics) that was to be taught.

This practice was similarly observed in the classes of teachers A3 and A4. They both had access to the Internet in their classrooms, and both used tutorial software from the Internet, employing the downloaded materials in discussion with the students, and supporting the necessary computations needed with the students' use of graphic calculators. Teacher A4 commented on calculus standard 3.3 (Solve problems and equations involving trigonometric functions):

> [Technology] was really helpful to ... see the graphs of the trigonometric functions and see the max. and min. points and the period of the graph. It's been really difficult in the past for students to understand that topic [trigonometry equations] but if they can actually see it and look at it I think they can get a much better understanding of it. Even the general rule, 'What increases the amplitude?' and that kind of thing.

The use of computers in promoting teaching of concepts, and not just skills, was strongly supported by many of the teachers. For example, teacher C2 put it this way:

> Say in Statistics look at the ideas of misleading aspects and they can very easily, by pressing a button or changing a number, easily see that [it] has a huge impact on the visual effect. So I think it's good for students to get right into the applications, rather than the tediousness of crunching out the numbers. Not to say that they don't need to know how to crunch it out.

Teacher C5 saw the computer as freeing up time for the more important aspects of investigating mathematical ideas:

> Once they've got a basic understanding, then they can investigate a whole lot more and a whole lot quicker if they get a computer to do the mechanical part of it … they have to be interpreting what it's giving it back to them. But the main reason I guess for that one is to make sure you can get a lot more time for the discussion and investigating different options … the important part of what we do in teaching is probably based on their conceptual learning.

One excellent lesson observed was that of teacher D2 using PowerPoint. Her aim was to assist students to create for themselves a model of the process for getting the volume of revolution using the "shell" approach. She used a number of objects in the classroom, such as a cylindrical cake, cheesy snack pieces, cupcakes, a Russian doll, toilet paper, and an onion both to illustrate the idea of "slices" and rings she needed for the shell method of integration, and to engage the students. During the lesson, she demonstrated on the board how the volume can be computed mathematically:

$$
\begin{aligned}
&(\pi x_0{}^2 - \pi x_1{}^2)h \\
&\pi h(x_0{}^2 - x_1{}^2) \\
&\pi h(x_0 + x_1)(x_0 - x_1) \\
&2\pi h(\frac{x_0 + x_1}{2})(x_0 - x_1) \\
&2\pi y(ave\, radius)dx \\
&2\pi y(x)dx
\end{aligned}
$$

She then employed PowerPoint to display a concave downward parabola in the first quadrant, where one of the roots was at the origin, to demonstrate the area bounded by the parabola and the x axis, and how a strip from it may be revolved around the y axis, using Java scripts to show in a dynamic way how the volume is formed. This promoted a three dimensional view of the process. She then demonstrated an element of the volume (a shell) taken from the parabola, together with the equation to demonstrate its volume, and the step-by-step process of obtaining the expression for the definite integral. In this way, she used the technology to encourage the students to build a multirepresentational view of the definite integral for a volume. The activity also seemed to contribute to students' learning processes, in terms of: encouraging students to communication among one another; giving them the chance to relate the mathematical concepts discussed with concrete objects; and to mathematise (by modelling through symbolisation).

One of the common good aspects the teachers demonstrated in their teaching was the promotion of multirepresentational presentations, which has been described as being at the heart of what it means to understand mathematics (Lesh, 2000). Thomas and Hong (2001) have argued for the importance of what they describe as *representational versatility*, a fluency of thought that includes the ability both to translate between representations and to interact procedurally and conceptually with individual representations. The teachers in our study often agreed that multirepresentational presentations are good for conceptual understanding, and the practice was demonstrated by many of the teachers observed. In contrast, there are teachers who use technology in a teacher-directed, subject-oriented manner, emphasising procedures and focusing on the skills that NCEA requires for examinations. As teacher C5 observed, this is often driven by the students desire to obtain NCEA credits:

> ... and so the students come from the point of view of 'show me what I need to do to get achieved' or 'show me what I need to do to get merit' rather than 'how does it all tie together' or 'how does it apply to the real world'. It's more like 'how can I get through the word problem, how can I find the numbers to put in the equation to get me the answer to get me the credits' … it's kind of hard to work from that, especially when you get close to the assessments then that tends to become immediate, and more important in a way, because that's really the end result for the student.

Hence, NCEA was also a focus of the teaching of the teachers with "good practice", but they also tried to emphasise concepts and links between concepts, and as they said, between different representations of the concepts they taught.

Another aspect of good practice may be described as the ability of the teacher to use the technology actively to engage the students in different learning activities. These activities include student participation in discussions wherein they are able to communicate their understanding, or working on assigned tasks and communicating with other students. This was observed in situations where the students were assigned investigative work. Regardless of whether the students share computers or have exclusive use of one, it was observed that the nature of the activity encourages the students to discuss with one another the results they get, and how they get those results.

To summarise, the researchers felt that good practice in the use of computers in the classroom can be characterised by the following:

- Confidence in the use of technology, whether a computer, a graphic calculator, or other tools such as interactive whiteboard. When the teacher uses hardware or software, he or she must be able to develop a certain level of expertise, especially with the commands that are necessary for the mathematics to be taught.
- An emphasis on mathematical ideas and concepts rather than on passing on to students operational thinking, such as key presses and menu operations, or on procedural calculations.
- An ability to teach the mathematics with a comfortable use of the technology, not as a "crutch" but as a "third arm". That is, not forcing the use of the technology just for the sake of using it, but knowing when and how to use technology appropriately in teaching a given mathematical concept or skill. Using the technology, not just because it makes computations and presentation faster and more efficient, but its use allows students to reflect more on mathematical results than simply producing answers.
- Teaching concepts without sacrificing skills, presenting the bigger picture, including multiple representations of concepts, while developing the skills that are necessary to understand those mathematical concepts better.
- An ability to engage the students in all technology teaching and learning activities. In doing so, monitoring closely each of the student's abilities and needs. In this way, the teacher is able to respond to, or support, the students more appropriately according to their abilities and needs.

- If there is more than one kind of technological tool in the classroom, the ability to shift swiftly between technologies that are to be used in the lesson.

While we have tried to describe above some aspects of what good practice teaching with technology may be, we recognise that it is not an easy task to develop it. As a teacher is part of an educational environment, their abilities and actions are supported, and at the same time constrained by that environment.

Concluding remarks

What does this research tell us about the changing face of computer use mathematics teaching in New Zealand secondary schools? The percentage of secondary mathematics teachers never using them has remained constant, at around 30 percent. While there are many more computers in the schools and an increased frequency of use, access to them is still the major obstacle to use in mathematics. They are usually in ICT rooms, and 89.6 percent of mathematics departments do not have their own technology budget. The primary uses of the computer are for graphical and statistical work, with the spreadsheet and a graph-drawing package the two most common pieces of software.

There has been a significant decrease in the use of mathematical programs and statistical packages, and an expected increase in the use of the Internet. While teachers are using computers less for skill development, its use is still high and they have increased the use of demonstrations. Use of the computer is directed over 80 percent of the time. This pattern of changing use could not really be described as teachers warmly adopting the computer, and there are two important factors worth mentioning here.

Only 20.7 percent of the schools had a technology policy in place, and when they did it usually comprised general statements, such as: "Technology should be used wherever possible as an aid to learning", "All teachers are expected to integrate ICT into their teaching and learning practices", "Access for all students to Internet", or it specified what technology would be used by which year groups, or set rules for Internet access and computer room use. Only rarely did it include the acquisition and replacement of software and hardware or the professional development of staff. Such an important omission has been noted previously (Andrews, 1999). It is not surprising that without such a policy the use of computers in schools will tend to lack clear focus and direction.

The second issue arose when the 2005 teachers were asked what they thought were the advantages and disadvantages of using computers (technology) in mathematics. While just 8 percent believed that it aided understanding (compared with 32 percent who thought it made working quicker or more efficient), 16.8 percent claimed that it impeded learning or understanding. As Manoucherhri (1999) reported, many "… teachers are not convinced of usefulness of computers in their instruction…" (p. 37), they still feel, like Cuban (2001), that benefits are small or exaggerated, and students rely on technology too much. As several teachers in this research put it, "I feel technology in lessons is overrated. I don't feel learning is significantly enhanced … I feel claims of computer benefits in education are often overstated", "Reliance on technology rather than understanding content", and "Sometimes some students rely too heavily on [technology] without really understanding basic concepts and [are] unable to calculate by hand." Clearly, teachers have a crucial role to play, and their beliefs and attitudes are major elements in the progress in computer use. This is an area for further research.

Calculators in mathematics teaching

As with computers, we made some comparisons with the data on technology in schools gathered by Thomas in 1995 (Jones & Thomas, 1995; Thomas, 1995, 1996) in order to look for trends as well as the current position. In 1995, there was an average of 22.63 calculators (52 percent Casio) owned by mathematics departments and 96 percent of Year 12 and 97 percent of Year 13 mathematics students owned their own calculators. In 2005, the average number of calculators owned by a mathematics department was 45.65 (of which 68.6 percent were Casio—see Table 24). In Year 12, 86.4 percent and Year 13, 87.9 percent owned their own calculator, which represented a drop on the 1995 figures. Of interest in 2005 was the calculator type owned, namely, scientific 76.1 percent, graphic calculator 27.1 percent, and CAS 0.2 percent.

Table 24 **Mean numbers of mathematics department calculators by brand (*n*=193)**

Calculator brand	Mean	Percentage (%)
Casio	31.3	68.6
Texas instruments	6.5	14.4
Sharp	7.0	15.4
Other	0.7	1.6
Total	45.5	100

From the survey for all secondary school teachers and HODs, 75.5 percent of respondents who teach Year 12 classes said that they sometimes used graphic calculators in their lessons. However, when they were asked as to whether they regularly used them, this number dropped to just under half (49.4 percent). Among teachers of Year 13 calculus, 91.8 percent sometimes use graphic calculators, while 75.4 percent regularly use them. Among teachers of Year 13 statistics, 79.4 percent sometimes use graphics calculator, while 66.7 percent regularly use them. During 1995 mathematics lessons, 75.8 percent of Year 12 and 62.5 percent of Year 13 regularly used calculators as an integral part of the lessons with 69.8 percent using them at least once a week, 14.2 percent at least once a month, and 9.2 percent at least once a term. In 1995, 6.2 percent of Year 12 and 5.0 percent of Year 13 used them only when directed by the teacher compared with a total of 10.2 percent in 2005. Thus, the majority of teachers surveyed said that students were using calculators in their lessons other than when directed, indicating that most students are in the habit of using calculators when they need to without the direction of a teacher.

The question of whether it is better for students to own their own technology or for the school to provide it was specifically addressed in the questionnaire. We can see from Table 25 that 66.0 percent of the teachers agreed that student ownership was the best situation, with only 14.8 percent disagreeing. The two clear benefits from students having their own technology are improved access and lowering of the pressure on already overcommitted department and school budgets. The questionnaire revealed that only 10.3 percent of mathematics departments have a technology budget, and the average size of these is NZ$2762.50.

Table 25 **Does best practice occur when students own their own technology?**

	2005 percent of responses (*n*=464)
Strongly agree	22.2
Agree	43.8
Neutral	18.5
Disagree	7.3
Strongly agree	7.5

Obstacles

There has been quite a lot said about the possible negative effects of calculator use in the mathematics classroom and we wanted to know what the opinion of the teachers was on this subject. The responses to the question of whether calculators "may be" (1995) or "are often" (2005) detrimental to students' mathematical understanding are given in Table 26. The summary shows that in 1995, 24.8 percent of teachers agreed that calculators may be detrimental, and in 2005, 26.6 percent thought that they often are. In the same period, the number disagreeing dropped from 60.2 percent to 47.1 percent (χ^2=13.7, p<0.001). It seems that what has happened in the intervening years has done nothing to alleviate the perception of a significant minority of teachers that calculators may be more damaging than useful to student understanding, and, in fact, on the basis of this question, there is some evidence here that the situation has changed so that fewer teachers are convinced about the value of calculators.

Table 26 **A summary of the teachers' views on whether calculators may be detrimental to understanding'**

	1995 percent of responses (*n*=339)	2005 percent of responses (*n*=464)
Strongly agree	4.7	5.0
Agree	20.1	21.6
Neutral	14.2	18.8
Disagree	35.1	33.1
Strongly disagree	25.1	14.0
No response	0.9	7.5

However, when we asked the teachers to respond whether they agreed with the statement that "calculators" (1995) or "technology" (2005) are of little benefit in mathematics teaching, we see from Table 27 that there was a strong majority disagreeing—87.3 percent in 1995 and 75.6 percent—although, this too has fallen. Since the calculator is the technology most often used in classrooms, one possible explanation for why many teachers see the calculator as of value, but why some also think that it can be detrimental is that it depends on the way in which it is used in teaching. This would agree with the argument of Thomas (1999) that, depending on how it is used, the calculator may be beneficial or harmful to learning.

Table 27 **A summary of the teachers' views on whether calculators or technology are of little benefit in teaching**

	1995 percent of responses (*n*=339)	2005 percent of responses (*n*=464)
Strongly agree	3.2	2.4
Agree	3.8	5.6
Neutral	4.7	9.7
Disagree	34.2	37.7
Strongly disagree	53.1	37.9
No response	1.0	6.7

The teachers were also asked whether or not they would like to use a calculator (1995) or graphic calculator (2005) more often, and 19 percent (1995) and 56.7 percent (2005) respectively said yes. Those who answered yes were asked to rank a number of obstacles, or give their own (see Appendix A). Table 28 shows the summary results of these responses.

