SECONDARY MATHEMATICS TEACHERS' RESPONSES TO COMPUTERS AND THEIR BELIEFS ABOUT THE ROLE OF COMPUTERS IN THEIR TEACHING

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International studies have indicated that mathematics teachers have been slow in taking up the use of computers in their teaching even where the resources have been available. In this study, survey and case study procedures were used to determine how frequently, and for what purposes, secondary mathematics teachers used computers in some Australian schools. It also investigated teachers' beliefs about the potential of computers in mathematics teaching and learning. The findings showed that the teachers in this study rarely used the computer resources available, particularly if they taught junior (Years 8-10) and less able senior students. Only teachers with special expertise used computers regularly and, then, mostly for the teaching of calculus and statistics and usually in a calculational way.

Internationally, education researchers have expressed high expectations for the potential of computer technology to improve the teaching and learning of mathematics (Gentile, Clements & Battista, 1994; Kaput & Roschelle, 1997; Stirling & Gray, 1991). In Australia, education boards and teacher union bodies also share these high expectations (Australian Association of Mathematics Teachers Inc., 1996; Department of Education, 1995). However, studies have indicated that mathematics teachers have been slow to introduce the use of computers into their classroom activities, even when the hardware has been accessible (Becker, 1991; Marcinkiewicz, 1994; Oliver, 1994; Rosen & Weil, 1995; Zammit, 1992). As well, computer use has often been restricted to drill facts or skills rather than develop understandings (Becker, 1994).

This study examines how secondary mathematics teachers are responding to the potential of computing power in seven technology rich Queensland schools.

METHOD

This study is a series of embedded qualitative educational case studies (Stenhouse, 1990) involving a hermeneutic, interpretive and naturalistic approach (Denzin & Lincoln, 1994).

Subjects and Contexts

The study was carried out in seven Brisbane suburban schools. The schools were all considered to be technology rich in that the ratio to students to available computers was not more than four to one. The schools included both metropolitan state and private schools, but were not intended to be a representative sample of Queensland schools. Rather, they were selected because the computing coordinators and Heads of Departments (HOD) in each school indicated that access was not a major obstacle to teachers use of computers in their mathematics teaching.

Data Sources and Procedures

The data were collected over a twelve-month period through three phases. The first phase involved interviewing the computer coordinators and Mathematics HODs in each school to confirm the availability of hardware and software and to gain background information on the use of computers in each school. The responses informed the construction of survey instruments designed to probe teachers' frequency of use of computers and their beliefs about the effectiveness of computers compared to traditional instruction. The second phase involved surveying most of the teachers who taught mathematics in each school by using the instruments constructed after the first phase. The third phase was a series of ten case studies from two schools involving a hermeneutic, interpretive and naturalistic approach (Denzin & Lincoln, 1994). The purpose of this phase was to add greater insight on how teachers were responding in their classrooms to the potential of computing power, specifically their images of the roles computers could play in mathematics teaching and learning.

There were six components to the third phase. First, the teachers were interviewed about their beliefs on the use of computers in mathematics teaching. Second, at least two of their lessons were observed, teacher and student activity and black board presentations were documented with field notes, and the teachers' dialogues with their students were audio-recorded and transcribed. Most often these lessons did not involve the use of computer technology. However, each teacher was observed teaching topics of either calculus or statistics where the use of computers was possible and software were available within their school. Third, the teachers were re-interviewed for their reasons for conducting the classes in the way that they did and for their goals for able and less able students. Fourth, the researcher conducted in-service professional development for each case study teacher on the use of the mathematics software *Maths Helper* (Vaughan, 1997). The teachers were asked to evaluate the software and comment on how they might use it. Fifthly, the researcher constructed student activities based around the *Maths Helper* software, offered to teach the teachers' with this software classes, and interviewed the teachers concerning their observations. The *Maths Helper* software matched the concepts the teachers were about to teach their classes. The teachers were asked for their perceptions about how the students learned, the effectiveness of the lesson and how they would approach the teaching of the same lessons. Finally, after the data were analysed, the case study subjects were asked to comment upon the credibility of the researchers' interpretations of their beliefs about the potential of computers.

