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Abstract

Despite the availability of hardware and software, the mathematics staff in a technology-rich secondary school rarely use computers in their teaching. This study investigates the reasons for this phenomenon. The results indicate that individual teachers' resistance was related to their beliefs about mathematics teaching and learning and their existing pedagogies, including their perceptions about examination concerns about time constraints, and preferences for particular text resources. It was also found that teachers with transmission-absorption images of teaching and learning and teacher-centred content-focused pedagogy had a restricted image of the potential of computers in mathematics teaching and learning. By contrast, one teacher with images of teaching consistent with social constructivist learning theory and a learner-focused pedagogy had a broader image of the potential of computers in mathematics teaching. Further, staff discourse was also found to be important in determining whether computers would be used by students to facilitate their conceptualisation of mathematics. These findings have implications for professional development related to the integrated use of computers in mathematics teaching. (Keywords: beliefs, computer use, mathematics, resistance to computers.)

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). In Australia, education boards and teacher union bodies also share these high expectations (Australian Association of Mathematics Teachers, 1996; State of Queensland Department of Education, 1995). However, studies have indicated that mathematics teachers have been slow to introduce computers into their classroom activities, even when the hardware has been accessible (Rosen & Weil, 1995). When computers are used, they often are restricted to drilling facts or skills rather than developing understanding (Becker, 1994).

School cultures and teaching practices are often reported as being conservative by nature (Cuban, 1984; Rosen & Weil, 1995; Thompson, 1992). This general conservatism may in part explain the apparently slow response of many mathematics teachers to the potential of computers in the classroom. Among the factors that have been cited as underpinning the stability of mathematics teaching practices are assessment methods (Barnes, Clarke, & Stephens, 1996; Gregg, 1995; Ri. 1994), resources such as textbooks (Neyland, 1996), student preferences for familiar teaching behaviours (Jaworski, 1989), and the relative isolation of classroom teachers from sources of professional stimulus (Kagan, 1992;
In addition to these general restraining influences, other specific factors slow teachers' use of computers in mathematics teaching, including lack of access to hardware and suitable software (Becker, 1994; Casey, 1995).

Other authors have made links between teachers' beliefs and attitudes toward the use of computers (Ernest, 1996; Galbraith & Chant, 1990; Jacobs Henry & Clements, 1999; Marcinkiewicz, 1994; Niederhauser & Stoddart, 1994; Sarama, Clements, & Jacobs Henry, 1998). Some authors contend that (1) existing knowledge and beliefs act as a filter through which teachers view and interpret not only their own teaching success but also the performances of others and (2) existing beliefs act as a filter in the process of interpreting and assimilating new views of mathematics and mathematics teaching (Alexander, 1996). Just as beliefs may act to limit the innovation of individuals, so too could they operate to collectively limit the receptivity of a staff to pedagogical changes including the use of computers in mathematics teaching and learning.

Two images of the teaching and learning interplay are used in this study as a framework to describe teachers' dominant beliefs about teaching and learning mathematics. The first is a belief that knowledge can be transmitted from the teacher to the learner (Atweh & Cooper, 1995; Crawford, 1996) and that the learner acquires knowledge by some kind of process of absorption (Hatfield & Bitter, 1994). The second image is that students learn by constructing mathematical meaning through exploration of ideas and problems, often in a social setting (Cobb, Wood, Yackel, & McNeal, 1992). This image of student learning rejects the notion that knowledge can be transmitted from one individual to another. In addition, it is recognised that teachers may have different beliefs about different students' capacity to learn and, thus, embrace different and sometimes contradictory paradigms with able and lesser-able students. Thus, in this study we sought to identify the collection of beliefs likely to underlie the teaching actions of experienced teachers when they teach able mathematics students. The assumption has been made that teachers' beliefs about teaching this group of students are most likely to represent their core beliefs about teaching and learning (Norton, 1999).

The model proposed by Kuhs and Ball (1986) has been used as a framework to describe teachers' behaviours. These authors proposed four distinct descriptors of pedagogy, but in this study, only three were found to be relevant. The first was a description of teaching as content focused with an emphasis on performance, which has been described as instrumental learning (Skemp, 1978) and calculational orientation (Thompson, Phillip, Thompson, & Boyd, 1994). This type of teaching focuses on teaching rules without explaining why such rules are valid and includes a preoccupation with the application of calculations and procedures for deriving numerical results. The second was a description of teaching as content focused with an emphasis on understanding. This image of teaching behaviour emphasises students' understanding the ideas and processes behind mathematics rules and is consistent with what Thompson et al. described as a conceptual orientation. Like the content performance teaching image, this image of teaching is based upon the assumption that mathematical ideas can be transmitted from teacher to student. Adherents of this image of teaching believe that students' misinterpretations can be reduced if the teachers' explanations are clear.
The final image of teaching used in this study is learner focused (Kuhs & Ball, 1986). This teaching behaviour is characterised by the teacher acting as a facilitator, posing interesting questions and situations for investigation, and helping students to uncover inadequacies in their own thinking. The constructivist view of learning underpins this image of teaching (Thompson, 1992).

The teaching orientations described by Thompson et al. (1994) as calculational and conceptual 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 in which computers are used primarily as instruments to carry out calculations and procedures for deriving a numerical result. The conceptual orientation can be used to describe an image of computer use where computers are used to focus students' attention on 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.