Table 28 **A summary of the obstacles to using the calculator more in 1995 and 2005**

	Percent of 1995 teachers (*n*=64)		Percent of 2005 teachers (*n*=257)	
Obstacles	**First mentioned**	**Mentioned**	**First mentioned**	**Mentioned**
Calculator availability	76.6	81.3	52.5	71.6
Lack of PD	4.6	12.5	19.1	48.2
Lack of confidence	4.7	10.9	13.6	42.4
Government policy	1.6	9.4	1.9	6.2
School policy	3.1	10.9	0	5.1

NB: There was a provision for an "other" response, which affects some percentage totals.

In 2005, these obstacles were examined along gender lines to see if there were any differences (see Table 29). The results show that females were a little less confident than males, but not significantly so (χ^2=2.27, n.s.).

Table 29 **A summary by gender of the obstacles to using the calculator more in 2005**

	First mentioned (%)		Mentioned (%)	
	Male	**Female**	**Male**	**Female**
Calculator availability	30.2	31.0	42.2	40.5
Lack of PD	12.1	10.0	29.7	26.2
Lack of confidence	6.9	8.6	21.6	28.1
Government policy	1.7	0.5	9.1	3.8
School policy	0.0	0.0	7.3	2.9

NB: There was a provision for an "other" response, which affects some percentage totals.

The subject of sufficient resources was not raised here, but was asked in a separate question: whether they agreed with the statement that a major obstacle to teachers using "calculators or computers" (1995) or "technology" (2005) is a "lack of good ideas which work in the classroom" (1995) or "classroom resources" (2005).

Table 30 **The need for more classroom ideas and resources in 1995 and 2005**

	1995 percent of responses (*n*=339)	2005 percent of responses (*n*=464)
Strongly agree	7.1	25.6
Agree	33.9	45.5
Neutral	25.1	10.8
Disagree	25.7	7.3
Strongly disagree	6.5	3.7
No response	1.6	7.1

While these questions are not precisely parallel, they do show (see Table 30) that the 41.0 percent agreeing in 1995 had increased significantly ($\chi^2=76.5$, $p<0.0001$) to 71.1 percent in 2005, with a corresponding drop in those who disagreed from 32.2 percent to just 11.0 percent. Clearly, the 10 years have seen an even greater need for classroom resources full of good ideas for teachers to use when teaching with technology. This is something that all in education need to be aware of.

A recent innovation that was not around in 1995 is the possible use of computer algebra system calculators in schools. There has been a lot of research in recent years on the perceived benefits of using these calculators in the mathematics classroom (e.g., Drijvers, 2000; Drijvers & van Herwaarden, 2000; Kendal & Stacey, 1999, 2001; Thomas, Monaghan & Pierce, 2003; Trouche, 2000). From our survey, we knew that only 1.8 percent of the teachers used CAS with their classes, but we wanted to know whether teachers are in favour of their use in examinations, since this raises the problem of how to set questions that are both equitable and still test the required knowledge. Some research on this has been conducted (Hong, Thomas, & Kiernan, 2001) and showed that, while it is possible to set examination questions that are equitable, there are considerations in terms of the possible disadvantages to weaker students of using CAS calculators. The responses to the question whether “All types of calculators should be allowed in examinations” are shown in Table 31. While 21.7 percent are in favour of this move, there is a sizeable majority of 60.5 percent who disagree. They may be against the use of any calculators, of course, but it is more likely that they do not think graphic calculators or CAS should be used. Since the Ministry of Education is moving towards allowing CAS in examinations from 2011, it seems that there is work to do to provide the professional development that will convince many teachers of the wisdom of this.

Table 31 **Whether all types of calculators should be allowed in examinations**

	2005 percent of responses (*n*=464)
Strongly agree	5.8
Agree	15.9
Neutral	11.2
Disagree	35.1
Strongly disagree	25.4
No response	6.4

Some of the teachers who were interviewed raised issues specifically about the use of graphic calculators in examinations. These may be categorised as follows:

1. Equity. They said that not all students can afford graphic calculators and so there is an equity issue about providing universal access to them.

2. Issue of having class sets. One said that it would have been better if they had class sets of graphic calculators. Of those with class sets, one said that they lend their calculators to the students, while another said that they used to lend them but not anymore because of problem of calculators not returned. One of the teachers said that they encourage their students to buy and that her school sells graphic calculators for a cheaper price than that in the market.
3. Lack of teacher support. Two of the teachers indicated that not all their teachers support the use of graphic calculators.

Affordances and constraints

One of the key factors in the use of graphic calculators in the learning of school mathematics (or indeed of tertiary mathematics) is the teacher. In turn, there are many factors that influence a teacher's use of graphic calculators, as with any technology. These include the *affordances* and *constraints* of the environment they work in (Greeno, 1994) their attitude to, and beliefs about, mathematics and the technology, as well as their confidence and ability in using it to teach mathematics. For example, teachers (A1, A2, A8, and A10) had to work around the obstacles of the lack of an overhead projector and a viewscreen to project the calculator screen. One teacher managed this by using the affordance of a poster of the graphic calculator to show students the right key strokes, but clearly a poster has constraints, such as not being able to show the result of the key strokes. Hence, when considering the obstacles and constraints that might be influencing the teachers' use of graphic calculators (and other technology) we decided to group them into three sections, departmental, school, and added personal teacher factors. Table 33 lists some of these obstacles and constraints. The level of confidence in graphic calculator use in mathematics of the 22 teachers using them was deduced through discussion with them and from classroom observation, and we found that 12 had strong, and 10 weak confidence. For example teacher A3 commented that "My belief is to do some calculation on the graphic calculators, you should know what you're doing. Without knowing what you are doing, they can't use it." The teachers were from 15 different schools, and our aim was to investigate the factors influencing the different levels of confidence and to see if confidence was linked to style of teaching with the graphic calculators.

Table 32 **Background factors influencing 22 teachers' use of graphic calculators**

Teacher	Teacher GC experience/confidence	Department HOD/teacher support	School use of GC/teacher support
		Weak Confidence Group	
A1	New user/Weak	Weak/None	New/Strong
A2	New user/Weak	Weak/None	New/Weak
A7	Experienced/Weak	Strong/Others	Experienced/Strong
A8	New user/Weak	Weak/None	New/Weak
A10	Experienced/Weak	Weak/None	New/Weak
B4	New user/Weak	Strong/Others	Experienced/Strong
C6	Some experience/Weak	Weak/None	Experienced/Weak
E4	Some experience/Weak	Strong/Others	Experienced/Strong
E5	Some experience/Weak	Weak/None	Experienced/Moderate
E6	Some experience/Weak	Moderate/Some	Experienced/Moderate
		Strong confidence group	
A3	Experienced/Strong	Strong/Others	New/Strong
A4	Experienced/Strong	Strong/Others	New/Strong
A5	Experienced/Strong	Strong/Others	Experienced/Strong
A6	Experienced/Strong	Strong/Others	Experienced/Strong
A9	Experienced/Strong	Weak/None	New/Strong
B3	Experienced/Strong	Strong/Others	Experienced/Strong
B5	Experienced/Strong	Strong/Others	Experienced/Strong
C3	New/Strong	Strong/Others	New/Strong
D2	Experienced/Strong	Strong/Others	Experienced/Strong
D5	Experienced/Strong	Weak/None	Experienced/Weak
E1	Experienced/Strong	Strong/Others	Experienced/Strong
E2	Experienced/Strong	Strong/Others	Experienced/Strong

From Table 32 we see that of the 12 teachers with strong confidence in their ability to teach with the graphic calculator, 11 were experienced users, 11 had strong school support, 10 had strong HOD support, and 11 had the support of other teachers in their department. In contrast, of the 10 teachers with weak confidence in their graphic calculator use, eight were inexperienced users, and seven had little HOD or other teacher support in their schools. Interestingly, the level of school support was split, with five being supportive and five not. This initial analysis seems to suggest that among the key variables in producing confident users of graphic calculators are the teachers' own experience and the immediate affordance of support from others in the mathematics department. However, these sometimes seem neither necessary nor sufficient, since there are exceptions to the general trend. On the one hand, teacher C3, who was new to using the graphic calculator was confident, but was in a school where there was strong support from the HOD and the school, even though the school was new to using the technology, and teachers D5 and A9 were confident in spite of no support (D5), or no support from the department (A9). On the other hand, teacher A7 was experienced, had strong support from both department and school, and yet lacked confidence in his ability to teach with the graphic calculator; teachers A10, C6, E5 and E6 all had some (limited) experience with the graphic calculator, but had little or no support from their department or school, and teacher E4 had some experience and strong support, yet they were all weak in confidence. It seems support from others in the school, and especially the mathematics department may be a primary environmental factor influencing teacher confidence.

Comparing the 22 teachers who used the graphic calculator with the 10 who did not, we found that there was no difference between these two groups on the subscales except, not surprisingly, weak evidence of a significantly more positive attitude ($p<0.1$) to using technology and/or the graphic calculator to learn mathematics on the part of those who did use the graphic calculator. Similarly, there were no significant differences between the graphic calculator users with weak confidence and the nonusers on any subscale.

We see from Table 33's comparisons between the group of users with strong confidence and the nonusers that, apart from their attitude to mathematics, there is evidence of a significant difference in attitude on all the other subscales, weak on the personal learning scale, but strong on the others. Thus, the teachers with strong confidence in using the graphic calculators have a more positive attitude to technology and to using to help students learn mathematics than those who do not use the graphic calculator. A corresponding comparison between the teachers with strong confidence and those with weak is shown in Table 34. This shows a remarkably similar pattern of significant difference between the attitudes of these two groups too.

Table 33 **Subscale mean comparison for confident graphic calculator (GC) users and nonusers**

	Attitude to maths	Attitude to technology	Technology in learning maths	GCs in learning maths	Personal learning
Strong confidence (*n*=12)	3.96	4.15	4.38	4.05	4.19
Nonusers (*n*=10)	3.93	3.53	3.89	3.40	3.95
p-value	n.s.	<0.005	<0.0005	<0.0005	0.07

We infer from these results that strong confidence in one's ability to teach with the graphic calculator is linked to a more positive attitude to technology, and, probably, to one's attitude to personal learning. Whether the relationship is unidirectional (and if so which way) or bidirectional is not clear. The latter trait is of interest in that it may imply that learning new things is beneficial for becoming a confident user of the graphic calculator in teaching mathematics (or that confident users learn more), since, for example, Q3 shows those with strong confidence were more likely to have lots of ideas for using technology to teach mathematics ($Mean_{strong}$=4.3, $Mean_{weak}$=3.6).

However, both groups wanted to improve their ability to teach with technology (Q11, $Mean_{strong}$=4.4, $Mean_{weak}$=4.5).

Table 34 **Subscale mean comparison for confident and nonconfident GC users**

	Attitude to maths	Attitude to technology	Technology in learning maths	GCs in learning maths	Personal learning
Strong confidence (*n*=12)	3.96	4.15	4.38	4.05	4.19
Weak confidence (*n*=10)	3.75	3.23	3.98	3.49	3.88
p-value	n.s.	<0.005	<0.05	<0.0005	0.06

In addition, while a positive attitude to technology in general is helpful, it is particularly the ability to comprehend that the technology, and here especially the graphic calculator, can be positive in helping students learn mathematics that the confident users possess in greater measure that the others. If we link this back to the concept of pedagogical technology knowledge (PTK) (Hong & Thomas, 2006; Thomas & Hong, 2005a), then we have a clear fit, since PTK involves the ability to relate the graphic calculator to the learning of mathematics, and the shift of focus this requires means that one must be open to learning new perspectives on teaching. Whichever way round the relationship here is, we can say that greater confidence in teaching with the graphic calculator is linked to more positive attitudes to the use of the graphic calculator in mathematics and to personal learning. Examples from individual questions show that the teachers with stronger confidence are more likely to think that students would be better motivated if they use graphic calculators (Q23, $Mean_{strong}$=3.9, $Mean_{weak}$=3.2), that the graphic calculator does not remove learning opportunities from students (Q24, $Mean_{strong}$=4.2, $Mean_{weak}$=3.3), and that students would understand maths better with a graphic calculator (Q25, $Mean_{strong}$=4.0, $Mean_{weak}$=3.0), while both groups agree that students still need to learn to draw graphs by hand even if they use the graphic calculator (Q28 $Mean_{strong}$=4.1, $Mean_{weak}$=4.3).

Examples of good practice in the classroom

We have previously described (Thomas & Hong, 2005a) how we found teachers' levels of instrumentation of the graphic calculator were linked to their confidence and how a low level of confidence in terms of teaching with the graphic calculator in the classroom influences teacher PTK so that it is characterised by an overemphasis on passing on to students operational matters, such as key presses and menu operations, along with procedural calculations, to the detriment of the mathematical ideas. In contrast, a higher level of instrumentation produces a higher level of confidence, which in turn frees the teacher to focus more on other important aspects, such as the linking of representations and investigation of concepts. In the current research, the teachers were asked in the interview in what respect the technology had been effective in improving student learning. The data (see selection in Table 35) revealed that the teachers with lower confidence tended to stress the speed factor, visualisation, accuracy, and motivation aspects of the graphic calculators, with only A2 mentioning concepts. In contrast, while the group with more confidence did mention some of these things too, they often talked about understanding of ideas, overviews, generalising, or linking.

