Learning to Teach Mathematics With Technology: A Study of Beliefs-In-Context

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This three year study is investigating the pedagogical practices and beliefs of pre-service and beginning teachers in integrating technology into the teaching of secondary school mathematics. A case study of one student teacher explores the influence of beliefs, attitudes towards technology, and constraints and affordances in the practicum school environment in shaping her identity as a teacher. The opportunity to experiment with technology-based lessons may assist beginning teachers to persist with the innovative approaches promoted by pre-service methods courses.

One of the major themes in current debates on educational reform identifies the need for teachers to become more effective, confident, and creative users of technology in their teaching (e.g., Web-Based Education Commission, 2000). As a result, there is growing recognition that pre-service teacher education programs should integrate technology into their own curricula to ensure beginning teachers are adequately prepared (McCoy, 1999). Within mathematics education, research studies have yielded descriptions of pre-service methods courses that help student teachers design technology enriched lessons or learning activities using, for example, spreadsheets, (Connell & Abramovich, 1999), multimedia (Kim, Sharp, & Thompson, 1998), and the Internet (Halpin & Kossegi, 1996). As graphics calculators are a relatively new technology their impact on teacher education courses has so far received little research attention. Nor has previous research looked at how neophyte mathematics teachers incorporate technology into their practice. These are gaps to be specifically addressed in a three year longitudinal study (2002-2004) that follows three successive cohorts of Bachelor of Education students into their initial years of teaching. The aim of the study is to investigate and compare the pedagogical practices and beliefs of pre-service and recently graduated teachers in integrating technologies such as graphics calculators, computers, and the Internet into the teaching of secondary school mathematics.

Technology, Pedagogy, and Teacher Education

Numerous research studies have examined the effects of technology use on school students' mathematical achievements and attitudes, and their understanding of mathematical concepts. However, less is known about relationships between technology use and issues of pedagogy, and the impact of new technologies on teachers' professional learning (Penglase & Arnold, 1996). Research on technology use by mathematics teachers has identified a range of factors influencing uptake and implementation, including: beliefs about mathematics and how it is learned; knowledge of how to integrate technology into mathematics teaching; previous experience in using technology; time and opportunities to learn (pre-service education, professional development); access to hardware (computers and calculators), software, and computer laboratories; availability of appropriate teaching materials; technical support; and support from colleagues and school administration (Fine & Fleener, 1994; Manoucherhri, 1999). However, studies such as these rarely consider possible relationships between beliefs, actions, and context, beyond treating contextual factors, such as lack of access to material or human resources, as an obstacle limiting teachers' capacity to put their beliefs into practice.

In reviewing research on mathematics teacher education, Lerman (2001) argues that the study of teacher beliefs is too static and decontextualised to adequately explain these apparent mismatches between beliefs and actions. He maintains that beliefs are related to the context in which they are elicited, and cannot simply be mapped onto practice as if the two were separate and stable entities, able to be examined via different instruments in different settings. This means that specific situations are "*productive* of beliefs, practices, purposes, and goals, not reflective of them" (p. 44, emphasis added). Lerman points to the work of Vygotsky (1978) and followers (e.g. Lave & Wenger, 1991) in suggesting that research on teaching and teacher education needs to look at individual teachers through their social settings. In such an approach, teachers' learning is understood as changing participation in sociocultural practices that develop their identities as teachers. The purpose of this paper, then, is to begin to explore the influence of a range of personal factors (beliefs about mathematics and mathematics education, attitudes towards technology) and contextual factors (affordances and constraints in the school and classroom environment) in shaping the pedagogical identities of pre-service mathematics teachers as users of technology.

The Research Study

Following a pilot study conducted in 1999-2000 (see Goos, 2002, for details), the present three year project was designed to span the transition from pre-service to beginning teaching of secondary school mathematics. Participants are prospective secondary mathematics teachers enrolled in a pre-service Bachelor of Education (BEd) program, which is available to undergraduates as a four year dual degree or to graduates as a single degree taken in four semesters over eighteen months. Students undertake mathematics curriculum studies as a single class group, in a one year course over the fourth year of the Dual Degree and the first two semesters of the Graduate Entry program. Twice during this year all students complete a seven week block of practice teaching.

