TEACHERS USING COMPUTERS IN MATHEMATICS: A LONGITUDINAL STUDY

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The computer has been in mathematics classrooms for over 20 years now, but with widely varying implementation in mathematics teaching and learning. This paper describes a ten-year longitudinal research study that has investigated the changing nature of how secondary school teachers use computers in their mathematics classroom, and their perception of constraints or obstacles to improving, or extending, such use. The results show that while there are now many more computers available in schools, access remains a key obstacle to their increased use as mathematical learning tools. There is also a change in the kinds of software used, away from content-specific programs and towards generic software, especially the spreadsheet. Teacher attitude remains a key factor in progress.

INTRODUCTION

While many mathematics educators, including the author have been positive about the possible role of computers in the learning of mathematics (see e.g., Thomas & Holton, 2003), there have been doubts raised about a) whether computers have any real value in learning (Cuban, 2001) and b) whether current teacher use is qualitatively and quantitatively sufficient to promote benefits that might exist. Around 10 years ago Askew and Wiliam (1995) reported on a review of research in mathematics education in the 5-16 year 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 report (DFE, 1995) also noted a low level of computer usage in mathematics, with an average of 15.6 minutes of lesson time per week spent using the computer, and in the United States the position was very similar (Ely, 1993). While some might hope that this position has changed in 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, including teacher inability to focus on the mathematics and its implications rather than the computer and many teachers not believing that the computer has real value in student learning. It has been argued that teacher factors outweigh school factors in the promotion of computer use, and Becker (2000a) reported on a national US survey of over 4000 teachers, concluding 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

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resources in their classroom (5 or more computers), and had a reasonable background experience of using computers, a majority of them made 'active and regular use of computers' in teaching. Becker (2000b) has added a description of some characteristics of such an 'exemplary' computer-using teacher, but concludes that extending these to other teachers would be expensive. This paper reports on a ten-year longitudinal study describing the changing pattern of computer use in the mathematics classroom in New Zealand. Both the level and kinds of use were recorded, together with some of the obstacles teachers perceive to increased use.

METHOD

Genuine longitudinal studies, where at least two sets of data are acquired from the same population over an extended time span, are relatively rare in mathematics education research. This longitudinal study, which has as its population all secondary mathematics teachers in New Zealand, began in 1995, when a postal questionnaire on computer use was sent to every secondary school in New Zealand. Replies were received from 90 of the 336 schools (26.8%), a reasonable response rate for a postal survey. Apart from information about the mathematics department in the school we received information from a total of 339 teachers in these 90 schools.

Some of the results of this survey were published at the time (Thomas, 1996). This original survey was followed by a second in 2005 in order to gain longitudinal data on how the situation might have changed over this period. In the years since 1995 teaching has become an even more stressful profession in many ways, particularly in terms of demands on time. Hence, teachers are more reluctant than ever to spend their valuable time filling in forms or research questionnaires. However, we had learned some lessons from 1995 and this time stamped, addressed envelopes were enclosed for all the schools and it was followed up several weeks later with a faxed copy. Using this approach we achieved a response from 193 of the 336 secondary schools in the country, an excellent 57.4% response. Completed questionnaires were received from a total of 465 teachers in these 193 schools, as well as the school information. In both years we are confident, due to the sample size, that the responses form a representative sample of the population of secondary school mathematics teachers, especially since we received a good proportion of responses from non-computer users (over 30% in each case). Of the respondents, in 1995 51.5% were male and 48.5% female, with a mean age of 41.5 years, whilst in 2005, 52.6% were male and 47.4% female, with a mean age of 44.8 years; the teachers are getting slightly older. While the questionnaires sent out in the two years were not identical, for example questions on the use of the internet were added in 2005, they had a considerable number of questions in common. They used closed and open questions to provide valuable data on issues such as: the number of computers in each school; the level of access to the computers; available software; the pattern of use in mathematics teaching; and teachers' perceived obstacles to computer use (see Figure 1 for a selection of questions from the second survey). This data enables us to come to some conclusions about the changing nature of computer use in the learning of mathematics in New Zealand secondary schools.

Q2	How often do you use computers in your mathematics lessons?	At least once a week	1
		At least once a month	2
		At least once a term	3
		At least once a year	4
		Never	5
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
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.	Graphical Work	___
		Algebra	___
		Trigonometry	___
		Geometry	___
		Statistics	___
		Calculus	___
		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 (ie 1 for biggest obstacle, 2 for the next, etc.).	Lack of confidence	___
		Lack of training	___
		Computer availability	___
		Availability of software	___
		School policy	___
	Other_____	Other_____	___
Q22	Please give the main advantage or benefit you have found, or feel to be true, of using technology in mathematics lessons_____		

Figure 1: Sample questions from the 2005 survey (some formatting changes).