The inservice in *Maths Helper* and the subsequent questioning of teachers were designed to probe the teachers' beliefs about the potential of computers in mathematics teaching and learning. It is an indirect way of collecting data about beliefs and is considered more effective than direct questioning (Kagan, 1992). It was successful in assisting interpretation of teachers' beliefs. In particular, one case study teacher refused to allow the researcher to teach any of his classes even though the researcher had prepared specific computer based lessons on the topics his classes were studying (quadratic functions in Year ten and calculus in Year 11). This rejection was taken as a statement to indicate low evaluation of the potential of computers in mathematics teaching.

The combination use of survey instruments, interviews, classroom observations, responses to the technology intervention, and comments on the assertions, was used because it had the potential to develop a rich description and promote trustworthiness in the study.

Analysis

Analysis was emergent, contingent and cumulative; that is, constructivist (Guba & Lincoln, 1989). The survey data was analysed qualitatively; that is, inferential statistics were not used because the data did not meet the assumptions necessary for such tests to be applied. Each data collection interaction (survey instruments, interviews, observations of classes, responses to the technology intervention, and comments on the assertions) was used to inform following interactions and to construct theory. This process of building relationships between data and theory has been described as data theory boot strapping (Richards & Richards, 1994).

RESULTS AND DISCUSSION

Phase One

All the computer coordinators claimed that mathematics teachers under-used the computer resources available to them. Four of the coordinators said that teachers used the excuse of difficulty of access to computers to mask other reasons; for example; lack of knowledge of suitable software; concerns about changes to teachers' roles; lack of time to plan computer based mathematics learning; concerns about not covering the syllabus; and computer phobia.

Phases Two and Three: Frequency of Computer Use

Within the seven schools, 73% of all the mathematics staff completed the survey instruments. The staff who did not complete the instruments tended to teach subjects in addition to mathematics (e.g., science and manual arts); thus, the sample is not representative of the total school population. Table 1 summarises teachers' frequency of use of computers in their mathematics teaching. *Demonstrative* means that teachers used the software to illustrate an explanation by projecting the computer read-out onto screen for the students to observe, *Student use* means that the students used the computers, and *Communication* means that the teachers used the computers for communication (e.g., accessing the Internet).

Table 1
Percentage Frequency of Computer Use among Teachers (N=51)

Type of Use / Frequency of use	Demonstrative (Valid %)	Student use (Valid %)	Communication (Valid %)
Never used for	33	25	33
Once or twice a year	37	31	37
Every month	18	20	18
Every week	8	14	8
Once or twice a week	2	8	2
Every day	2	2	2

The table shows that 33% of the teachers responded that they never used computers for demonstrations, 25% never had their students use computers and 33% never used computers for communication. Clearly the data indicates that computers were used sparingly by mathematics teachers in the schools. Only one (2%) of the fifty teachers sampled had students use computers every day, whilst about seven (14%) had students use computers weekly. Three of these seven teachers were clustered in the school where each student owned a lap-top computer, one teacher operated *SuccessMaker* for remedial students, and the others were subject coordinators or acting coordinators. Thus, it is apparent that not only were computers used infrequently by most teachers, but also the students who used computers in their learning of mathematics tended to be taught by subject coordinators or HODs; that is, the most experienced teachers in the schools. Very few ordinary classroom teachers frequently used or had their students frequently use computers as part of their learning. About 55% of teachers reported that they either never or hardly ever used computers in their classrooms. Fewer still used computers as a demonstrative tool.

Whether mathematics teachers used computers regularly or not tended to be a school-based decision, and this was strongly influenced by the beliefs of the senior mathematics teachers. For example, in one of the case study schools, the HOD and another senior teacher were regarded as the computer experts in mathematics. These teachers were acknowledged, by the school administration and the computer coordinator, as having great influence upon the way mathematics was taught in the school. They exercised this influence by allocating resource expenditure for software and texts book and writing most of the assessment items for mathematics. (The importance of text book selection (Carnine, 1993; Robinson, 1995) and assessment instruments (Barnes, Clarke & Stephens, 1996) has been recognised previously.) They believed that computers were not appropriate for teaching mathematics, particularly for concepts. As a consequence, except for occasional use of graphing calculators to teach statistics and calculus, computers were not used in the teaching of the senior or junior mathematics classes at the school.