The aim of our study was (1) to investigate the relations between teachers' beliefs about teaching mathematics and their practices and their attitudes toward using computers in their mathematics teaching and (2) to examine the staff discourse that facilitates or hinders the use of computers.

METHOD

Our study comprised a series of embedded qualitative case studies (Stenhouse, 1990) involving a hermeneutic naturalistic approach (Denzin & Lincoln, 1994). The design of the study and the analysis of the data heeded the criteria for qualitative inquiry (Guba & Lincoln, 1989), which involves concerns for the trustworthiness and authenticity of the data and the benefits of the hermeneutic cycle approach. Techniques to enhance trustworthiness included member checking, peer review, the triangulation of multiple data sources, the testing of developing assertions on emerging and previously collected data, and actively seeking negative instances of developing assertions. The first author interacted with the participants in the study.

The relationships between the images and beliefs of the teachers were examined for each teacher individually and for interactions between the individuals who dominated a mathematics staff. That is, the study examined the individual teacher's beliefs and practices and their interactions with their peers in the broader school context as such contexts have been shown to be important influences on practice (Casey, 1995; Hyde, Ormiston, & Hyde, 1994; Sarama et al., 1998).

Subjects and Contexts

The study was carried out in a technology-rich private girls school (known by the pseudonym "Hill View"). Caution should be exercised in applying the findings beyond this school. The school was chosen because difficulties associated with access to hardware and software seemed not to be a major obstacle. For a student population of 650, there were seven designated computer laboratories, each with 25–30 networked Pentium computers. Thus, the ratio of students to computers was less than 4 to 1. The school also had a digital projector.
staff had their own computer room with sufficient computers for ready access. The mathematics staff also had a class set of graphing calculators.

Eight of the 10 teachers who taught mathematics at this school were surveyed, with the five most influential of those teachers selected for more in-depth case study. Their peers regarded each of these teachers as very competent, and lesson observations confirmed that their classes were well managed. Thus, differences in descriptions of their pedagogy are not judgmental but reflective of different beliefs about the most effective way to teach mathematics. The subjects included Peter, who also had an extensive background in the use of computer technology; the junior mathematics coordinator Eva; Mary, who was previously a subject coordinator at another school; the senior mathematics coordinator Julie; and finally Emm, who was responsible for compiling the statistics for student exit results. They exercised control by writing the work programs that stipulated which concepts would be taught and when they would be taught. These teachers also wrote the assessment or oversaw its construction; assessment at all levels was internal. The two coordinators (Eva and Julie) selected resources (including textbooks) that all teachers would use and, thus, had a strong influence on the pedagogy adopted by teachers in the school (Crawford, 1996; Kagan, 1992). The five case study teachers were selected because they were the most senior teachers in the school and their ideas, actions, and beliefs could strongly influence the way mathematics was taught at the school. The three case studies reported in detail were selected because they represent the divergence of beliefs and practices in relation to the use of computers in mathematics teaching in the mathematics staff at this school. Eva and Peter shared similar beliefs about the potential of computers, but Eva had little expertise in computer use, while Peter had considerable experience. Mary had very different beliefs and practices.

Procedure
The study was divided into three phases with the last phase further divided into three subphases. Table 1 gives an overview of the research design and methods.

Entry Phase
The computing coordinator was interviewed about the computer resources available to the mathematics staff and how the mathematics teachers used them.

Survey Phase
The survey instruments were constructed by the researcher or based upon existing instruments modified by the researcher from the sources indicated. Data were collected on demographics, use of computers and beliefs about their effectiveness compared to traditional instruction, factors limiting classroom computer usage, beliefs about mathematics, and beliefs about the nature of teaching mathematics (Ernest, 1996). They were also used as a stimulus for further discussion with the participants. They are reported in detail in Norton (1999).

Case Study Phase
Exploring beliefs. In this phase, teachers were interviewed on their beliefs about the nature of mathematics and their images of teaching and learning. Rather than relying solely on directly asking the teachers what they thought
# Table 1. Overview of Research Design and Methods

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about aspects of teaching, the researcher also asked the teachers what they thought about particular textbooks, resources, and instances in mathematics teaching. For example, the teachers commented at length on the textbook series *Investigating Change: An Introduction to Calculus for Australian Schools* (Barnes, 1993) and *Access to Algebra* (Lowe, Willis, Kissane, & Grace, 1994), and these responses revealed much about their beliefs. These text series have many activities that are learner focused and encourage conceptual development through physical activity, discovering patterns, and then formalising the mathematics. Although it is an indirect way to collect data about beliefs, it is considered to be more effective than direct questioning (Ernest, 1989; Kagan, 1992). Similarly, teachers were questioned on their beliefs about the use of computers in mathematics teaching, for example, “How effective are computers compared with more traditional teaching practice for developing students’ higher-order thinking skills?”

**Exploring practice.** In this phase, teachers’ pedagogies were explored by observing and audiotaping several lessons for each teacher. Detailed field notes were kept on each lesson, and samples of student work were also examined. Following each lesson, the teacher was questioned about that lesson and why he or she had conducted it as he or she had.