Table 35 **Some responses to the value of technology in student learning**

Teacher	Answer
	Weak confidence
A1	It can also provide a visual help to understanding.
A2	We want them to be able to see what the concept is … It's much faster, quicker and easier.
A7	Well for students 'seeing is believing'. They can actually see…the comparisons.
A8	You're on a time constraint. I think with just a calculator … makes it easier in that respect.
A10	Students find it really stimulating and fun.
B4	They aren't occupied in … worrying … have they actually entered all the data.
C6	It allows them … to check the reasonableness of it and we clear up a lot of careless errors.
E4	It's good for understanding the bits that you have to do many times … it would take a long time to do it by hand.
E5	You can see very quickly and visually that the graphs are producing parallel lines.
	Strong confidence
A3	They really understood the concepts and answered the things in all cases the correct way.
A4	If they are more comfortable with the idea and can understand the big idea then they are happier.
A5	The ideas can be fed back to the original function … with pencil and paper … there's too much room for error.
A6	It's the amount of visual information … they can generalise for themselves … they had a much better concept.
A9	The visual impact.
B5	Technology is really important for multiple representations … visual is … really important.
C3	Trying to make it a bit of fun … not learning necessarily step-by-step processes.
E1	Understand it a lot better just by being given a chance to play and make those connections.
E2	A lot quicker for them to get to the same point … actually see what a particular value was doing … transfer that knowledge very quickly … It becomes visual.

There was also evidence of these same emphases from the classroom observations. While we can only present limited data here, Figure 3 shows two examples of how the teachers with less confidence put more time and emphasis on operational areas, such as key presses.

Figure 3 **An emphasis on operational matters**

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

A7 A10

In this study, we tried to lay down criteria to identify teachers who could be described as exemplary graphic calculator users. We describe and analyse the kinds of use that these teachers are making of the graphic calculator in terms of a conceptual or procedural divide, and identify individual, departmental and school factors that could be assisting or preventing technology use. From among these factors, key variables that seem to be driving successful implementation of graphic calculator use are identified.

Teacher one

Teacher A6 works in a high socioeconomic school (decile 10). She has 20 years' teaching experience and has been using graphic calculators for three years. We made three visits to observe her classroom. The first involved Year 12 students (age 17 years) studying probability simulations in statistics, and the second and third observations were of Year 13 students (age 18 years) working on calculus, stationary points and trigonometry. In each lesson, the teacher and all her students had access to TI-83+ calculators. While in her interview she stressed the value of the technology for covering more ground:

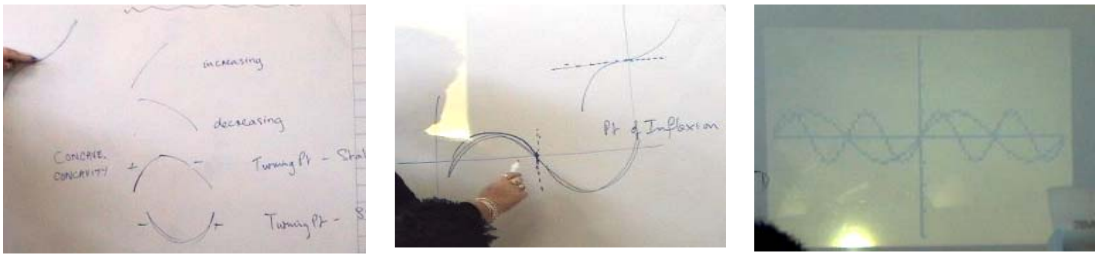
> … the number of things that they can do in any one lesson is far greater so it's better than drawing. Usually it takes you all lesson to draw three (graphs). You can draw ten with a graphics calculator and they can really understand it for themselves …

She mentions student understanding, which was a focus for her. She also stressed the visual benefits of the graphic calculators in this:

> … it gives the students a visual interpretation, a hands-on approach; it's not all just writing, they can see things happening, particularly with the probability simulations yesterday. I felt they had a much better comprehension of what was actually happening so they got a visual picture but also every time they did it … they could see it happening differently every time.

These two ideas converge in her mind to give students the ability to generalise: "I think it's the amount of visual information they can get, and the amount of examples they can get through, so they really feel they understood it because they've seen so many that they can actually accept and they can generalise for themselves and it gives a better understanding." Rather than focussing simply on getting her students to perform procedures she talked about how "they had a much better concept of what was actually happening". She does not put the emphasis in class on the instrumentation of the GC, instead: “Basically if I’m organised I’ll make a worksheet with the five keys we’ll use that day or put the five keys we’ll use on the blackboard, go over those and just spend five minutes on what we’re going to do for the day.” This approach was confirmed by the observation of her second lesson, on concavity. Her teaching was focused on using the technology to improve conceptual understanding, with an emphasis on visual representations of functions. She explained the concept of concavity on the whiteboard (see Figure 4), followed by turning point, stationary point, local maximum and minimum points. Teacher A6 also gave the definition of a point of inflection, showing that it may have a nonzero gradient. The students then worked on the function $y = x^4 - 2x^3$, to find its key features, such as concavity, being encouraged to work by-hand and on the GC (with, e.g., [2^{nd}] [Trace] to find turning points) in parallel.

Figure 4 **Teacher S’s conceptual emphasis in differentiation**

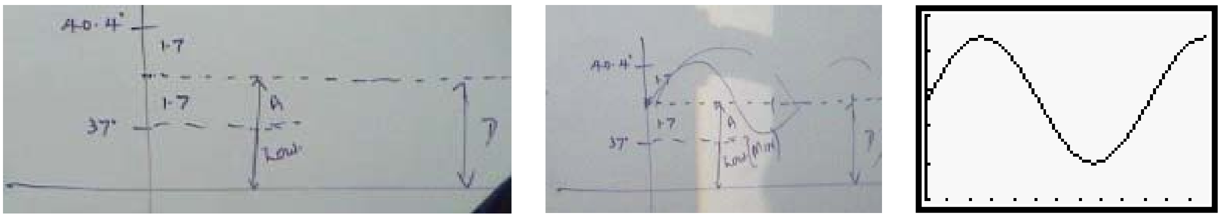


The lesson’s concepts | The point of inflection | The GC use

In her third lesson, she considered how the graphic calculator could help her students understand and recognise key concepts of functions $y = A\sin B(x + C) + D$, such as amplitude, period, maximum and minimum values. This led to a question using trig functions to model temperature:

> A patient in the hospital had an illness in which his temperature (in degrees census) varied from a low of 37° to a high of 40.4°. The length of time between successive highs is 16 days. Determine the formula for the temperature, T, of the patient at time in days since the beginning of the illness. Assume that the function describing the temperature can be modelled with a sine function, with no phase shift.

Figure 5 **Teacher A6 integrates the graphic calculator in modelling**



a) Preliminary data | b) Beginning the curve | c) Using the GC

In this she got the students to work by-hand on the conceptual structure of the problem, and then integrated the graphic calculator into the solution process. The students found *A* as 1.7 from (40.4–37)/2 (Figure 4.4a), *D* as 38.7 (37+1.7), and *B* as $\frac{\pi}{8}$ from *B*=2π/period, to give $y = 1.7\sin\left(\frac{\pi x}{8}\right) + 38.7$.

Teacher A6 was able to accommodate the graphic calculator into her didactic contract, one embracing quite a traditional method of teaching. She was able to include within the bounds of her contract a method of helping students cope with facets of their instrumental genesis of the graphic calculator, especially with the use of buttons and menus. She was able to have as an aim to get students to consider the graphic calculator as an instrument that could assist them with conceptual understanding of mathematical ideas, and not just as a black box procedural tool. As part of this she employed, and welcomed, getting her students to generalise by abstraction of properties from multiple examples. When we asked her what advantages she saw to teaching with graphic calculator she valued the ability to move between multiple representations of concepts. Such representational fluency has been described as a very important part of mathematical understanding (see Lesh, 2000), and she used the the graphic calculator to enhance it.

Teacher two

Teacher A2 works in a medium socioeconomic level school (decile 5). She has nine years' teaching experience and has also been using graphic calculators for three years. We made two observation visits to her classroom, both involving Year 13 students (age 18 years) studying firstly trigonometric graphs and their transformations, and then the solution of trigonometric equations. The school allowed graphic calculator use in examinations and encouraged students to buy their own calculator, but the financial situation at the school was not considered good enough to support technology; according to the head of the department "the budget doesn't allow for it." Hence, the mathematics department did not have a class set of graphic calculators or a viewscreen, so she had an obstacle to overcome when she wanted to demonstrate working with a graphic calculator. When we visited teacher A2's class only seven of the 14 students had their own scientific or graphic calculator, and so the students shared with each other or worked without a calculator. Thus, she worked under the constraint that the calculators were not all the same, and so she had to explain how to work with each model. Teacher A2 used a CASIO fx-9750G graphic calculator and an overhead projector (OHP) on which she wrote to demonstrate and explain key points.

In her interview, teacher A2 spoke about the visual value of the graphic calculator, how "when they have a graphics calculator, it's very useful for them to see how the graphs … what the graphs look like, and you can change numbers". She also mentioned the time-saving aspects of its use "It's much faster, quicker and easier". However, she also thinks of the conceptual value of the graphic calculator in helping students make connections:

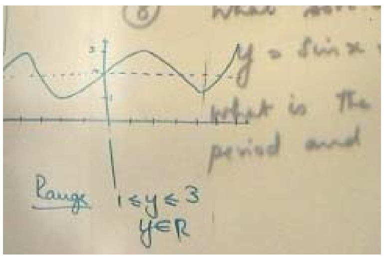
> I think it's important for them to understand concepts in mathematics and there's got to be a balance between the skills they do and the word problems … Basically we want them to be able to see what the concept is, and instead of sketching it every time … so if you want them to check for 'y=3cos(4x)', they have independently seen what is happening to 'cos (4x)' and what happens when they [do] '2cos(x)', and they can put the two together and get it from the graphics calculator quicker and they can see the changes much faster.

On the subject of GC instrumentation, teacher A2 does not put a lot of emphasis on getting students to think about what buttons to press, etc. She says that once they have the basics students are quick to pick up what they need in each lesson: "I don't put it all up at the beginning of the lesson or they'll get confused with it. I do it as and when I feel it's necessary. But generally, switching it on, feeling the menu and how to use the cursor, most of the students know. That's why I put the instructions up and most of them caught on to it very quickly." Her emphasis on conceptual understanding was seen in an interview comment: "I think it's important for them to understand concepts in mathematics and there's got to be a balance between the skills they do and the word problems they work out."

In her first lesson with the Year 13 students (age 18 years), teacher A2 used the GC to allow students to investigate graphs of the form $y = A\sin B(x+C)+D$, etc. First she concentrated on the effect of a single parameter, using $y = A\sin x$, with A=2, 3 and 0.5, and asking what these numbers signified, and then moved on to graphs of the form y=cos(Bx), with B=2 and 3. Students were encouraged to work together, "Discuss with the person sitting next to you the effect of y=sin(Bx).", and she also got students to come out and sketch graphs on the white board. In each case she tried to get students to focus on the concepts of domain, range, period, amplitude and frequency, asking questions such as: "What does the number 2 signify?" She explained the conceptual approach, and the role of the GC this way:

> Instead of just sketching 'y = cos (2x)' and then after it doing 'y = cos (3x)', they've got to see the connection. If they see ... keep changing the variables, and they see the effect of that, that's conceptual understanding and that's what we should be getting at and the graphics calculator is really useful for that.

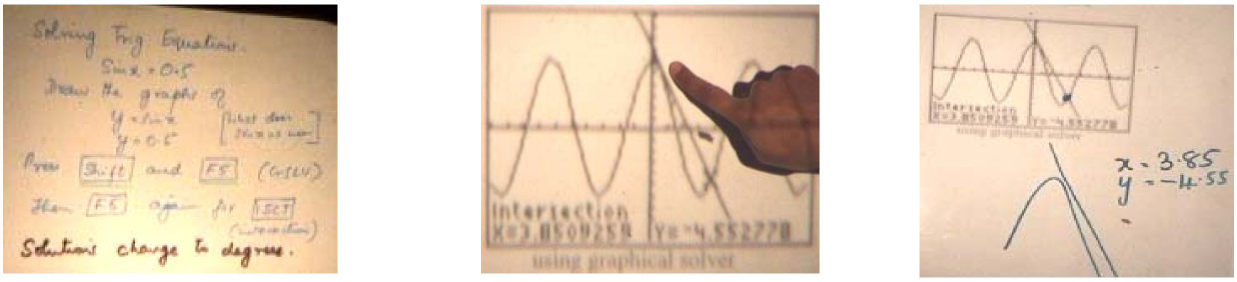
Figure 6 **Teacher A2 stresses the concepts of range and period for *y*=sin*x* + 2**



Moving on she focused on the concept of translation, asking "What sort of translation is y=sin$x$+2? What is [sic] the domain, range and period? What does [the] graph look like?" Figure 6 shows her use of some of the key ideas on the overhead projector. In the second lesson was spent solving equations such as sin$x$ = 0.5. To do this she got the students to draw the graphs of y=sin$x$

and y=0.5 on the GC (see Figure 7a) and consider their intersection. Afterwards she used this same concept to get them to solve 7–3x = 6cos$x$. Since she did not want her students to be procedural users of the GC, but to think about the mathematics, she used this example as an opportunity to get them to look through what they saw on the screen. She pointed to the apparent intersection of the two graphs near the y-axis (see Figure 7b) and asked the students to use the GC to zoom in on that area. They could then see that the line does not actually intersect the curve (see Figure 7c) and that was why there was no solution given by the GC, instead "When you press [G-Solve], it always give you first intersection from left to right, then x = 3.85, y = –4.55."

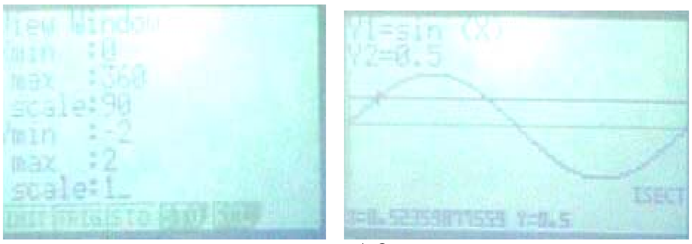
Figure 7 **Teacher A2 shows that trig equations can be solved with intersecting graphs**



a) y=sin$x$ and y=0.5 for sin$x$ = 0.5 b) y=7–3x and y=6cos$x$ for 7–3x = 6cos$x$ c) Zooming in

Figure 8 is a glimpse of another conceptual emphasis of a more confident teacher, A9, here looking at the importance of units and scale in graph intersections on the GC.