As well, the use of computers was affected by the teachers' perceptions of their students. For example, in the other case-study school, computer use took two forms. In the junior part of the school, the less able junior students used computers while the able did not. The less able were given drill and practice using the software *Successmaker* once a week to help them learn basic mathematics skills and facts. In the senior school (Years 11 and 12), this was reversed; the able used computers while the less able did not. Mathematics B (Board of Senior Secondary School Studies, 1992a) students used computers in the study of calculus and statistics. For calculus, the students used graphing claculators or computers with the software *Capgraph* to plot functions and their derivatives. As a result, about half the Year 12 Mathematics B classes were competent in plotting functions and finding intersection points. For statistics, all students had some practice in summarising data using computers to calculate stem-and-leaf plots, histograms, box-and-whisker plots and measures of central tendency. Meanwhile, the teachers of senior students who did not study advanced senior mathematics (Mathematics B or Mathematics C) did not use computers in their teaching of these less able classes even though spreadsheets could have been used in the teaching of finance units and statistics software could also have been used.

Phases Two and Three: The Nature of Computer Use

In their description of teaching orientations Thompson, Phillip, Thompson, & Boyd, (1994) noted that mathematics teachers had two orientations, *calculational* and *conceptual*. These orientations can be extended to teachers' images of the potential of computers in mathematics teaching. For example, the calculational orientation can be used to describe an image of computer use where computers are used primarily as instruments to carry out calculations and procedures for deriving a numerical result, while the conceptual orientation can be used to describe an image of computer use where computers are used to focus students' attention upon the concepts underlying the mathematical procedures. This conceptual image of computer use is one where students' attention is toward rich conceptions, mathematical ideas and relationships between ideas.

Table 2
Percentage Effectiveness of Computers Compared with Traditional Instruction for Specific Objectives (N=51)

Specific Objectives	Response (Valid %)				
	1	2	3	4	5
A Makings sure that students get the right answer (Cal)	4	11	43	32	9
B Reinforcing each right answer (Cal)	2	7	43	23	25
C Providing students with practice in basic skills (Cal)	2	9	32	36	21
D Correcting student lack of understanding (Con)	14	35	25	21	5
E Helping student to construct their own representations of concepts (Con)	2	24	37	27	10
F Developing student higher order thinking skills (Con)	10	19	40	28	5
G Guiding students through prob solving process (Con)	16	21	30	30	2

Table 2 summarises teachers' responses to a survey instrument designed to probe teachers' beliefs about the effectiveness of using software compared with more traditional instruction. The items were selected from a number of scales designed by Mergendollar, Stoddart and Niederhauser (1992). Each item has been labelled either *Cal* to indicate it probes teachers' beliefs about the calculational use of computers in mathematics teaching or *Con* if it probes teachers' beliefs in the conceptual potential of computers in mathematics teaching and learning. Teachers responded on a 5 point Likert scale: 1 - "much less effective"; 2 - "somewhat less effective"; 3 - "same"; 4 - "somewhat more effective"; and 5 - "much more effective". That is, if they believed using computers was much more effective than traditional instruction in achieving an objective they responded with a "1."

One crude way of examining the data is to add the percentage of teachers who responded much less effective and somewhat less effective, thus for item A about 15% of teachers responded that using computers was less effective than traditional instruction for making sure students get the right answer, and about 41% responded that computers were more effective than traditional instruction. Thus, for the three items labelled "Cal" or calculational, between 41% and 57% of teachers believed that using computers was more effective than more traditional instructional in achieving these goals. On the other hand between 11% and 15% indicated that traditional instruction was more effective in helping students to achieve these calculational goals.

In contrast, 49% of teachers responded that traditional instruction was more effective than using computers for correcting student lack of understanding where only 26% of teachers believed using computers were more effective. Overall, between 26% and 37% of teachers believed that computers could be more effective than traditional instruction in achieving these conceptual objectives. In contrast, between 26% and 49% of the teachers responded that they believed that traditional instruction was more effective. Clearly the data shows teachers were more convinced of the potential of computers to be used to achieve calculational objectives rather conceptual objectives.