**Responses to intervention.** In this phase, teachers’ beliefs about the use of computers were explored through interviews and indirectly by their responses to an intervention. The intervention involved the researcher constructing lessons on the specific topics that the teachers were about to teach in which the students would use the mathematics exploratory software Maths Helper (Vaughan, 1997). This software contains mathematics tools that enable students to explore mathematics concepts and engage in mathematical modelling. For example, it contains a line tool that can be placed on any curve to give the linear function of the tangent at that point, the maximum and minimum tool, an angle tool that gives readings in both degrees and radians, and an intersection tool. In addition, the software can calculate and plot derivatives, integrals, normals, and lines of best fit for most functions that students encounter in secondary mathematics, and it can display the results including the steps involved in the calculations. In one-to-one and whole group demonstrations, the first author briefed the teachers on the software and its potential use. The first author offered to construct additional lessons or modify existing class activities and to model the use of the software in mathematics teaching by teaching the classes in which the students would use the software. The lessons constructed by the first author involved exploration of the nature of quadratic functions, periodic functions, exponential functions, and derivatives of these, as well as mathematical modelling of phenomena for which these concepts were relevant. Most of the lessons involved students exploring the underlying concepts using Maths Helper (Vaughan) tools. Following the teaching of some teachers’ classes, the teachers were asked to critique the lessons and suggest changes. Their comments were informative about their beliefs about using exploratory software in mathematics teaching.
RESULTS
The results commence with an overview of the mathematics staff, which is followed by detailed case studies of three teachers selected to illustrate the process of constructing data summaries of the five teachers studied. These three teachers were also chosen because they reflected divergent beliefs and practices. Each of the three case study teachers is described in terms of their experience in teaching, familiarity with computers, and position of responsibility within the mathematics department. Their beliefs about mathematics and teaching are described along with classroom observations of lessons and interviews and discussions about those lessons. Each of the teachers' responses to the professional development intervention—that is, the first author's attempt to demonstrate teaching with technology—is also presented and discussed. The data from the five teachers studied are summarised, and the five teachers' perceptions about factors influencing computer use in the school are then presented. Finally, the influence of the discourse between individuals which helped form teachers' beliefs and practices and which had potential to affect the use of computers within the school's mathematics department is described.

Overview of the Staff
These data were collected from the completed survey forms. The mathematics staff was mature and experienced. Eva was the only staff member less than 35 years old. The average length of teaching service was 18 years.

Most of the teachers, including Peter and Emm, had taken no mathematics professional development courses in the last 12 months. Julie had been to six professional development sessions. Eva had not attended any in 1997, and she had attended only one session on problem solving in 1998. Except for Julie, the lack of almost any form of mathematics-related professional development education in the last 12 months was a reflection of the attitudes of both the coordinators and individual staff members. It was the responsibility of the two coordinators (Julie and Eva) to organise in-house professional development sessions for all mathematics teachers. This was not done in 1997. It was the responsibility of individual teachers to attend some of the many mathematics professional development opportunities that were offered by state and other education groups.

All teachers except Peter reported that lack of access and lack of knowledge of suitable mathematical software were important factors that limited their use of computers. This contradicts the statements of the computer studies coordinator, who reported that one laboratory had only approximately 10% usage. He stated that the mathematics department did not forward a plan for the use of computers at the beginning of each semester when block bookings of rooms were made. He further noted that there were "a few occasions only" when mathematics staff had complained about the lack of access, and that on each occasion staff had not negotiated with the other departments (who had block-booked computer resources) to determine if those staff in the other departments were actually using the rooms that they had booked. The computer coordinator also explained that each subject area was given an allocation of
money to spend on software, and the mathematics department had not spent their allocation in 1997 or 1998. These observations indicated that integrating the use of computers into the teaching and learning of mathematics appeared to be a low priority for most of the mathematics staff leadership.

Case Study 1: Eva

Eva was 28 years old, had received a bachelor’s degree in mathematics and psychology, and had taught at Hill View since she began teaching six years before. She had taken short professional development courses in Lotus and Microsoft Word and taught junior mathematics and Mathematics A (Board of Senior Secondary School Studies, 1992). In 1996, she was made coordinator of junior mathematics. In this position it was her responsibility to coordinate assessment, select resources, and organise professional development courses for the other junior mathematics staff. Other teachers who worked with Eva (Peter and Mary) claimed that she had a consensus style of management and she “listened and did not push a particular way of teaching.” Since Eva took over the junior mathematics responsibility, the frequency of open-ended student assignments had been reduced from approximately four per semester to one per semester. The use of the problem-solving, student-centred, and activity-based text *Access to Algebra* (Lowe et al., 1994) had been reduced and a traditional text adopted in its place.