Figure 8 **A conceptual emphasis**



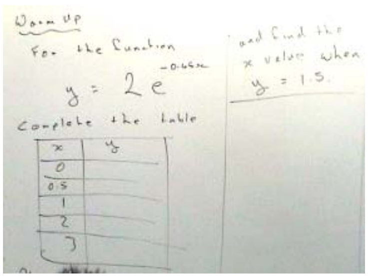
A9

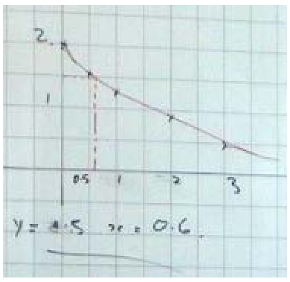
Teacher three

Teacher A1 works in a low socio-economic level school (decile 2). He is less experienced than the other two, with 4 years' teaching, was new to using graphic calculators in his teaching and had not attended any GC professional development course. As with teacher A2, the school allowed GC use in examinations and encouraged students to buy them, but the majority of the students could not afford one. However, the school was trying to support technology use so the mathematics department had purchased one class set of CASIO fx-9750G calculators and had one classroom with a computer set up for PowerPoint use. Teacher A1 commented on this constraint that "Very few of the students can afford their own graphics calculator therefore, the only chance they get to practise with them is in the lesson when we hand them out and draw them back again, so they don't get the familiarity …they haven't had the practice in using the technology." We made 3 observations of his classroom. All three lessons involved year 13 students (age 18 years) using the class set of graphic calculators, one studying the binomial distribution in statistics, and the others the use of power and exponential functions in statistical modelling. Once again teacher A1 had to work around the obstacles of the lack of an overhead projector and a viewscreen to project his calculator screen. He managed this by using the affordance of a poster of the GC to show students the right key presses, but clearly a poster has constraints, such as not being able to show the result of the key presses.

In his interview teacher A1 showed that he did not want students simply to use the GC in a procedural manner, but saw the value of an inter-representational approach. The graphical side of the GC was important to him since "it can also provide a visual help to understanding the overall idea.", and he talked about how "students have come to me and said, 'I now understand what you're saying', by having a little presentation of the graph." He also confirmed his desire for a non-procedural approach, saying that his "prime aim would be for them to understand the method and be able to apply it rather than to arrive at the right answer." Actually, his first lesson was rather procedural, using the computing power of the GC to calculate p(x=6)= ${}^{9}C_{6}\,0.4^{6}(1–0.4)^{3}$, and finding other probabilities, p($x \geq k$) or p($x \leq k$). It appeared from his interview that the purpose of this lesson was revision, since "Basically the type that they're going to get in the exam." However, for the second lesson on power and exponential functions he tried to integrate the GC into thinking. He gave students the function $y=2e^{-0.45x}$, asking them to sketch the graph for x values from 0 to 3, by completing a table he gave them (see Figure 9a) and then plotting the function. Students completed the table by putting x=0, 0.5, 1, 2, 3 into the function $y = 2e^{-0.45x}$ on their GC and then plotting by hand (Figure 9b). He used this method rather than getting the GC to draw the final graph so that the students could see how the graph was constructed.

Figure 9 **Teacher A1 integrates the GC into graph plotting**





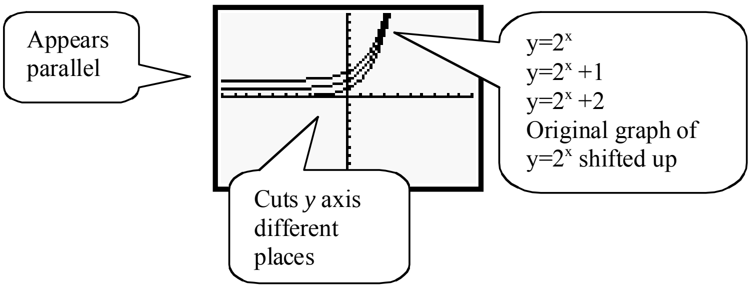
A similar process was then followed for graphs of the form $y = x^{k}$, for k=–2, 1.5 and –0.5. Finally a problem involving the volume of water in a lake at time t, with the function $V = 1275t^{-0.72}$, was considered. Here the function was drawn using the GC. Teacher A1 asked the students "At what point does the amount of water in the lake drop below 200m^3? When y=200, what is x-value? Use [Trace] key, approach to y=200, you can find the x-value." (variables had been changed on the GC). Here the students had a choice of method. They could either use [G-solve], which gave them the x-value directly, or the [Trace] key on the GC; they preferred the former. This work led into the third lesson on using power and exponential functions to model two variable regression.

Teacher four

In a previous paper (Thomas & Hong, 2005a) we have described some characteristics and practices of a teacher (A) who has made greater strides forward in her PTK. She had over six years' experience of using graphic calculators in her teaching but admitted "Sometimes it's hard to see how to use it effectively so I don't use it as continuously as I should." Her motive was a rather pragmatic "We should move with the times" and she had a small reservation about the GC that "It is OK. By now expected better resolution though." She appeared confident in her use of the GC and described how "In the past I have also done some exploratory graphs lessons where students get more freedom to input functions and observe the plots." Further, she explained that she was happy to loosen control of the students and let them explore the GC and help one another: "Students learn a lot by their own exploration…In past lessons I have never had a student get lost while using a graphics calculator. Sometimes friends around will assist someone" She described how she wanted her students to learn the challenge of the depth of mathematics, and was convinced that the novel and challenging nature of the GC could motivate students. She also recognised an important factor of the integration of technology use into mathematics, namely learning what is better done by hand and what could be done better with the technology (Thomas, Monaghan, & Pierce, 2004).

One of her lessons with the GC was with Year 12 students and she considered families of functions with the aim of exploring exponential and hyperbolic graphs and noting some of their features, "we're going to utilise the calculator to show that main graph and then we're going to go through families of $y=2^x$". She was comfortable enough to direct them to link a second representation "Another feature of the calculator I want you to be aware of..[pause] you've got also a list of x and y values already done for you in a table." Teacher A had moved away from giving explicit key press instructions, instead declaring "I want you to put these functions in and graph them and see what's going on.", and "You can change the window if you want to see more detail, and if you want to see where it cuts the x-axis, you can use the "trace" function." Figure 10 shows a copy of her whiteboard working.

Figure 10 **Teacher A's whiteboard working: viewscreen projection and overwriting**



She was also able to move towards an investigative mode of teaching "if you're not sure where the intercepts are, you can use the "trace" key, remember, and I want you to observe what is happening.", encouraging students to use the GC in a predictive manner, to investigate a different family.

We want to do some predictions … Looking at the screen try to predict where 3×2^x will go then press "$y = …$" and see if it went where you expected it to go. You may get a shock … Can you predict where "$y = 4 \times 2^x$" will be? Now you learned from that, so can you predict where it'll lie. The gap between them gets smaller. If you're interested put in "$y = 100 \times 2^x$". Does it go where you expect?

There was also some discussion of mathematical concepts and how this could help with interpretation of the GC graph. She linked $2{\times}2^x$ with 2^{x+1} and then during examination of the family of equations $y=2^x$, $y=2^{x+1}$, $y=2^{x+2}$ said of $y=2^{x+1}$ "We expect this to shift 1 unit to the left [compared with 2^x]. Did it?" In this way she made a link with previous knowledge of translations of graphs parallel to the x-axis, and then reinforced this with the comment that "With this family, when you look at the graph can you see that the distance between them stays the same because it's sliding along 1 unit at a time. The whole graph shifts along 1 unit at a time." In addition, there was a discussion of the relationship between the graphs in the family of $y=2^x + k$, and the relative sizes of 2^x and k.

… as the exponential value gets larger, because we're adding a constant term that is quite small, it lands up becoming almost negligible. So, when…all they're differing by is the constant part, you'll find that they appear to come together. Do they actually equal the same values ever? Do they ever meet at a point? No, because of the difference by a constant, but because of the scaling we have, they appear to merge.

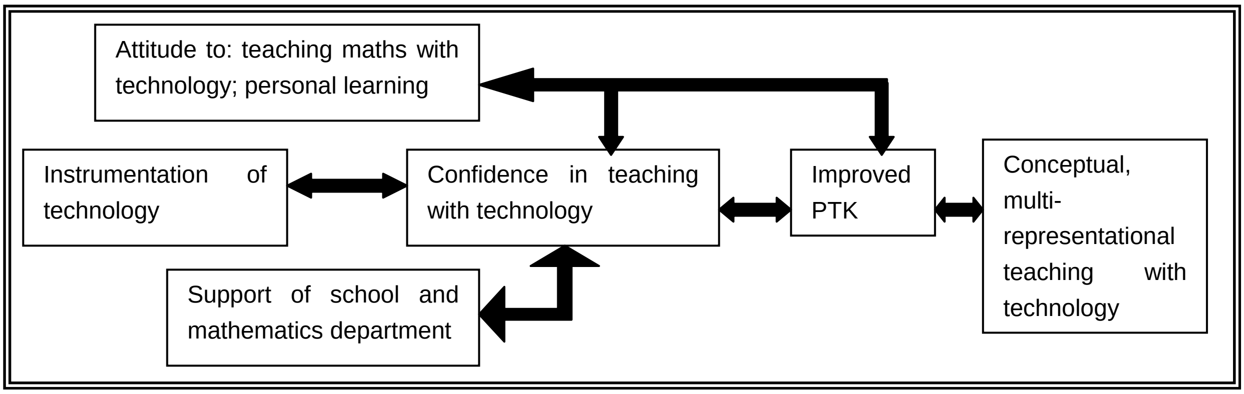
The discussion on the relative size of terms in the function continued with "How significant is "+1" or "+2"? We know that 2^5 is 32." and again the use of prediction was evident "I want you to predict where $y=2^x + 3$" would be."

Summary of GC teaching styles

From the above discussion we see that this current project, and our previous research, suggest that we can delineate two clearly identifiable groups, with a third progressing between the two. The first group may be identified in terms of their instrumental genesis (Lagrange, 1999) as teachers who are still coming to grips with basic operational aspects of the technology, such as key presses and menu operations. This leads to a low level of confidence in terms of teaching with the GC in the classroom. In terms of their PTK, this group is characterised by an over-emphasis on passing on to students operational matters, such as key presses and menu operations to the detriment of the mathematical ideas. Furthermore, the mathematics approached through the technology has an emphasis on technology, and work tends to be very process-oriented; based on procedures and calculating specific answers to standard problems. There is little or no freedom given to students to explore with the GC, and it tends to be seen as an add-on to the lesson rather than an integral part of it. These features then become part of the teacher-initiated expectations in the didactic contract (Brousseau, 1997).

In contrast to this, the second group have advanced to the point where they are competent in basic instrumentation of the GC, and hence more able focus on other important aspects, such as the linking of representations such as graphs, tables, and algebra (Lesh, 2000), and to use other features of graphic calculators. In turn, this better instrumentation of the GC produces a higher level of confidence in classroom use. Considering their PTK they begin to see the GC in a wider way than simply as a calculator. They feel free to loosen control and encourage students to engage with conceptual ideas of mathematics through individual and group exploration of the GC, investigation of mathematical ideas, and the use of prediction and test methodology. For these teachers the mathematics rather than the technology has again been thrust into the foreground, and the GC has been better integrated into the lessons and the didactic contract. This current project further suggests that we can add the affordances produced by a supportive school and mathematics department as other strong influences on confidence, that this confidence is also linked to a teacher's attitude to using technology in teaching mathematics and to personal learning, as well as to quality of teaching with graphic calculators. We are thus able to suggest a tentative model (see Figure 11), with teacher confidence as a pivotal variable in producing conceptual teaching with technology.

Figure 11 **A model of factors influencing conceptual teaching with technology**



Interactive whiteboards (IAW)

As the use of the interactive whiteboard (IAW) in the teaching and learning of Mathematics in Senior Secondary Schools in New Zealand is not commonplace, research literature on the value of this technology is not readily available. However the number of IAW within schools is increasing rapidly, including countries overseas (see e.g., Becta, 2003; Tanner, Jones, Kennewell, & Beauchamp, 2005). At the time of our classroom observations as part of the TLRI research project (Terms Two and Three, 2005) only a few of the schools that responded to our initial questionnaire, indicated that they used IAW in their teaching of mathematics. We report on the observations made at three of these schools: A (Decile 5), B (Decile 9) and C (Decile 3), all Auckland Schools.

It was apparent from our discussions with the teachers observed at these schools that a lack of professional development in the use of IAW together with a lack of commercially produced materials impacted significantly on their ability to use the technology efficiently and effectively. Any comments made on IAW use in this report must be viewed in light of these comments. Indeed, one of the teachers found himself in a classroom with an IAW that he had never used. He contacted the suppliers of the hardware, who put him in touch with two other teachers elsewhere in the North Island, only to discover that neither were in a position to assist him. However, subsequent to this, with the increasing uptake of IAW in schools, suppliers are making an attempt in the Auckland region, and almost certainly in other areas of the country, to establish a database of interested Mathematics teachers, in particular. This could help to facilitate interaction between these teachers with the aim of encouraging the sharing of ideas and resources in an attempt to ease workloads and create Mathematics-specific materials. The benefits of IAW use lies in the ability of teacher to extend and transform learning so that the cost of this technology (relative to the use of a data projectors and conventional whiteboards) is justified in schools.

The use of IAW in other curriculum areas and at earlier stages of schooling has been a part of Project ACTIvate, a Ministry of Education, Digital Opportunities Project (2005) which aims to bring students from Auckland to Invercargill together through Interactive Whiteboard technology.