This deduction is supported by what happened in the case-study schools. Four months after the surveys were collected, several case-study teachers made the following comments supporting calculational use of computers: "good for number cruching", "taking the worry out of endless calculations", "computers are a time saver, you just plug the stuff (numbers) in", "doing things that we used to take ages to do like graphing lines and calculating standard deviations", "it's a mechanical devices that does all the work for you", "a gadget to do the work", "they can draw graphs faster than I can", and "I think it is very good for demonstrating a lot of things very quickly". The image of computers as being an instrument to take the tedium out of calculations and computations was the dominant image that the teachers saw of the potential of computers. The teachers did not mention the potential of computers to develop students conceptual understandings of mathematics concepts, nor did they use graphing calculators or computers in the observed lessons in a way that indicated they appreciated this potential. When they had an opportunity to observe a computer lesson, the teachers responded in a way which indicated that they were not inclined to use computers in a conceptual way. Rather, they made comments such as "I like the colour, it would be good on a large screen, demonstrating on a large screen". In addition, they made comments which indicated that they believed computers could hinder conceptual development: "if you let them do it on their own ... they are like parasites of (each other) rather than working themselves", "you see computers in conceptual development, I don't, the students must understand it first by doing it by hand", "technology won't help (develop understanding) it is up to the individual", "the kids won't see the processes, they will miss out on the concepts behind", "they (students) could miss out (on a concept) because they may be playing around with their computers", "students don't get the opportunity to work it out for themselves (when using computers)", and "I don't like the idea of relying upon it to teach a concept - I think it works better the other way (explain the concept first)".

Three of the teachers had both a calculational and conceptual image of the potential of computers at the beginning of the study and one teacher showed signs of appreciating their potential to be use in conceptual development at the following professional development. They showed appreciation for computers' having a role in developing student conceptual understanding by making statements such as: "I do on occasions use computers to develop concepts even if they are more time consuming", "well the good thing about computers is they are dumb ... you have got to formulate in your own mind and tell the computer how to do it ... all kids should learn programming ... I prefer kids to write their own spreadsheets", and "with the mathematics of the future, you're not going to sit down and calculate a derivative, a computer will do that for you, but you have to know why do I want to calculate this derivative, what is it going to tell me".

Thus, what teachers said supported the survey data in indicating that, although most mathematics teachers in the school had an appreciation the potential of computers to play a calculating role in student learning, few appreciated the potential of computers to play a role in student conceptual development. In fact, most teachers considered that using computers could interfere with conceptual development.

CONCLUSIONS AND IMPLICATIONS

A number of conclusions can be made from the data. First, secondary mathematics teachers in the schools surveyed have responded slowly to the potential of computers even when the resources have been available. Few teachers used computers at least weekly. When the interpreting the data from this study it must be remembered that the teachers who responded to the survey instruments were mostly specialist mathematics teachers and most of the case study teachers were very experienced senior teachers. In fact seven of the ten case study teachers were either HODs, AST (Advanced Skill Teachers) or senior coordinators. Frequency of computer use over the population of mathematics teachers in these schools would almost certainly be lower.

Second, most teachers appreciated the calculational potential of computers and rated them as equally effective or more effective than traditional instruction for doing calculations or providing practice in basic skills. Few teachers had images of computers as useful in developing students' conceptual understandings of mathematics concepts. In fact most teachers found educational explanations of how the use of computers could hinder student understanding of mathematics concepts. Thus, many of the teachers were arguing against the use of computers in the area in which they have great potential to contribute to mathematics learning, that is developing students' intuitions and understanding of concepts.

Third, none of the teachers said they used computers in the teaching of less able senior students who studied Mathematics A (Board of Senior Secondary School Studies, 1992b). These students were not only deprived of the potential of using computers to help them develop conceptual understandings, but were also deprived of the opportunity to learn industry based skills such as using spreadsheets.

These findings have implications for professional development and further research. First, professional development of secondary mathematics teachers in the use of technology needs to consider the use of computers in both calculational and conceptual contexts. To do this effectively further research is necessary to explore the relationships between teachers' images of teaching and learning, their educational goals and how these relate to computer use. That is we need to study why some teachers resist the use of computers in their teaching, particularly for helping some students to understand the concepts of mathematics and in their teaching of less able senior students.

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