In her responses on the survey instruments and in her discussions, Eva indicated that she placed a low value on using computers in mathematics education. She pointed out that computers could deprive students of valuable learning strategies, as “students don’t get the opportunity to work it out for themselves ... They’ve got a gadget to do it for them.” Eva favoured a clear explanation in class and doing the procedures manually because “going through the algorithms is very important because everything is based upon those algorithms.” Eva initially neither wanted the first author to show her the specialist investigative software Maths Helper (Vaughan, 1997) nor did she want him to teach her class a lesson on the quadratics topic using the software. However, the researcher subsequently taught two classes for her colleague Mary, who then urged Eva to look at the software. After the first author taught a lesson on quadratic functions to her class, Eva became more positive toward the software. She commented “The whole software package is easy to use ... and I think they enjoyed working with the computers.” Eva concluded that she might use the software after the theory had been done in class using traditional methods of explanation and practice. (“It worked because they had done the theory, they understood, they know what a quadratic is and how to factorise.”) She could then use the software to “show students where quadratics were going” and might use the software “on the big screen, [or] show them.” That is, Eva appeared to see the role of computers as limited to supporting her existing pedagogy, and she believed that technology would be best used following traditional teaching if time permitted. Her concern about not having enough time to allow her students to explore quadratic functions using the lessons prepared by the researcher or even setting them as a homework task is consistent with her focus on preparing her students to pass the semester test. For example, when the first author asked if he
could model the use of Maths Helper (Vaughan) by teaching her Year 10 class, she responded, "Well, considering our timing I'll see how I go and when the examination is, and we will take it from there." It should be noted that her students were well ahead of most other classes, and this test, which was five weeks away, was formative and only used to inform parents of their daughter's progress. Thus, it could be argued that she probably had no real reason to be concerned that her students would suffer by spending time learning their work with the assistance of Maths Helper (Vaughan). There may have been an additional reason that Eva was so concerned about the coming test. She had only been teaching for six years; thus, she may have been conscious of her lack of experience in comparison with her peers who had all taught for more than 20 years. She may have been anxious to ensure that her students performed well on all assessments, especially because she and Peter had the top streamed students. Latent competition among teachers has been previously cited as a hindrance to innovation (Hyde et al., 1994).

Six months after the data collection phase, Eva was presented with the following assertion for comment:

You have used graphing calculators occasionally, and this was usually after students had learnt the concepts through traditional instruction. The computing technology is good for illustrating a concept or doing computations quickly. One of the biggest factors limiting your use of computers is that they are not as efficient as your explanations (time wise) and you have a commitment to get your students through assessment.

Eva responded, "Absolutely! Spot on." In essence, this is a calculational orientation to the use of computers in mathematics teaching and learning.

Discussions with Eva indicated that she believed rules and procedures were the essence of secondary mathematics, and this belief had implications for the use of computers in her teaching. This image was reflected in her beliefs about the importance of learning algorithms. She explained:

Firstly, I think everything is based upon those algorithms. I mean mathematics is the universal language. It's based upon laws and theorems and algorithms. I think pressing a button and the computer giving the answer doesn't help students' understanding of what mathematics is all about. And they start to get the impression that mathematics understanding can be gained by pushing a button that generates all of this information. Eventually that's what happens. ... However, once you understand an algorithm you can start to see the links between all the types of mathematics. Students sometimes cannot see that all the various types of mathematics they all link together. Doing it that way (using technology to reduce the emphasis on procedure), they can't see the link.

Eva's description of her pedagogy and observations of her teaching confirmed that her pedagogy conformed to the description of content oriented with an emphasis on performance (Kuh & Ball, 1986). She liked to sit students in
rows, discouraged student communication, and made her explanations of rules and procedures clear by modelling them on the blackboard. For example, her teaching of trigonometry started by writing on the blackboard SOHCAHTOA (sine, opposite, hypotenuse, cosine, adjacent, hypotenuse, tangent, opposite, adjacent). indicative of a rule-based approach without a clear explanation of the concepts. Her students' exercise books contained no evidence of the derivation of concepts. She tightly controlled student discourse, justifying this by:

From the moment they meet me, every new class I have I make it very clear to them what my expectations are. I have only one simple rule, that is when I am teaching please do not distract me or anyone around you. I set those rules and make those expectations.

During question-and-answer sessions students who were fast at computation did parts of each solution. Students did not complete solutions and did not explain their reason for doing procedures a particular way. If students faltered, they were quickly passed over. Eva explained it was important for students to experience success. “The aim in the classroom is for the students to increase their confidence.” Ample evidence from classroom observations showed that Eva did not confront students with their lack of knowledge or misconceptions. Her responses on the survey instruments, her explanations of her pedagogy, and classroom observations confirm that she had a rule-based pedagogy based essentially on transmission of facts and procedures. The following assertion was presented to Eva by the researcher for comment:

In teaching in secondary school, you are concerned that students understand the rules and know how to apply them. Thus, your teaching is dominated by explanation and modelling procedures. Students need to attend carefully and be able to follow your demonstrations. So far you have not seen software that can help you in this regard.

Eva responded:

Well, in the sense that I really believe that the foundations (basics) have to be there, and I demonstrate them very clearly.

Earlier comments and observations supported the claim that she employed a predominantly transmission approach to teaching and that, at this point, she did not see a major role for computers in that process. Thus, it was apparent that (1) her beliefs about the nature of school mathematics were linked to her focus on teaching mathematics as a series of rules to be explained and (2) computers had a limited role in this process.