This pilot project using an action based research model includes 5 Auckland and 10 Southland schools and aims to enhance cooperative distance and inquiry-based learning. However, none of these schools has focused on the teaching and learning of Mathematics using IAW.

Teacher one

Two classes were observed for school B's teacher E1. She was teaching Level 2 Mathematics AS 90284 (2.1) Graphs and although there was an IAW in the classroom it was used as a conventional whiteboard on which to project slides of a PowerPoint presentation that suggested hints for students to follow as they attempted to reproduce screen dumps, prepared by the teacher, on their graphic calculators.

When teacher E1 was interviewed she said that she used the IAW when teaching Algebra, Graphs, Co-ordinate Geometry, Trigonometric equations and Calculus to Level 2 students. She felt that the use of the IAW motivated students but more importantly allowed them to make valuable connections when new concepts were introduced. In particular, she used the IAW with web-based resources and PowerPoint presentations in whole-class teaching when introducing Calculus.

Teacher two

Teacher E5 in school C found himself in the situation of having an IAW in the classroom where he taught his Mathematics classes and used it in the teaching of all his NCEA classes across all Achievement Standards. He, too, recognises the motivational effect on students in the use of the technology and the ability to quickly produce accurate, clear diagrams. Although time consuming, he has developed PowerPoint presentations and developed resources using software provided with the IAW. The observations of E5's classes, included two Level 3 Statistics and Modelling classes (Confidence Intervals and Linear Programming), and two Level 2 Mathematics classes (Differentiation and Solving Trigonometric Equations). Whilst technology was extensively used in all four lessons, the IAW was used interactively only in the Level 2 class in a lesson reviewing the differentiation of polynomials. In this lesson, students were asked to drag tangent lines, already created by the teacher, and place them at a point on the curve $y = x^2 + 1$. Students were then required to match a triangle (also prepared in advance by the teacher) with each of the tangent lines drawn. Using this triangle, the gradient of the tangent and hence the gradient of the curve at each point was calculated (see Figure 12).

Figure 12 **Teacher E5's use of the IAW**

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Teacher three

Like E5, teacher C1 of school A, an experienced teacher, also came to be teaching in a classroom in which an interactive whiteboard (IAW) had been permanently installed, with no prior knowledge or experience of their use or operation. Two of his lessons were observed, on Trigonometric Modelling (AS90637) Level 3 Mathematics with Calculus, and they focussed on the data collected by some of the students in their Year 12 Mathematics class at Piha beach. This data could be modelled by a sine curve. An investigation of the form y = A sin B(x + C) + D to determine the required transformations of a sine curve in order to express it in symbolic form, was the lesson aim.

The technologies in the classroom (the IAW linked to the teacher's laptop through a data projector, and a handful of graphic calculators—about 7/25 students had graphic calculators—were used seamlessly. The students had 'ownership' of the data that they had collected, so the use of technology was appropriate and never contrived. The classroom environment was traditional in its layout, and an environment in which students clearly felt encouraged and confident about discussing Mathematics, was evident. Whilst some students worked with the teacher when entering data on the Excel spreadsheet, on the IAW, other student 'experts' were encouraged to share their knowledge on the use of their graphic calculators to enter the data to obtain a trig model. A lot of meaningful mathematics was seen and heard discussed between students. As the teacher circulated around the classroom, he skilfully facilitated discussion and questioned students about their assumptions and conclusions. The mathematics and the technologies were inextricably linked - at times by the teacher only or the students only or by both the teacher and the students, using the data collected by students themselves and, later in the lesson, data accessed from a website. The teaching style was mainly one of investigation with skilful intervention by the teacher when appropriate. The lesson seemed to encompass so many positive elements of the technologies being used, including inter-representational aspects.

The overriding affordance offered in this lesson was the IAW. It provided a point of focus in the classroom for students to gather and discuss the curve fitting of a translated sine curve. Students had been encouraged by the teacher to come to the front of the room. A core of about four students actively engaged with the technology, including Excel, and began to relate this work with

(AS90645 Select and analyse continuous bi-variate data, Level 3 Statistics and Modelling) that studied on correlation and regression earlier in the term. Earlier in the lesson, the teacher had simply ‘dragged’ the sine curve graph to demonstrate the change in both amplitude and period. The motivational aspect of the IAW was obvious. Other students were just as confident, and as demonstrated, competent with modelling the data on their graphic calculators. Only some of the group had graphic calculators but nevertheless there was active interaction and engagement by all students as they discussed the data. There appeared to be few constraints to the use of technology. Had this lesson taken place in a computer room where individuals could have had direct access to Excel software, the learning outcome may have been enhanced. On the other hand if students were working individually the affordances provided by the IAW may not have resulted. The discussion amongst teacher and students and amongst the students themselves was a highlight of this lesson.

There is considerable interest in the use of IAW in education and at present articles tend to focus on anecdotal evidence alone. Only when more rigorous quantitative and qualitative research is conducted will the success of the use of the IAW in Mathematics teaching and learning be more critically evaluated.

Implementing technology in NCEA mathematics teaching

One of the key research questions for this study was to examine how technology use might be related to implementation of NCEA assessment. The discussion in this section is based on two sets of data: one consisting of survey responses of heads of departments and teachers, obtained from questionnaires; and a second set from interview responses of the teachers who volunteered to participate further in the study whose use of technology in the classroom was observed and who were individually interviewed.

In this section we consider answers to the following questions:

- What do mathematics departments currently do in implementing technology in NCEA mathematics teaching?
- What are the perceived obstacles in implementing technology in NCEA mathematics teaching?
- In which NCEA standards do teachers actively use technology in teaching?
- What is the teachers’ current pattern of technology use for internally and externally assessed NCEA standards? and
- What changes do teachers foresee in the future of technology use in mathematics classroom?

When the heads of the departments were asked (through section A of the questionnaire, completed by HODs) whether their department has a technology policy or not, a simple majority (160, 51 percent) offered an answer while the rest did not give a response. From those who responded, 73 percent said “yes”, 18 percent gave a negative answer, and the other 9 percent were not sure. On the question of what their departments do to implement technology in NCEA mathematics teaching, the majority of responses focused on the kinds of technologies they use. On the top of the list of technologies that the HODs identified as being used in their classrooms were computers (80 out of 160) and graphic calculators (75). Twelve respondents mentioned other types of technology such as interactive whiteboards or smartboards, PowerPoint presentations, ClassPad, Internet and emailing.

With regard to student ownership of graphic calculators, a number of teachers (thirteen) mentioned how their students acquire them. Their answers ranged from stating that some students already have their own, to teachers encouraging or requiring them to buy. Another category of answers the HODs provided concerns their use of technology in the following areas: teaching, assessment, student learning, and student projects. Many of them wrote the different NCEA achievement standards where particular technologies are used (see Table 36).

Table 36 **Achievement standards where technology is used**

	Computers	Graphic calculators
Level 1	1.2, 1.3,1.5, 1.8	All AS, 1.2
Level 2	2.2, 2.5, 2.6, 2.7, 2.8	All AS, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8
Level 3	3.1, 3.2, 3.3, 3.4, 3.6, 3.7	All AS, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, L3 Calculus, L3 Statistics

Perceived obstacles in implementation

The use of technology in teaching is not always smooth sailing for the mathematics departments in schools. This was raised by the HODs when they were specifically asked to identify what they perceived as a major obstacle in using technology in NCEA mathematics teaching. The obstacles or constraints they identified can be categorised into the following:

- Financial constraints
- Teacher-related constraints
- Student-learning related constraints
- Equity issues
- Negative attitude

and these are discussed individually below.

Financial constraints. The first thing mentioned by the HODs was the lack of money to fund the acquisition of both software and hardware (such as computers, graphic calculators, interactive whiteboards and overhead projectors). Their comments also included the need for money for hardware maintenance, for technical support, and for teachers' professional development. They pointed to the lack of government funding to finance these needs, and even added that the cost of technology use in the classroom often falls on parents/families/students. In relation to financial constraints, the HODs mentioned the lack of sufficient numbers of the equipment. They specifically talked about the lack of computers, about overused computers and limited number of machines, as well as a lack of graphic calculators and data projectors. Because of these limitations, many of the HODs tied another problem to financial constraints, namely the problem of access to computer laboratories. This included difficulties of booking and timetabling, and the logistics of moving students from classroom to laboratories. Some also mentioned the security of computers as a concern

Teacher-related constraints. The HODs were also concerned about their teachers' knowledge of the technology, understanding of its capabilities, their confidence in using it for teaching, and the possibility of teacher resistance to its use in teaching. Representative categories of the responses that relate to teacher constraints were: professional development, teacher skills/knowledge/competence, understanding of the capabilities of technology and best ways to use them, confidence, resistance to change, not convinced that graphic calculators are essential (in teaching and learning), and too busy.

Student-related constraints. There was just a handful of concerns related to student learning expressed by the HODs in describing obstacles to technology use in NCEA, and some of those mentioned were: they (students) prefer to solve by hand, lack of application knowledge, and lack of good understanding of how to use technology.

Equity issues. There were only two responses concerned with equity issues in the obstacles answers. One HOD said that the use of technology would give an "unfair advantage to the well-off", while another wrote, "girls do not play to investigate."

Negative reactions. There were four responses reflecting a negative attitude on the use of technology in the classroom. They included: "computers are fools", "computers have no use in NCEA standards", "dependence on graphic calculator will not aid students' understanding", and "are we teaching students maths or turning them to be technicians". Given the explicit statement in all NCEA standards that it is expected that available technology will be used, the objection that it has no place in NCEA is surprising. This may be the result of a lack of professional development that could attune the teacher to the value of the technology.

Achievement standards where technology is used

The overall analysis of the questionnaire data showed that there are two broad areas where teachers used technology for Levels 1 to 3 of NCEA: statistics (with 148 responses); and graphing (88). Table 37 shows the specific achievement standards where the teachers have used technology; the table shows the frequency for which each of the achievement standards is identified. One of the striking facts we see here is that technology is used much more in teaching Level 3 statistics standards 3.1, 3.5 and 3.7 than it is for any other standard at any level, while in contrast the use in Level 3 calculus is low.

Table 37 **Achievement standards where technology is used**

Level 1	1.1	3
	1.2	11
	1.3	2
	1.4	1
	1.5	12
	1.6	0
	1.7	2
	1.8	1
	1.9	1
Level 2	2.1	11
	2.2	28
	2.3	8
	2.4	14
	2.5	17
	2.6	17
	2.7	8
	2.8	6
	2.9	18
Level 3: Calculus	3.1	7
	3.2	6
	3.3	11
	3.4	11
	3.5	5
Level 3: Statistics	3.1	76
	3.2	10
	3.3	7
	3.4	8
	3.5	66
	3.6	1
	3.7	58

An analysis of how often the computer is used in each of the standards in response to question two in section B, 'How often do you use computers in your year 12 or 13 mathematics lessons?' is presented in Table 38. The figures indicate that in calculus around one quarter use the computer at least weekly (calculating the first three columns as a percentage of the 5-column total—note that not all teachers teach each standard), but in statistics and modelling the corresponding figures are

66.7 percent for standard 3.1, 63.6 percent for 3.5 and 55.1 percent for 3.7, the most popular standards for computer use. The other statistics standards average about 20 percent.

Table 38 **Frequency of computer use in mathematics lessons**

Standard	Every lesson (1)	Most lessons (2)	At least once a week (3)	At least once (4)	Never (5)	Mean
C3.1	4	12	20	67	34	3.84
C3.2	3	9	23	64	35	3.89
C3.3	4	14	22	66	31	3.77
C3.4	3	10	20	64	33	3.88
C3.5	3	14	19	68	29	3.80
SM3.1	32	84	38	67	6	2.70
SM3.2	2	8	22	81	63	4.11
SM3.3	2	12	23	74	68	4.08
SM3.4	2	11	28	81	57	4.01
SM3.5	25	75	38	68	11	2.84
SM3.6	2	10	22	83	57	4.05
SM3.7	18	65	35	78	18	3.06

Table 39 shows the subject areas mentioned where the teachers have used technology. However, some of these numbers, such as those for statistics, transformation of graphs and points of intersection are too low to be reliable.

While teachers support the use of technology in many of the achievement standards, as seen above, the survey also indicated that they do not believe that *all* of the NCEA's achievement standards should be supported with technology. One teacher commented:

> We are getting a mixed message from the NCEA examiners. The standard says 'appropriate technology' should be used but the Merit and Excellence questions are often designed to require algebraic manipulation, so we generally teach algebraic techniques for solving equations, knowing that weak girls will depend more on their calculators than strong ones.

One reason for the ambivalence is that some teachers are not aware that it is promoted for all standards. For example, many of the teachers (44.7 percent, mean agreement score 2.71 out of 5) disagreed when asked if technology use is expected in all NCEA standards, with only 26.3 percent agreeing or strongly agreeing.