RESULTS

In 1995 67.2% of the teachers said that they used computers in their teaching, and this remained steady at 68.4% in 2005. Of these, in 1995, 5.9% said they used them at least once a week, and by 2005 this had risen to 13.3%. In 1995 the schools reported a mean of 40.0 computers per school, with 1.7 in the mathematics department. By 2005 this had increased to a mean of 74.4 computers per school (one outlier school with 1800 laptops was excluded), 21.9 of which are laptops and 26.9% of the schools now have over 100 computers. Mathematics departments have 6.5 computers on average (4.2 of which are laptops). One change has been the increase in the number of ICT rooms, up from 71% of schools in 1995 to 96%, with a mean of 2.46 rooms per school, up from 1.79 in 1995. However, while in 1995 89.1% of mathematics teachers usually used computers in labs this had dropped to 59.1% in 2005, with 10.7% using them mostly in their classroom. While numbers of computers have increased, has the pattern of use in teaching mathematics changed?

Computer use in mathematics teaching

The mathematics curriculum in New Zealand schools is divided up into Number, Statistics, Geometry, Algebra and Measurement strands, along with a Processes

strand. Number and Measurement are principally primary and intermediate school activities (secondary school usually starts at age 13 years) so those using the computer were asked in which of the remaining curriculum areas (along with specific topics of graphs, trigonometry and calculus) they used them (see Table 1).

Area of Use	% of 1995 teachers (n=229)		% of 2005 teachers (n=318)	
	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

Table 1: Curriculum areas where secondary teachers are using computers.

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 New Zealand 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 (NZ$1≈US$0.63), and one head of department commented that "Annual [software] fees also take up a lot of the allocated budgets".

To gain some idea of the variety of uses that computers are being put to in schools each survey asked the teachers to rank in order of regularity of use the types of software they employed in teaching mathematics (see Table 2).

Area of Use	% of 1995 teachers (n=229)		% of 2005 teachers (n=318)	
	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

Table 2: Types of software used with computers.

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 may handle statistical work well enough for secondary schools. The trend away from specific graphical packages is a little surprising since there are now some excellent programs, such as Autograph, available. Possibly 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% of the teachers reported some use of it to teach mathematics. 61.1% of the teachers have access in their classroom (and 68.4% in a staff room). For the students, only 26.4% have classroom access, although 95.6% of schools have ICT rooms connected for them.

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., von Glasersfeld, 1991; Ernest, 1997). Has this influenced how computers are used, as one might predict?

Method	% of 1995 teachers (n=229)		% of 2005 teachers (n=318)	
	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

Table 3: Teaching methods used with computers.

We can get some idea of what has happened in the classroom by looking at Table 3, 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. 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% 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 ($\chi^2=4.79$, $p<0.05$), and in those allowing free use of the computer ($\chi^2=18.0$, $p<0.001$). However, the use of demonstrations significantly increased ($\chi^2=19.5$, $p<0.001$), 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 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. 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.

Obstacles to computer use

In the original 1995 survey 93.5% 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%. 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 4.

Obstacle	% of 1995 teachers (n=339)		% of 2005 teachers (n=452)	
	First Mentioned	Mentioned	First Mentioned	Mentioned
Available Software	17.4	52.5	10.8	39.4
Available Computers	43.7	67.8	42.7	58.0
Lack of Training	17.4	45.4	7.5	31.9
Lack of Confidence	12.7	34.8	5.3	22.4
Government Policy	4.1	12.4	---	---
School Policy	0.6	8.0	0.4	9.3

Table 4: Obstacles teachers mention as preventing computer use in teaching.

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 has been better addressed, with significantly fewer teachers mentioning it (χ^2=15.2, p<0.001), although only 39.6% 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 department heads 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, significantly fewer feel that they lack confidence in computer use (χ^2=15.0, p<0.001), possibly due to greater penetration of computers in homes over the period. Further, the need for software may have been covered by the 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. 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. The 2005 survey asked teachers if they seldom used the computer room what was the reason, and 38.7% said that it was because of the difficulty with booking the room, and a few said that it was too difficult to organize. There were very few other reasons of note given. Typical teacher comment 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% of teachers mentioned some other obstacle, and in 2005 the figure was 18.4%. 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.

CONCLUSION

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%. 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% 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% 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% 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% believed that it aided understanding (compared with 32% who thought it made working quicker or more efficient), 16.8% claimed that it impeded learning or understanding. As Manoucherhri (1999, p. 37) reported many "…teachers are not convinced of usefulness of computers in their instruction…", 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 over-rated. I don't feel learning is significantly enhanced…I feel claims of computer benefits in education are often over-stated.", "Reliance on technology rather than understanding content. ", and "Sometimes some students rely too heavily on [technology] without really understanding basic concepts and 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.

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