It can be concluded that Eva was prepared to use computers in a limited and calculational way to support her pedagogy focusing on content and emphasising performance, a pedagogy consistent with her beliefs that mathematical knowledge was best learnt by a process of transmission. She mostly saw the role of computers as doing large calculations, quickly graphing data, and demonstrating mathematics concepts.
Case Study 2: Peter

Peter had extensive experience in software that has been used in mathematics education, such as spreadsheets, Logo, function plotters, and statistics software. In addition, he had used Structured Query Language (SQL) to construct database shells for the school, constructed the school Web page, and set up spreadsheet templates for analysing the school sports results. His formal qualifications included a bachelor's degree, a Diploma of Education (a postgraduate preservice teaching award), a Graduate Diploma in Education for computer education (an inservice award in computer education), and a master's degree in information and technology. He taught both computing and mathematics in his technology-rich suburban secondary school at the time of the study, information processing and technology (IPT) to Years 11 and 12 students and mathematics to Years 10 and 12 students. He stated that personal lack of expertise in using computers was not important at all in influencing his use of computers in his teaching. After acknowledging that the school was rich in technology, he stated that, if he wished to, he could use computers quite extensively in his teaching of mathematics.

Peter rarely used computers in his teaching of mathematics because he saw their potential as calculational and he believed that they did not facilitate student conceptualisation. Peter reported that using computers in mathematics teaching was "less effective than traditional methods in developing higher-order thinking." However, he argued that they could be used to "do more complex situations where large numbers were involved" and "for crunching numbers." He stated, "I have not seen software that enhances students' mathematical thinking skills." Peter believed that computers were not useful in explaining mathematics concepts to students or in illustrating examples of mathematics procedures. He claimed that teacher explanation and student practice were most effective for teaching mathematics.

I would be extremely explicit, and I would be explaining things, the knowledge is coming from me, so I believe that I am explaining it. I am a great believer in example, learning by example, learning skills, and you actually learn skills from examples. Obviously, it needs prerequisite knowledge, and if you know the prerequisite knowledge you can just extend, extend slightly for people's area [of comfort] to be covering a new concept, then the students will be happy.

Peter's explanations gave insight into his image of teaching as well as his role as a teacher. He stated that students "should be able to perform basic skills and have the theoretical background to use numerical methods with understanding." The statements above support the conclusion that Peter had a content-focused pedagogy with an emphasis-on-understanding orientation toward teaching (Kuhs & Ball, 1986). In aiming to achieve this goal, he rejected learner-focused approaches because he believed that students would be like him and "much rather have an expert to help me quickly than spend hours trying to work out a solution for myself." He believed that software, including the exploratory software Maths Helper (Vaughan, 1997), could not aid in this pro-
As he explained, “I don’t think it [computer technology] should be a substitute for theoretical approaches.” For these reasons, Peter would not allow the first author to teach his Year 10 students about the nature of quadratic functions using Maths Helper (Vaughan).

Lesson observations showed that his practices supported his statements: he taught by example and explanation.

Peter compared the learning of mathematics to music learning. He said mathematics was “like a performance and, as in music, learning required that the student practise until the task could be done fast and faultlessly.” He stated: “I believe it is important to drill, in that there is a need for doing the same thing so many times it becomes second nature.” On his school Web site, he noted:

Teachers often convey information to the full student group orally, with perhaps the aid of visual cues. Teachers often give instructions and explanations using this technique because it can be a very efficient and economic way of communicating with a group of students. Listening should occur while performing no other tasks, apart perhaps, from taking notes on what is being communicated. It is imperative that all students listen to the teacher when required. Students need to practise their mathematics even after they have initially had success at a task, just like a musician practises a tune after she has learnt it.

In summary, Peter had an essentially calculational orientation in relation to the potential of computers in secondary mathematics learning. He did not believe that computer use (including spreadsheets and exploratory software) could compete with his existing teaching strategies in developing students’ abilities to do and understand mathematics. His reasons for not using computers in his teaching of mathematics related to his beliefs about the nature of secondary mathematics, teaching, and learning.

Case Study 3: Mary

Mary was in her fifties, had taught mathematics for 26 years, and had a bachelor’s degree in mathematics. She had also commenced a master’s degree in mathematics education. Before coming to Hill View, Mary was the mathematics coordinator at another private school. In 1997, she had attended three hours of training on WINGEOM and had also attended other professional development courses on mathematics education. She had no formal computer training but she was proficient in the use of the graphing program Capgraph (Clayton, Farrands, & Kennedy, 1996), the spreadsheet program Excel (1985–1999), and Word (1983–1999).

Mary used graphing calculators and mathematics computer software more than her colleagues. She expressed the view that computers could reduce the tedium of computations. Unlike Peter, Emm, and Eva, Mary did not see the necessity to practise these computations to gain an understanding of the underlying concepts. Although Mary had not previously used computers in Mathematics B (Board of Senior Secondary School Studies, 1992) other than graphing calculators, she saw the potential of Maths Helper (Vaughan, 1997). “It would
be really useful in sine and cosine. I think it would be really terrific. ... I also really like that radians/degrees thing. I'd like to see a bit more on how that angle tool works." Mary willingly let the researcher teach two lessons to her Year 10 mathematics class using Maths Helper (Vaughan). The topic of the lessons was quadratic functions. Mary specifically requested that part of the time be allocated to an applied problem. This request was consistent with her responses about the importance of locating mathematics in real-life contexts.

Mary saw computers as providing further opportunity to investigate real phenomenon using mathematics. Further, she stated that much of the mathematics contained in traditional texts presented a simplified model of reality that gave students an unrealistic view of the nature of mathematics. Mary considered that debunking this perception was a good thing. This view stands in contrast to that held by Peter and Eva. Mary concluded her comments on the intervention as follows:

I felt when they were reading through that problem at the end and working on it, well, they talked to each other and were working at their own pace. ... I liked that bit.