Table 39 **Subject areas where technology is used**

Probability	16
Calculus	14
Differentiation	6
Integration	6
Geometry	10
Trigonometry	16
Algebra	23
Numbers	2
Numerical methods	7
Factorising	4
Basic calculation	1
Conic sections	1
Graphing quadratics/cubics	5
Transformation of graphs	1
Simultaneous equations	4
Points of intersections	1

When asked whether "NCEA has too much emphasis on technology", only 11.7 percent either agreed or strongly agreed, although those who disagreed or strongly disagreed did not reach a majority (44.2 percent), with 36.9 percent giving a "neutral" response (mean agreement score 2.59 out of 5). One teacher mentioned that "NCEA encourages [us] to teach students to get answers only (working is not marked) to questions they do not understand." When asked the reverse question of whether they believe that "NCEA has too little emphasis on technology", 43.3 percent either disagreed or strongly disagreed while a small number (6.2 percent) agreed (mean agreement score 2.52 out of 5). Hence the survey seems to indicate that the teachers believe that NCEA has enough ("not too little" and "not too much") emphasis on technology. This appears to be in consonance with the list of achievement standards they have listed where they use technology

Technology in NCEA assessment

Based on teacher interviews, most have said that they use computers and graphic calculators for internal assessment, and that their students use graphic calculators for external assessment. There were, however, some issues that a number of them have mentioned with regard to the use of graphic calculators for external examinations. Some of the comments include the problem of not every student having access to graphic calculators during examinations as not all of them can afford to have one. To remedy such a problem, two teachers said that they loan the school's calculators to the students during examination periods. One teacher said that, in order for the students to be able to use calculators in externals, the school buy in bulk and sell them to the students at a price cheaper than the commercial price. Another teacher said that they stopped loaning their calculators for the reason that some of the calculators get lost or not returned to the school.

Some of the teachers were asked how NCEA had affected their teaching, especially with technology. Some of the responses were positive about the change:

> D3: … it has been a positive thing, in terms of getting computers and using them because we've been able to write our own standards and activities using the basis of what we want to do. Like we are doing three statistics achievement standards that are internal, that are suitable for using computers; and doing (NCEA) has increased our use of technology in terms of teaching … not that boring monotonous low skill stuff.

> D4: NCEA has been really positive for technology in mathematics because it has enabled us to take the documentation from looking at the standards and it says, students will use appropriate technology and you have a go to the school management, have a go to the board and look … if they're gonna do NCEA, they must use appropriate technology, and school's been really supportive and provided the money.

> D2: The beauty of NCEA is that you can now teach things properly. I don't necessarily agree with the way it was set up but it's very much better than ... bursary. We use it [technology] a lot. It has increased our work load a lot, but it is far more valuable in terms of long term gain for students.

Others were less favourable in their comments on the influence of NCEA, such as the change in teaching practice previously mentioned, "Before NCEA, all taught to same level. With NCEA, teach certain students up to a certain level that they want to aim for. Students just go to the basics."

Based on responses to the question, What change do you foresee in the future in the use of technology in maths teaching?, we can categorise into five areas teachers' responses in which they foresee change in the future on the use of technology in maths teaching. These categories are as follows:

- Increase in the number of, and thus in the use of and access to, technology in the classroom.
- Presence of different kinds of technology other than desktop computers and graphic calculators. Some of the technology mentioned as part of classroom technology includes: laptops, CAS calculators, Smartboards, Palmtops, Interactive Whiteboard, more PowerPoint presentations and data projectors.
- *Change in curriculum*. Representative responses under this category include the "need to re-look at the curriculum," "Maths must be adapted to utilise the technology." Many see that there will be less emphasis on skills and a shift to more conceptual teaching. One wrote that students will have more time to tackle and think about more challenging work instead of learning and practicing methods of calculations. There were several mentions of a multi-representational approach to teaching and an emphasis on problem solving.

- *Change in ways of teaching and learning*. A number of the responses said they see more of technology-based lessons. Some teachers said that they expect more programs and software to be available to cover more topics, that there will be more emphasis on visualization, and that teaching will become much more easier and effective. Some also said that teaching will be more fun.
- They also said that there will be less time spent on teaching repetitive tasks, and instead more on exploration, with an increased emphasis on teaching concepts. Others said that analysis of data will be a priority rather than simply generation of data or simply producing results. Many mentioned that students will be exposed to, and will be solving, a variety of real-life mathematical problems. The presence of technology was seen by some to produce "learning" as this technology will help students to "see things" from a different perspective.
- *Change in assessment*. Many mentioned that they expect the presence of technology will change the way they assess. Some even noted that technology will *revolutionise* assessment. They included the idea that the types of questions asked will change, and that new technology will be used in assessment. One wrote that technology will be forced into the curriculum through assessment.

NCEA assessment and technology summary

From the analysis of data, it may be deduced that there are several factors that are seen as crucial from the perspective of the HODs and teachers in the field regarding the introduction and use of technology for NCEA. With the NCEA standards encouraging teachers to use technology in the classroom, it is obvious that there will need to be funding for the schools' acquisition of the machines in order for them to be accessible both for the teachers and the students. However, this is one of the concerns identified by the HODs when asked what they see as a major obstacle to the implementation of technology in NCEA mathematics teaching. This obstacle/constraint necessarily led to another obstacle/constraint, which is the problem of access to computer laboratories due to insufficient number of computers.

Another factor that is believed to affect the implementation of a technology rich NCEA curriculum is the training of teachers, not just on the use of technology but in its use in relation to teaching and student learning. In relation to Shulman's pedagogical content knowledge (1986), and that Thomas' (Thomas & Hong, 2005a; Hong & Thomas, 2006) who use of the term pedagogical technology knowledge (PTK), teacher training and professional development in the use of technology to teach mathematics is a core activity.

It is believed that there are other issues that must be addressed in relation to teachers' attitude, belief and abilities. For instance, there are teachers who still believe that the use of technology will hinder students learning of mathematics. With the support of research outlining the benefits that can be had with the proper use and integration of technology in teaching, it is believed that many of these teachers can be won over.

Reasons for technology use

Two of the questions on the teacher questionnaire (Q's 22, 23) asked what they perceived as the primary advantages and disadvantages of technology use, in order to try and get an idea of the motivation behind its use. There was a wide variety of responses to Q22 about the advantages of technology use. Among these improved efficiency of calculation (quicker calculations) was regularly mentioned, as was the benefit of visual explanation. Some teachers felt that students gained confidence through the use of technology, as they were able to check their solutions, spend less time on trivial manipulation, and eliminate careless errors. Calculators are widely believed to provide "efficient and accurate calculations and predictions". Motivation was seen as another advantage with a response that technology, in the form of graphic calculators or computers "can hook students' interest". However, according to Thomas and Hong (2005a), these are the kinds of advantages that teachers see who are new to technology use and have not made great progress in its implementation. Those who have better PTK tend to perceive the mathematical benefits more. However, in this survey, opinion was split as to whether the use of technology aids understanding of mathematical concepts. One teacher had apparently moved to this point, saying that technology "allows [the] class to concentrate on [the] application of Maths techniques etc, rather than calculations, graph drawing, etc", while on the other hand another responded that "traditional skills and techniques are being lost". It was also mentioned that technology use can prepare students for how the real world uses mathematics. A summary of the number of occurrences of particular advantages is given in Table 40.

Table 40 **Distribution of types of advantages mentioned for technology use**

Advantage	Frequency (*n*=465)	Mentioned (%)
More efficient, quicker	149	32.0
Visualisation/visual display	42	9.0
Student motivation/interest	39	8.4
Aids understanding	37	8.0
Improves confidence	14	3.0
Fewer errors in calculation	7	1.5
Other/no response*	177	38.1

* Mostly no response.

In Q23 teachers were asked about the main disadvantages of technology use. Interestingly, although some said that the use of technology aided understanding, others said that it did the opposite. A common concern was that teachers thought that students are not gaining a full understanding of the topics, and are instead relying on their calculators to tell them the answer. Also mentioned was that students are more likely to accept answers without considering how reasonable they are. One teacher said that graphical calculators "encourage kids to take short cuts, especially in algebra. Real algebra skills are lacking as a result" and 31 teachers mentioned that students often become very dependent on the calculator. Some respondents said that they felt that the benefits of technology are small and often exaggerated, and that they feel that the technology should only used to support the main content being taught. Some teachers also felt that technology is sometimes not appropriate, depending on what is being taught, and that they should not try and force the subject to fit the technology. Some felt that students take advantage of lessons including technology, one saying that it is "seen as an easy period by students". The impedance of understanding was closely linked to a dependence on technology by many respondents. The depth of such feeling some have can be seen in the comment of one teacher who said that "NCEA encourages [us] to teach students to get answers only (working is not marked) to questions they do not understand by learning which buttons to press, on a piece of technology that nobody outside a classroom uses, and which will be out of date within 3 years".

Several teachers complained that an excessive amount of time is wasted when technology fails, and that sometimes not much learning takes place when students are distracted with some of the other things that technology can do. Varying standards of competence also cause difficulties in the classroom, with some students being highly skilled with computers, while others are computer illiterate. Some teachers feel that they themselves lack the required expertise to include technology in their lessons. For example one said that there is a "lack of time to develop [my] own skills". Problems with availability and affordability of equipment were pre-eminent, with many teachers bemoaning a lack of funding. One said that "our students are not rich and so cannot afford calculators that our more sophisticated than a basic scientific. I am concerned that there is a growing gap between the experience of rich and poor students. State schools are not sufficiently funded to rectify this problem". Table 41 summarises the teachers' perceived disadvantages of technology use.

Table 41 **Distribution of types of disadvantages mentioned for technology use**

Disadvantage	Frequency (*n*=465)	Mentioned (%)
Equipment: availability/quality/functionality/ cost	93	20.0
Impedes learning/understanding	78	16.8
Dependence on calculator	58	12.5
Lack of confidence/knowledge about the technology from teachers or students	33	7.1
Time constraints	24	5.2
Distraction	11	2.4
Other/no response*	168	36.1

* Mostly no response.

In spite of the above, based on the survey, we can infer that teachers generally believe that there are benefits in using technology in mathematics teaching. When asked to respond on the statement "Technology is of little benefit in maths teaching", only 8 percent agree or strongly agree", while

75.6 percent “disagree or strongly disagree.” In the teacher interviews, the following is a summary of the reasons for using technology in teaching that were put forward:

- Saves time (2); how much time I was saving; reduce time; speeds up the process (4); it’s fast; we all became very aware of how much more quickly it can process; quickly get to graph using EXCEL.
- Makes things easier. Takes away some of the ‘donkey work’; removes possibility that students will make procedural mistakes when they are trying to solve problems.
- Visual representation. Gives students visual interpretation; visual representation provides/clarifies the concept; to visually see the concept is really helpful; good for visual learners; better visuals; getting a picture of a function; I make some students do some of the graphs.
- Multiple representations. Technology is really important for multiple representations especially that graph/table/equation link; enables the students to see graphs; more ways of seeing things; can see things from different angles; visual impact and relates this to letters and symbols; the connections—there are the things that we do with graphs and patterns and rules; it really makes a really strong link (normal distribution) to the area under the curve.
- Better understanding. Gives students better understanding; getting (concepts) across clearer and quicker; good way for making students understand the concepts better; better comprehension; help them concentrate on the concepts more; it is important that students understand the big picture; more analysing…we are not doing skill based things.
- Allows students to investigate. Hands-on approach, particularly with problem simulation.
- Allows students to decide on their own. A good picture …before they decide what method they want to use.
- Allows more time for discussion.
- Keeps them [students] interested.
- Makes assessment easier. The success we had last year…huge number of excellences and merits.
- Required by the NCEA curriculum.
- It (computer) is in the room.

Equity issues

We were concerned to try and identify any particular problems surrounded culture and equity, in order to address the research question ‘What…cultural and equity issues (if any) are identifiable in this pattern of [technology] use?’ As well as our own observations we used a question in the interviews with the 32 teachers using technology to see what they thought. The questions asked were: “What is your view on the use of graphic calculators in assessment such as examinations? Are there any equity or cultural issues you can see with the use of technology?”

It was clear from the responses that there was only one issue that the teachers could see, namely the inequity arising from the fact that some students could not afford their own calculators, and schools were often not able to purchase them either:

A1: Well, first of all we have a lot of refugees at school who can't afford graphic calculators so that's why we tend to have some with and some without (calculators), and we can't make them compulsory…it is just really a financial thing.

B1: There are certainly equity issues among students that come from poorer homes where they can't afford them. I think that is probably going to be very, very difficult for schools in the lower decile areas.

D4: This is a … decile 3. It's not a high decile school. A lot of our students will come from even low[er] decile areas … and they'll pay fees to come here as well. The parents are committed to their education and there's a lot of support. But when you are asking for another $75, that's the cheapest we could buy, $75 for a graphic calculator, it's just nah, it's not gonna happen.

E5: Yes there are equity issues in the fact that a kid who can afford it is going to have an advantage over a kid that doesn't … most of our kids can't afford the graphic calculators … I think in my class this year, there's three with graphic calculators out of 27, which is quite a small percentage.

The teachers thought that this might show itself particularly in the examination arena:

A7: The problem with exams is that all the students do their exams at the same time (at the end of the year), and so it's not possible to loan students … when the crunch comes for the exam, if they don't have their own calculators then they won't be able to use them. So there's a basic equity issue there.

A10: Surely there is an equity problem because … students in a high decile area …will be well trained with the graphics calculator and so most effectively (of all the students) use the machine in the examinations, and so just to be fair, I think the exam has to be designed in a way in which they can still test the manual understanding so that the students can only really rely on the graphics calculator to a certain extent.

B5: I don't necessarily think that a student with a GC knows the work any better but I think that we buy … (the girls using the GC, especially I am thinking of Y12 here) buy themselves time to think.

E5: I worry about the results indicating that that kid knows more in that assessment than a kid without a graphic calculator, when in fact the other kid may know more about maths and have a better understanding but they've run out of time and they've never had a chance to show what they know.

However, some schools provided them and so the issue did not really arise. However, while they may provide them it was felt that the students did not then get sufficient access, and again lost out in examinations:

C6: Equity issues. There's some that don't have, but at this particular school it's not a question of money or anything like that because they are provided.

A8: We're a decile 3 school. Very few of the students can afford their own graphics calculator therefore, the only chance they get to practice with them is in the lesson when we hand them out and draw them back again, so they don't get the familiarity that the more economically better situated student would get, so as a result they are at a distinct disadvantage compared to those students when they do the exams because they haven't had the practice in using the technology.

In other schools the problem of access to calculators was not seen as acute, even in the decile 3 school of teacher C1, and the situation was considered to be possibly improving, with lower prices now available:

C1: Equity well it's just the cost, they are getting cheaper and cheaper at $70-80 for a good one now is not that bad ... I went to the mid-year exams when the seniors are all doing their exam hall full of people there were so many graphic calculators I don't think there is even an equity issue. Maybe one or two kids but.

B1: They are now down, the GC is now under $80 so they are quite attainable. They are less than a cellphone. I try to encourage the girls to see them as their next best accessory and they will probably get the thing in vibrant colours soon just like the cell phones.

B3: Yes, there are equity issues there for schools that are not necessarily going to have whole sets available. I think it's getting better … I don't know whether it's coming from the calculator companies or from the ministry that sets are being sold at reasonable rates to schools.

Those who though that access was a real problem sometimes had clear feelings on what could, or should, be done to ameliorate the situation.

A6: Obviously there are equity and cultural issues because some people can't afford them but if you start a lot earlier, like in year 10, you've got, for some of them, you've at least got 2 or 3 years and for some of them as well, they've got a younger brother or sister. When I've mentioned it to parents, the parents would say, 'well that's alright because the next one can use it as well.' So it is an investment.

B3: Equity is not an issue in our school but I would be fighting unbelievably hard and strongly to overcome an equity issue in any other school - by buying class sets, loaning calculators to kids, setting up some sort of lease thing, persuading the principal to give us more budget… I believe the ministry has got a responsibility to invest in making this technology available to students.

Others felt that the problem is currently being addressed, with the Ministry of Education already assisting students in lower decile schools through the funding regime, as seen in this comment from a decile 10 teacher:

A5: The only other thing would be if the person can't afford it. Then the Ministry of Education should be supplying funding for families so that they can have the same technology available for the education of their children, and they do. I mean you get your lower decile schools that have extra funding for exactly that sort of thing.

In summary we can report that the only equity issue of concern raised by the teachers in the study was that of affordability of, and hence equality of access to, calculators. However, there was little evidence that this was perceived as a major problem since sufficient access was generally difficult.

Some concluding remarks

We would like to summarise here some of the main findings of this research study. It is our belief that our research has shown:

- That only about 36 percent of mathematics departments have a technology policy.
- Around one third of all secondary mathematics teachers never use a computer in their teaching. 75 percent of teachers would like to use the computer more often, and availability of computers is the primary obstacle, with lack of training and confidence also important.
- The greatest use of computers is in teaching statistics (58.5 percent of teachers) and graphical work (51.6 percent). In contrast less than a quarter of teachers used them in either geometry, algebra, trigonometry, or calculus. The most popular standards for computer use are SM3.1 (67.8 percent use at least weekly), SM3.5 (63.6 percent use at least weekly) and SM3.7 (55.1 percent use at least weekly). This use in statistics has grown significantly in the last 10 years.
- There are more computers in secondary schools in 2006 than 10 years earlier, but they are primarily in ICT rooms and access for mathematics teachers is a major problem.
- In the last 10 years there has been a significant move away from content-specific graphical and mathematical programs towards generic software, especially the spreadsheet. This may be due to availability and cost.
- Computers are used for both investigations and skills, and this, with the significant increase in their use as a demonstration tool, suggest that many teachers do not feel constrained to teaching according to a constructivist paradigm.
- There is a range of teaching practice with technology, from using computers with a program such as PowerPoint as an alternative for lesson note presentation to technology use as an tool to investigative concepts in a multi-representational environment.
- Some of the key attributes of good practice in teaching with technology have been identified (see page 26) along with a model showing factors that may influence it (see page 42).
- There is a need for professional development that specifically addresses methods of integrating technology into mathematics teaching in the classroom in a manner that focuses on the mathematics.

- A significant minority of teachers (27 percent) think that using calculators can be detrimental to student understanding of mathematics, depending on how it is used.
- A majority of teachers (56.7 percent) would like to use a GC more often in their teaching. Major obstacles to such use are availability of calculators, relevant PD, suitable classroom resources and teacher confidence.
- 60.5 percent of teachers are opposed to the use of all types of calculators in examinations.
- The only equity issue raised by teachers in the study was that of affordability of, and hence equality of access to, calculators. However, this was not perceived as a major problem.
- Key variables in teachers' use of Graphic calculators, given their availability, are their attitude to teaching mathematics with technology, their attitude to personal learning, their level of proficiency in using the GC, the support of school and colleagues, and especially their confidence.
- Low-level pedagogical technology knowledge (PTK) is characterised by an emphasis on the technology, such as operational matters, and teaching is often procedure and skill oriented. High-level pedagogical technology knowledge (PTK) is characterised by an emphasis on the mathematics and its concepts, and is often multi-representational and conceptual in focus.
- IAW use is low but increasing and they have the potential to impact positively on mathematics teaching. However, there is a considerable learning curve in their implementation.
- Teachers think that the emphasis on technology in NCEA is about right.

We note in concluding that although mathematics teachers often claim to be supportive of the use of technology in their teaching (Forgasz, 2006; Thomas, 2006), the degree and type of use in the classroom often does not correlate with this (see Becker, 2000a). Research into the uptake and implementation of technology in mathematics teaching has identified a range of factors influencing it. Goos (2005) lists some of these as: skill and previous experience in using technology; time and opportunities to learn (pre-service education, guidance during practicum and beginning teaching, professional development); access to hardware (computers and calculators), software, and computer laboratories; availability of appropriate teaching materials; technical support; support from colleagues and school administration; curriculum and assessment requirements and how teachers interpret these for students perceived to have different mathematical abilities; knowledge of how to integrate technology into mathematics teaching; and beliefs about mathematics and how it is learned. Forgasz (2006) agrees, with her computer survey listing access to computers and/or computer laboratories as the most prevalent inhibiting factor (constraint), with lack of professional development and technical problems, including lack of technical support next. Thomas's (1996) survey of computer use in all New Zealand secondary schools found that teachers make similar statements, citing availability of computers as the major issue, followed by a lack of software, training and confidence. The first two may be described as obstacles, while the last two are constraints.

Some literature points out the influence of teacher beliefs and attitudes on their teaching practice. In her study, Forgasz (2005) found that teacher confidence, experience, skills or enjoyment of computers was the third highest factor encouraging computer use. This study shows that teachers who have few school resources, are not well supported by their head of department, and who do not have strong personal technology skills can do quite well in implementing technology use. It appears that the teacher's personal attitudes and beliefs, if strong enough, will override these other negative constraints and obstacles. In particular, our results suggest that a strong belief in the value of technology in learning mathematics coupled with a strong willingness to be open to personal learning could be crucial factors. Further research will be necessary to test this hypothesis.

Some teachers have advanced to the point where they are competent in basic instrumentation of the technology and are thus more able focus on other important aspects, such as the linking of representations such as graphs, tables, and algebra (Lesh, 2000), and to use other features of technology. In turn, this better instrumentation produces a higher level of confidence in classroom use. Considering their PTK they begin to see the technology in a wider way than simply as a calculator. They feel free to loosen control and encourage students to engage with conceptual ideas of mathematics through individual and group exploration, investigation of mathematical ideas, and the use of prediction and test methodology. For these teachers the mathematics rather than the technology has again been thrust into the foreground, and the technology has been better integrated into the lessons and the didactic contract. If we think that the approach of this second group is preferable, then we must ask how we assist teachers to progress towards it. One answer is by the provision of pedagogically focussed professional development, relevant resources and good lines of communication.

5. Limitations of this research

One of the key limitations of this research, compared with the original plan, was that we were constrained by human resources to consider only teaching aspects of technology use, and not learning. We were unable to investigate examples of the kinds of learning that were taking place in the classrooms, or whether technology assists with student learning. A second area concerns the selection of the staff that we chose to observe. We were limited here to a self-selected sample who responded positively from the survey, and those who were readily accessible from among these. Hence, our sample is not randomly chosen and therefore our results may not generalise to the whole teacher population.

We had originally anticipated targeting technology use in specific NCEA standards, however, we were limited due to time constraints to observations of what standard the teachers were teaching in the term(s) during which the observations took place. Hence, we could only observe what they were teaching at the time and could not see what we would have liked to have seen. Sometimes the two did intersect, but not always.

The amount of data collected soon became enormous and it was difficult to keep track of it, get an overview of it all, to structure it into information that was useful for analysis, and to describe the research results. One aspect of this was the variations in data received from teachers. Teacher diaries were very variable, although for those who did it well it was most useful. Also, trying to cover a wide ground makes it difficult to have a common focus in data and outcomes, and due to the diversity of the data it was not easy to work within a single theoretical framework.

Finally, the researchers felt that there was a lack of depth in some of the observations. We would have liked to have spent more time with each individual teacher, since this would have assisted with a more robust description of best practice across the NCEA standards. We were not always sure whether we were seeing the best of the teachers' work, or whether the technology use that we observed represented normal practice.

6. Contribution to building capability and capacity

This research has contributed to building improved research capability and capacity among those participating. One of the teacher-researchers commented how she had gained an appreciation of the detail and logistics involved in research, citing as examples: distribution and collection of questionnaire; gaining of consents from the principal, teachers, and students for observations; and organising and recording interviews and observations. This same teacher was engaged in a comparison of the data collected in 1995 and 2005 (from the questionnaire) on the use of the GC, and stated that this was "particularly interesting". She enjoyed looking at the comparisons and how the information quantified changes in classrooms made over the 10 years that were intuitively thought to be the case.

A second teacher-researcher also appreciated what she had gained from being part of the project, including benefits that she could reflect on for her own classroom practice:

> It was really interesting to be involved in the project, both from observing and [privately] critiquing situations in the classroom, to simply being involved with a university-based research project. I frequently came away from our meetings at [the school] quite enthused after being challenged to think about things differently and found opinions expressed in current academic research [such as affordances and constraints] challenged me to think about my personal classroom practice.

The third teacher-researcher took up this same theme of benefit to his own practice, and had gained insight into teaching with technology that he has already put into use:

> Overall, this project has made me more aware of using technology in teaching mathematics and how this can enhance the learning of the subject. Having observed many lessons on how technology can be used in teaching and learning, I have been able to pick up techniques in using technology in teaching mathematics. This has enabled me to use technology, i.e., the graphics calculator, PowerPoint presentation, interactive whiteboard, in my lessons. For example, having observed how the interactive whiteboard has been used to engage students in learning, this has helped me use this tool.

He did express a word of caution too: "However, I have found that there are pitfalls in using technology and one needs to be cautious and get feedback from the students whether they are benefiting from the use of technology." A teacher-researcher mentioned how she had enjoyed and benefited from the research process, meeting with others to analyse data and write up outcomes:

> Under the leadership of [the principal researcher] we further discussed and classified how technology had been used as well as affordances and constraints on the use. The discussion and subsequent observation write-ups … were particularly valuable because it was a thoughtful process involving the refinement of ideas. Reading material produced by other researchers as well as other team members was educational and stimulating.

She also found the fieldwork stimulating and valuable, learning from the participants as well as sharing ideas:

> The observations and interviews were thought-provoking and illustrated for me how each teacher has a unique approach to any task. The observations of [B2] were particularly interesting because she was teaching level 2 US 5248 'Using Sequences and Series to solve problems' using spreadsheets rather than traditional approach using formulae. Her skill and knowledge of spreadsheet functions was impressive.

Of the university researchers, one was able to pass on to the group her summaries and data analysis that were meticulous in their detail and enabled the others to gain from seeing the kind of detailed accounts that researchers need to produce. She benefited by extending her capabilities with statistical data analysis. The second university researcher found the study of value too:

> As a researcher, it broadened the scope of my experiential understanding of the use of technology in the classroom, particularly for teaching. The research also helped me understand better the New Zealand curriculum and how the students are assessed both internally and externally. I have learned about some of the teachers' reflections on NCEA.

He also found benefit from the research in terms of his own experiences of teaching with technology:

> As a teacher … the research has prepared me to have an open mind in learning more about NZ education. Hopefully my experience in teaching with technology will not only benefit me but also the students who I will be teaching in the future.

The principal researcher gained much from working with a group of dedicated and professional people who were committed to completing the project. Their insights and experience contributed greatly to the results presented in this report, and much of their writing also appears above. They are now in a much better position to contribute their skills and knowledge to future research projects. It is also our belief that all of the 32 teachers who so willingly allowed us into their classrooms to observe their practice have also benefited from the reflection on their teaching with technology that this research stimulated. Such reflection can only make them all even better teachers than they already are. We conclude by expressing agreement with the sentiments of one of the researchers who wrote that:

> I hope that in the future, teachers will be actively participating in similar research, not just as a subject but also as a researcher in their own domain, in their own area so that their voices will be heard from their own perspective and not from the perspective of the researcher.

7. Recommendations

From our study we recommend that:

- all school mathematics departments consider writing a policy for technology use, along with a plan for implementing it
- providers of teacher professional development consider the major need for classroom-oriented professional development in classroom use of technology for the teaching and learning of mathematics, and its assessment
- individual schools review their provision of, and access to, ICT rooms so that subjects like mathematics can make better use of computer technology in teaching
- the Ministry of Education act to address perceived inadequacies in the provision of computer hardware, software and calculators that many teachers in this study have described. In spite of previous efforts to provide equality of education for all it appears that funding provision for technology is at the centre of the problem
- further research be conducted into possible uses of IAW’s in mathematics teaching.

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Appendices

Appendix A: Technology In Mathematics Teaching Questionnaire

SECTION A—HOD Mathematics

This questionnaire has been designed as part of a national Ministry of Education funded survey to find out how mathematics teachers are using calculators and computers in their lessons. Your assistance in taking some of your valuable time to fill it in is much appreciated and I thank you in advance for doing so.