Her responses indicated that she would encourage students to use software to explore phenomena and to make sense of their observations. In addition, Mary recognised that the software offered her the opportunity to encourage her students to explore and model situations, tasks that previously would have been very difficult for some students because of the long computations involved. Finally, she saw the software as an opportunity to present to students an image of mathematics as a human construction that went beyond rules and algorithms. Thus, Mary appreciated the use of computers both as a calculational tool and as an aid to conceptualisation. After the data were analysed, the following assertion was given to her for comment:

You believe computers can help students to see the subjective part of this process [mathematics]; by using computers students can see that mathematics is not fixed and absolute, mathematics is just a fallible and approximate idea?

Mary responded, "Oh yeah, I agree with that." When she was further asked by the researcher whether she thought it important that students saw that subjectivity, she replied, "Oh yeah, oh yeah."

Mary's responses to the survey instruments indicated she was particularly concerned that mathematics be practical. Her comments about the textbooks she liked to use and about the pedagogical arguments she had with her colleagues revealed aspects of her beliefs about the nature of mathematics. Several years ago she had written a junior work program that included the use of the text Access to Algebra (Lowe et al., 1994). After Eva became the junior mathematics co-ordinator in 1997, the use of this text in Years 9 and 10 was then "voted out," and Mary anticipated it would soon be rejected in Year 8. Mary was disappointed with this decision.
Mary: I'm really upset that they are going to get rid of that Access to Algebra and I know they will. Because they don't want to have two books! Some people can't even handle that. They want one book, and they open the book, and it's got it [all] in. I mean, to a point, I'm not saying that they're that, that slavish, but they're fairly slavish.

First author: And the Access to Algebra was pushing discovery-type learning and also hands-on type of leaning?

Mary: And also explaining things. Now there are a lot of teachers here, they don't want them [students] to explain anything, they just want them to write numbers. They don't like it [Access to Algebra] because there are too many words for them.

Data from her comments on pedagogy, the survey instruments, and lesson observations all indicated that Mary had a learner-focused pedagogy as described by Kuhs and Ball (1986). It was important to Mary that students be actively engaged in constructing their own meanings. This was one of the reasons she liked the Barnes (1993) text. A rationale for her learner-focused teaching was contained in her comments about the Barnes resources:

Mary: I just like her [Barnes's] approach. It's a lot of doing. You've got to do it and explain it. I just feel it makes mathematics understandable to the kids. I like her approach to derivatives, to graphs, you know, where she does changes, and the way she gets to the derivative. I just like it. It just seems that she's got really good examples.

First author: Why is it important for the kids to be doing the activities like those in Mary Barnes?

Mary: Well, of course if they do it, they can get a better understanding of it rather than me telling them... I think, that they understand what they're doing and how it applies to problems that they're doing. For example, we've been doing rates. Last Friday we all went outside and walked and skipped and hopped and took the time and came back, changed metres per second into kilometres per hour, because that's how you like to think of it. And, that made a big difference.

In contrast to the classrooms of Peter and Eva, the classroom atmosphere of Mary's class was one of cooperative group work and open discussion. Mary explained that student discussion was very important.

They were telling each other what they were doing and why they were doing it. Helping each other... They learn a lot more from each other than when it comes from on high; they often tune out. For them to actually have to explain it to someone makes a lot of difference.

In the two observed classes, Mary acted more as a facilitator for the students' construction of their understandings rather than as a transmitter of concepts to
them. She accepted different ways that students did problems and asked them to explain their reasons. The highly social and discursive nature of her classes, including her insistence that students explain their answers, indicated that Mary believed that mathematical knowing has social as well as cognitive aspects.

In conclusion, Mary believed that computers could help students conceptualise mathematics and empower them to explore practical applications of mathematics. She had not used computers to a significant degree in the past in part because of a perception of lack of resources and lack of expertise.

Summary of Case Study Data

The beliefs and practices of the five senior mathematics teachers in the study school have been summarised in Table 2. The data for Julie and Emm were constructed in a similar way to that for Eva, Peter, and Mary.

Staff Discourse and Cultural Press

Mary was relatively isolated within the mathematics school culture. She had spoken candidly about the pedagogical and ideological tensions that existed within the department that influenced her pedagogy and that had implications for the use of computers in the teaching of mathematics.

Mary stated that she felt out-of-step with the school ethos, and this affected her morale, “Some days when all the teachers drive up in their Mercedes and whatever and don’t have any understanding of what it is like to be poor.” Mary used this description to illustrate that she thought that some of the teachers were “divorced from reality.” She reported, “I feel like with the talents that I have maybe they would have been better given to someone who needs them more ... because these kids are so privileged.” By contrast, Peter stated “I know it may be a bit elitist but it is important to aim for the top students.” Mary’s feelings of being out-of-step with the school ethos may have indirectly reduced her commitment to pedagogical reform including the use of computers within the school.