Please fill in as many of the questions and replies as you can, ticking boxes, ringing numbers or writing in information as appropriate. Feel free to append additional information or comments as you may feel appropriate.

When complete please return in the envelope provided (or fax) to:

Mike Thomas

Mathematics Education Unit

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The University of Auckland

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Please feel free to email me if you have any questions or comments:
moj.thomas@auckland.ac.nz

A1—NCEA

Q1 Is your department involved in teaching NCEA mathematics Levels 2 and 3?

Level 2 ☐ Level 3 ☐ Neither ☐

Please list alternatives taught (e.g., Cambridge, IB, etc)__________________________________

IF YOU TICKED NEITHER THEN PLEASE GO TO SECTION A2

Q2 Please list the numbers (e.g., 3.2) of any NCEA mathematics standards your department does NOT teach.

Level 2______________________ Level 3 Calculus ___________________________

Level 3 Statistics and Modelling ___________________________

Q3 If you filled in some standards above please give the reason for not teaching them.

____

____

____

A2—School Details

Q1 Type of school

Boys ☐ Girls ☐ Co-ed ☐

State ☐ Private ☐ Independent ☐ Integrated ☐

Q2 Number of students in Years 9 to 13

<300 ☐ 300-400 ☐ 401-500 ☐ 501-600 ☐ 601-700 ☐ 701-800 ☐ 801-900 ☐

900-1000 ☐ 1001-1100 ☐ 1101-1200 ☐ 1201-1300 ☐ >1300☐

Q3 Are you Male ☐ Female ☐ ?

Q4 What is your age group? 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61- ☐

Q5	How many mathematics teachers are in your school?	Full Time	______
		Part time (□0.5)	______
		Part Time (<0.5)	______

A3—Department technology use

Q1	Approximately how many of each of these types of computers does your school have for teaching purposes? (Exclude computers used for administration purposes only)	IBM (or compatible)	______
		Macintosh	______
	How many are laptops? ___________	Other ___________	______

Q2 How many computers have Internet connections?

None ☐ Some ☐ Most ☐ All ☐

Q3 Where do *teachers* have access to computers at school?

In their Classroom ☐ ICT Room ☐ Staffroom ☐ Library ☐ Office ☐ Nowhere ☐

Other____

Q4 Where do *teachers* have access to the Internet at school?

In their Classroom ☐ ICT Room(s) ☐ Staffroom ☐ Library ☐ Office ☐ Nowhere ☐

Other____

Q5 Where do *students* have access to the Internet at school?

In their Classroom ☐ ICT Room(s) ☐ Library ☐ Nowhere ☐

Other____

Q6 Approximately how many computers do most teachers have access to in their classrooms?

None ☐ One ☐ Two ☐ Three ☐ Four ☐ Other____________________

Are these computers connected to the Internet?

No ☐ Some ☐ Most ☐ All ☐

Q7 Approximately how many of each of these computers does your mathematics department have?

IBM (or compatible) ______

Macintosh ______

Other ____________ ______

How many are laptops? _________

Q8 Approximately how many of each of these calculator types does your mathematics department own?

Casio ______

Texas Instruments ______

Sharp ______

Other ____________ ______

Q9 Approximately what % of your school's senior mathematics students own their own calculators?

Year 12 ____%

Year 13 ____%

Q10 Of those students owning a calculator, what % would you estimate to own each of the following types of calculators?

Scientific ____% Graphic ____% Computer algebra ____% Other ____%

Q11 Approximately how many of your mathematics teachers would NOT feel confident using technology in their mathematics teaching?

______

Q12 How many computer rooms/suites does your school have?

______

Q13 Who is responsible for the computers in your school?

HOD Maths ☐ IT director ☐ Other ___________________________________

Q14 Does your department or school have a technology policy? If so please briefly describe it.

____

____

____

____

Q15 Does your department have a technology budget? If so please give the amount per year.

No ☐ Yes ☐ Amount $ ___________ per year

Q16 What is your department currently doing to implement technology in particular NCEA standards mathematics?

Standard(s):____

____

Standard(s):____

____

Q17 What do you perceive as the major obstacles to such implementation?

____

Any other comments:

Technology In Mathematics Teaching Questionnaire

SECTION B—Mathematics Teachers

This section of the questionnaire has been designed to find out how individual mathematics teachers are using calculators and computers in their Years 12 and 13 lessons. Please copy it for any of your department members who would be willing to fill it in. Your assistance in taking some of your valuable time to fill it in is much appreciated and I thank you in advance for doing so.

Please fill in as many of the questions and replies as you can, ticking boxes, ringing numbers or writing in information as appropriate. Feel free to append additional information or comments as you may feel appropriate.

When complete please return in the envelope provided (or fax) to:

Mike Thomas

Mathematics Education Unit

Department of Mathematics

The University of Auckland

PB 92019

Auckland

Fax: (09) 373 7457

Please feel free to email me if you have any questions or comments: moj.thomas@auckland.ac.nz

B1—Personal details

Are you Male ☐ Female ☐ ?

What is your age group? 21–30 ☐ 31–40 ☐ 41–50 ☐ 51–60 ☐ 61– ☐

Which do you currently teach? NCEA Year 12 Maths ☐ Year 13 Calculus ☐ Year 13 Statistics ☐

Other (Please list): ____

B2 —Technology use

Please ring the appropriate number(s) below

Q1	Do you ever use computers in your mathematics lessons?	Yes	1
	If you answered 'No' please go straight to Q13	No	2
Q2	How often do you use computers in your Years 12 or 13 mathematics lessons? Please put 1 to 5 alongside each standard.	Every lesson	1
		Most lessons	2
	C3.1 ___ SM 3.1 ___ SM 3.6 ___	At least once a week	3
	C3.2 ___ SM 3.2 ___ SM 3.7 ___		
	C3.3 ___ SM 3.3 ___	At least once	4
	C3.4 ___ SM 3.4 ___		
	C3.5 ___ SM 3.5 ___	Never	5

Q3 With which years do you sometimes use computers in your mathematics lessons?

Year 12 ☐ Year 13 Calculus ☐ Year 13 Statistics & Modelling ☐ None ☐

With which years do you regularly use computers as an integral part of mathematics lessons.

Year 12 ☐ Year 13 Calculus ☐ Year 13 Statistics & Modelling ☐ Neither ☐

Q4 Do your Years 12 and 13 students use computers in their mathematics lessons only when directed by you?

Yes ☐ No ☐ Sometimes ☐ Depends on ______________________ ☐

Q5	Where are the computers you use usually situated?	In the computer room	1
		In the mathematics room	2
Q6	If the computers are in the mathematics room, how many do you usually have?	One	1
		Two	2
		Three	3
		Four	4
		Other____________	5
Q7	If you very seldom use the school computer rooms/suites, please indicate any reason(s) why.	School doesn't have any	1
		Difficulty booking	2
		Computer staff unhelpful	3
	Other ______________________________	Unaware of the system	4
	______________________________	Too far away	5
		Difficult to organise	6
		Other ___________	7
Q8	Do you sometimes use laptop computers in your teaching?	Yes	1
		No	2

Q9 Do most of your students own laptop computers?	Yes	1
Year 9__ Year 10__ Year 11 __ Year 12 __ Year 13 __	No	2

Q10 Please rank these areas of mathematics in the order in which you most often use the computer in your mathematics lessons, i.e., 1 for most often, 2 for next etc. Leave blank any you do not use the computer for.

Other

____

Graphical Work	___
Algebra	___
Trigonometry	___
Geometry	___
Statistics	___
Calculus	___
Other______________	___

Q11 Please rank these in the order of greatest to least use in your mathematics lessons, i.e., 1 for most often, 2 for next etc. Leave blank any you do not use.

Other

____

Please give the URL of any Internet site you use regularly

____

Graph drawing package	___
Statistics Package	___
Spreadsheet	___
Mathematics software	___
Internet	___
Other______________	___

Q12	Please rank these types of computer use in the order of greatest to least use in your mathematics lessons i.e. 1 for most often, 2 for next etc. Leave blank any that you do not use.	Programming	___
		Demonstrations	___
		Skill Development	___
	Other ____	Investigations/Problem Solving	___
		Free Use by Students	___
		Other______________	___
Q13	Would you like to use computers more often in your mathematics lessons?	Yes	1
		No	2
Q14	If you answered yes to question 13, what do you see as obstacles to your use of them? Please rank in order any of these that apply (i.e., 1 for biggest obstacle, 2 for the next, etc.).	Lack of confidence	___
		Lack of training	___
		Computer availability	___
	Other____	Availability of software	___
		School policy	___
		Other______________	___
Q15	Would you like to use graphic calculators more often in your mathematics lessons?	Yes	1
		No	2

Q16	If you answered yes to question 15, what do you see as obstacles to your use of them? Please rank in order any of these which apply (i.e., 1 for biggest obstacle, 2 for the next, etc.).	Lack of confidence	___
		Lack of PD	___
		Calculator availability	___
	Other ______________________________	School policy	___
		Government policy	___
		Other_____________	___

Q17 With which years do you sometimes use graphic calculators in your mathematics lessons?

Year 12 ☐ Year 13 Calculus ☐ Year 13 Statistics & Modelling ☐ None ☐

Q18 With which years do you regularly use graphic calculators as an integral part of mathematics lessons.

Year 12 ☐ Year 13 Calculus ☐ Year 13 Statistics & Modelling ☐ None ☐

Q19 Do your students use calculators in their mathematics lessons only when directed by you?

Yes ☐ No ☐ Sometimes ☐ Depends on _________________________ ☐

Q20 What kinds of calculators do your students use in their mathematics lessons ?

Scientific ☐ Graphic ☐ Computer Algebra System (CAS) ☐ None of these ☐

Q21 Have you recently been on any professional development courses on using technology in mathematics?

Yes ☐ No ☐

If yes, what?____

What was its value? ____

Q22 Please give the main advantage or benefit you have found, or feel to be true, of using technology in mathematics lessons.

____

____

Q23 Please give the main disadvantage you have found, or feel to be true, in using technology in mathematics lessons.

____

____

Q24 Please list any specific content topics in the NCEA achievement standards where you use technology in your teaching.

____

____

Q25 What is the main criterion by which you would identify a good mathematics lesson using technology?

____

____

Q26 Please describe the one main change you foresee in the future in the use of technology in mathematics teaching.

Any other comments:

Please circle the numbers on the right below corresponding to which of the following indicates your level of agreement with each statement.

5 – I STRONGLY AGREE (SA)

4 – I AGREE (A)

3 – NEUTRAL (N)

2 – I DISAGREE (D)

1 – I STRONGLY DISAGREE (SD)

		SA	A	N	D	SD
1.	Technology is of little benefit in mathematics teaching.	5	4	3	2	1
2.	Calculators are often detrimental to students' mathematical understanding.	5	4	3	2	1
3.	A major obstacle to teachers using technology is a lack of good classroom resources.	5	4	3	2	1
4.	NCEA has too much emphasis on technology.	5	4	3	2	1
5.	A major obstacle to teachers using technology is classroom organisation or management.	5	4	3	2	1
6.	A major obstacle to teachers using technology in the classroom is a lack of teacher confidence.	5	4	3	2	1
7.	A major obstacle to teachers using computers in the classroom is the lack of good software appropriate to the mathematics.	5	4	3	2	1
8.	A major factor inhibiting teacher use of technology in the classroom is that its use in external assessment is not compulsory.	5	4	3	2	1
9.	Technology use is expected in all NCEA standards.	5	4	3	2	1
10.	Computers will be used much more in the mathematics classroom of the future.	5	4	3	2	1
11.	NCEA has too little emphasis on technology.	5	4	3	2	1
12.	All types of calculators should be allowed in examinations.	5	4	3	2	1
13.	Lack of student access to technology is the major obstacle to effective use.	5	4	3	2	1
14.	Best practice occurs when students own their own technology.	5	4	3	2	1

We are very interested in observing examples of technology use in NCEA Levels 2 and 3. If you would be willing to consider being part of the follow-up research and professional development on technology use in school classrooms please give your name and the name of your school here. We will then contact you to discuss this.

COMPLETION OF THE PART BELOW IS NOT NECESSARY FOR RETURN OF THIS QUESTIONNAIRE.

Yes I would be happy to be contacted.

Name: ________________________________ Position: ____________________

School: ____

Contact details: ____

What topics do you like teaching with technology? __________________________

____

Appendix B: Teacher interview questions

1. In which achievement/unit standards (algebra, statistics, geometry, numbers, measurement) have you used technology? (Matrix here…)

   What type of technology (e.g., graphic calculators, CAS, computers) do you use for these standards?

2. Why did you decide to use this technology when planning your lessons?

3. What do you want your students to learn from your teaching of mathematics? eg. What kind of things is it important to learn? Give some examples.

   How do you introduce the important ideas?

4. How do you think the technology you have used can help students to learn these things?

   Do you think the technology is effective for better understanding of your students? If so, then in which aspect especially?

5. Can you give any examples of how technology has been useful in the learning of your students? e.g., 1 particular student or the whole class.

   What kind of examples did you use in your lesson?

6. How do you organize the use of technology in your lessons? Why? Are there any methods you would like to use but can't? Are there any you don't allow?

7. What kind of training in the use of technology, do you think students need? How do you provide this?

   Do you spend time getting students to master the basic facilities of the technology before your lessons? If so, then how long do you spend on this and how do you introduce it?

8. What are the kinds of problems your students meet when using technology?

9. What kind of recent professional development in using technology have you had? What would be of most benefit to you?

10. What is your view on the use of graphic calculators in assessment, such as examinations? Are there any equity or cultural issues you can see?

11. What is the current pattern of technology use in your school for internally and externally assessed NCEA standards?

12. Has the introduction of NCEA changed your pattern of technology use in teaching mathematics?