Mary did not share her peers’ values on assessment. Peter, Eva, Julie, and Emm seemed to have accepted the dominant role of examinations. They had accepted that getting students to “jump through hoops” was part of their responsibility as teachers. Peter stated “assessment is what we are about ... My teaching is geared towards assessment.” Eva carefully drilled the rules and algorithms that would be on the next examination and explained that “algorithms are very important since everything is based upon those algorithms.” Julie would not allow the researcher to use software to teach her classes because internal examinations were scheduled in a month’s time. Emm stated that her main goal was to prepare “good students for tertiary entrance and help poor students gain a sound achievement.” Mary, however, lamented this: “They’re [her peers] so mark-orientated! You know! The whole community is like that, the parents are and the principal is like that, too.” She explained her feelings about use of the Barnes (1993) resource, “If you use it more than the others, and they write the test and don’t incorporate that way of thinking, you know, you’re just up the creek!” The same argument is likely to apply to the use of computer technology to facilitate student exploration of mathematical concepts.
# Table 2. Summary of Data from Hill View

<table>
<thead>
<tr>
<th>Variable</th>
<th>Eva</th>
<th>Mary</th>
<th>Peter</th>
<th>Julie</th>
<th>Emm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Junior mathematics coordinator</td>
<td>Senior teacher</td>
<td>Senior teacher</td>
<td>Senior mathematics coordinator</td>
<td>Senior teacher</td>
</tr>
<tr>
<td>Beliefs about computer usage in mathematics teaching</td>
<td>Calculational and possibly demonstrative</td>
<td>Calculational and conceptual</td>
<td>Should not be used</td>
<td>Calculations and demonstrations</td>
<td>Calculations and demonstrations</td>
</tr>
<tr>
<td>Use of computers</td>
<td>Rarely</td>
<td>Rarely but would like to use them much more</td>
<td>None</td>
<td>Rarely</td>
<td>None</td>
</tr>
<tr>
<td>Stated main reason for not using computers more</td>
<td>Lack of expertise, concerned that using computers is not as effective and efficient as explanation</td>
<td>Lack of expertise, lack of models of how to integrate technology into mathematics teaching</td>
<td>Belief that they could hinder learning and do not prepare students for assessment</td>
<td>Lack of expertise and interest, belief that student use of computers is not as effective as other methods</td>
<td>Belief in clear explanation as the most effective and efficient way of teaching mathematics</td>
</tr>
</tbody>
</table>
Table 2. cont.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Eva</th>
<th>Maty</th>
<th>Peter</th>
<th>Julie</th>
<th>Emm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special contributions</td>
<td>Flexible attitude and may have been influenced by researcher's demonstration, consensus leadership</td>
<td>Ideologically isolated in this staff community</td>
<td>The mathematics teacher with the most computer expertise rejected their use in mathematics teaching</td>
<td>Displayed passive leadership</td>
<td>Supported conservatism in teaching with an emphasis on logical explanations</td>
</tr>
<tr>
<td>Pedagogy</td>
<td>Content-focused with an emphasis on performance</td>
<td>Learner-focused</td>
<td>Content-focused with an emphasis on understanding</td>
<td>Content-focused with an emphasis on understanding</td>
<td>Content-focused with an emphasis on understanding</td>
</tr>
</tbody>
</table>
Peter, Eva, and Emm all liked tight control over their students' activities and insisted on compliance and obedience. This was strongly manifested in the nature of their classroom discourse. In their classes, the teacher did almost all the talking, and students were limited to very precise responses. Peter and Emm liked to decide what skills and activities were appropriate for the students to such a degree that they both decided it was inappropriate for their students to be exposed to mathematical software. Julie simply stated she was too busy to investigate the use of software in mathematics teaching at this point. Further, she noted that her senior class was already a week behind Emm's class. In contrast to the highly structured discourse in her peers' classes, in Mary's classes students were asked to explain their constructs in their own words; the discourse in Mary's classes was much more democratic. Mary recognised her isolation in regard to her pedagogy and desire to use software such as Maths Helper (Vaughan, 1997) in her teaching. She stated, “I will do my own thing” and “try not to get too worried and worked up about things.”

Most of the senior mathematics teachers had formed the opinion that investigating the potential of using software such as Maths Helper (Vaughan, 1997) was not a high priority. It was Mary's perseverance in convincing Eva that it would be worthwhile that enabled the researcher to conduct professional development for Mary, Eva, and three other junior mathematics teachers in the use of Maths Helper (Vaughan) mathematics teaching. Peter, Emm, and Julie did not attend this group session and rejected subsequent offers for professional development on the use of Maths Helper (Vaughan) or for the researcher to teach their classes using the software. In this way, they rejected the opportunity to evaluate models of teaching that might have differed from their own. Thus, three of the key decision makers demonstrated through their actions a low regard of this type of pedagogical input.

DISCUSSION

Despite the availability of computers for the mathematics staff, computer use in mathematics teaching at Hill View was almost nonexistent. Teachers' images of mathematics teaching and learning, pedagogy, and use of technology appeared to be related to the low level of use. The teachers described as showing a transmission/absorption image of teaching and learning (which was articulated in teacher-centred pedagogy) recognised the calculational potential of computers. That is, these teachers indicated that they would use computers to support their present transmission of mathematical knowledge or to take the tedium out of large computations. However, Peter and Eva also noted that student use of computers could have negative effects. For example, they noted that student use of computers could deprive students of the opportunity to practise basic skills and procedures that they believed were the essence of secondary school mathematics learning.

The extent to which teachers were likely to use computers was related to their beliefs about the time effectiveness of teaching with computers. Mary’s peers believed that their current teaching practices were more efficient and effective in meeting their educational goals of covering the syllabus and helping students to
pass examinations than having students use computers. This low evaluation of
the potential of computers to enhance secondary school mathematics learning
found expression in their unwillingness to investigate its potential. By contrast,
Mary’s image of learning was more closely aligned with a social constructivist
view of teaching and learning. Her pedagogy reflected this by embracing ele­
ments of a learner-focused pedagogy. Mary saw computers as a tool by which
students could construct mathematical meaning and explore the fallible nature
of mathematics. That is, she believed students could use computers to help
them conceptualise mathematical concepts and as a calculation tool and as an
instrument for demonstration.

Mary may have been an instigator of change in relation to the use of comput­
ers in this school. Unfortunately she was already ideologically and pedagogically
isolated within the school; she held different opinions about assessment, success
and failure, text preferences, and authority. These differences were likely to di­
minish her ability to influence her peers and also to use computers with her
own classes. The rejection of students’ investigative use of computers was linked
to their reasons for their rejection of the Barnes (1993) and Lowe et al. (1994)
resources. That is, these resources were not used because the pedagogy, which
was implicit in the activities contained in these resources, did not support the
teacher’s preferred teaching strategies. It has been argued that the use of soft­
ware such as Maths Helper (Vaughan, 1997) was rejected in part because it did
not support the teachers’ preferred methods of teaching.

In this school, Mary’s task of persuading her colleagues to integrate the use of
computers, especially exploratory software, into their teaching is likely to be dif­
ficult. Further, in order to have her students use computers, she would have had
to persuade her colleagues to do likewise because they had greater control over
the selection of resources, such as textbooks and software purchased, and be­
because they defined the nature of student testing. Mary had stated in April 1998
that she would attempt to persuade the mathematics department to purchase
copies of Maths Helper (Vaughan, 1997). By the end of April 1999, no attempt
had been made by that school to purchase the software. It is true she was able to
engage in learner-focused teaching methods in isolation. However, given the
added logistics of purchasing software, booking computer access, and covering
the same work program in which computers played no part, it seems unlikely
that she will be able to “do her own thing” with regard to the use of computing
technology in her mathematics teaching. Finally, she said, “I have decided not
to worry about it. In the grand scheme of things is it worth getting all worked
up about it? Life has a lot more to offer.” This sounded like an admission that
she recognised that it was probably going to be too much effort to convince
other teachers to embrace the conceptual use of computer technology such as
Maths Helper (Vaughan) in their teaching. Finally, she lamented, “If we get the
software, they will expect me to write all the lessons for it.” This was a burden
she was not looking forward to. Thus, she is likely to be forced into compliance
and not be able to use computers to the extent that she wishes. The collabora­
tive patterns among the teachers in this school have important implications for
educational change (Becker, 1994; Riel, 1994; Sarama et al., 1998).
CONCLUSIONS

At Hill View it appeared that most of the senior staff had philosophical and educational reasons for rejecting the integration of computers into mathematics learning. Because their nonuse was essentially based on their beliefs, they did not feel it was necessary to take action to increase their expertise with software and ensure access. In this way, the teachers could continue to say that access and knowledge of suitable software was a major obstacle to their use of computers, although it may not have been the root reason.

The limited image of the potential of computers in mathematics teaching was able to dominate the culture of the mathematics staff in part because of the consensus leadership styles of Julie and Eva. This leadership style was such that much of the responsibility for professional development was up to individual teachers. Further, the nature of the staff discourse was such that the conservatism of Peter and Emm dominated mathematical teaching reform in terms of the use of computer technology.

Many implications emerge from this study. First, simply having the technology resources in the school does not necessarily mean that the mathematics staff will use them in their teaching. Educational planners wishing to increase the use of computers by students in their learning of mathematical concepts may need to account for teachers’ images and beliefs about mathematics teaching and learning. In addition, the findings of this study suggest that when planning professional development programs, professional development providers need to consider not only individual teachers’ beliefs, images, and attitudes, but also the staff dynamics within the working cultures in which individual teachers are embedded. Evidence from this study indicates that changing teachers’ beliefs may be a difficult task. In the study school, it appeared that the mathematics staff culture was such that insufficient critical momentum or critical desire for reform existed. The implication of this is that if reformers wish to encourage teachers to adopt the potential of computers, the teachers need to be convinced that the use of computers can make their tasks more effective and efficient than their current strategies. Further, it appears that for innovative use of computers to become reality, positive and sustained leadership is needed. The data from this study have demonstrated that unsupported reform driven by individuals who lack status and support is likely to fail. This appears likely because (1) the tasks of developing new material and implementing new methods are considerable and (2) at least in the short term, the innovative teachers may feel they are disadvantaging their students in completing assessment tasks. Thus, attempts to encourage teachers to explore the potential of computers need to consider individual beliefs, group dynamics of the staff, and structural factors that support the status quo. Such factors include the types of texts, resources, and assessment criteria that exist in a school.

Contributors

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References


Kuhs, T., & Ball, D. (1986). Approaches to teaching mathematics: Mapping the domains of knowledge, skills, and dispositions. East Lansing, Michigan State University, Center of Teacher Education.