The pre-service methods course (taught by the author) aims to create a learning environment consistent with recent curriculum reforms (e.g., Australian Education Council 1991) and socioculturally oriented research in mathematics education (e.g., Goos, Galbraith, & Renshaw, 1999) in emphasising mathematical thinking, real world applications, and collaborative inquiry. BEd students also experience regular and intensive use of graphics calculators, computer software, and Internet/multimedia applications (see Goos, 1999). Integration of technology into mathematics education is emphasised through continuous personal access to a graphics calculator for the duration of the course (including the practicum), assignment tasks that ask students to prepare technology related classroom activities, and encouragement for students to contribute to the professional community through publication of resources they have produced and presentation of student workshops at professional association seminars and conferences.

Research Design and Data Collection Methods

This paper draws on 2002 data from: (a) a cohort study (n = 18) of pre-service students' beliefs about mathematics teaching and learning, and their practicum experiences in technology integration; and (b) individual case studies of selected students.

Cohort study. All students were asked to complete a Technology Survey of their schools during the first practicum session (April/May 2002) to record information on the availability and accessibility of technology resources (computers and graphics calculators), and the frequency and mode of technology use during lessons they observed or taught, and in assessment tasks. Students were also asked to share their findings electronically via the course bulletin board in response to questions posted by the lecturer/researcher.

Students' mathematical and pedagogical beliefs were investigated by administering at the beginning and end of the one year course a questionnaire that focused on their beliefs about the nature of mathematics, mathematics teaching, and mathematics learning (see Frid, 2000). The questionnaire consists of 40 statements to which students respond using a Likert-type scale based on scores from 1 (Strongly Disagree) to 5 (Strongly Agree), with a score of 3 corresponding to Undecided. The statements are underpinned by current research on mathematics teaching and learning and are representative of the values enacted in the pre-service course.

Section 1 includes 14 statements about the nature of mathematics, Section 2 has 12 statements about mathematics teaching in secondary schools, and Section 3 has 14 statements on mathematics learning in secondary schools. Within each section, statements are paired to create positive and negative poles of a particular idea; for example, items 27 and 34 represent contrasting positions with respect to mathematics learning:

27. Mathematics learning is about learning to get the right answers.
34. Understanding ideas and procedures in essential in mathematics learning.

In the literature these poles have been variously referred to as representing beliefs about mathematics being transmissive versus child-centred (Perry, Howard, & Tracey, 1999), or rule-based versus non-rule-based (Tharp, Fitzsimmons, & Ayers, 1997).

Case studies. Six students were also selected for individual case studies to represent a range of initial school placements (government vs independent schools, capital city vs regional location) and program formats (Dual Degree vs Graduate Entry). These students were visited in their schools during the second practicum session, in September 2002. (Further school visits to these recently graduated students are planned for 2003-2004.) The school visits involved lesson observations, collection of teaching materials, and audiotaped interviews. A Post-lesson Interview assisted participants to reflect on pedagogical beliefs that influenced lesson goals and methods, while a more general Technology Interview sought perceptions of constraints and opportunities affecting technology integration, and the influence of technology on mathematics curricula, learning, teaching, and assessment.

Cohort Study: Beliefs Versus Contexts

General pedagogical beliefs of mathematics teachers seem to be reflected in the ways they use technologies such as graphics calculators in the classroom (Tharp, Fitzsimmons, & Ayers, 1997). For example, teachers who view mathematics as more rule-based and procedural, and mathematics learning as involving memorisation and symbol manipulation, are more likely to use calculators only as a checking device or graphing tool, if at all. On the other hand, teachers with more inquiry-based views about mathematics are more likely to use calculators as a means of developing students' conceptual understanding.

Pre-service students' espoused beliefs were investigated via the Mathematical Beliefs Questionnaire described previously. Since the item scores ranged from 1 (Strongly Disagree) to 5 (Strongly Agree), and there were 12 students who completed the questionnaire both pre-course and post-course, the total score on any item could vary from 12 to 60. The magnitude of scores is important for indicating the degree of support for each statement; thus scores of 48 or more, and 24 or less, were taken as indicating general agreement and general disagreement respectively with particular statements. Also, a shift in scores of 6 – equivalent to half the class changing their score by 1 in the same direction – was considered as having some significance.

Space limitations prevent presentation here of full results of the questionnaire analysis (see Goos & Bennison, 2002, for these details); however, score totals for representative item pairs from each Section are shown in Table 1. Statements with which the group as a whole generally agreed or disagreed are indicated by <u>underlined</u> score totals, while shifts in beliefs are indicated by score totals in bold type. This analysis suggests that the group of students entered the BEd course with relatively student-centred, non-rule-based beliefs – concerning, for example, the creative nature of mathematical activity, the teacher's role as encouraging exploration, and learning by using manipulatives and real life examples – and that these beliefs were maintained throughout the year. In addition, there were some shifts towards less procedural views of mathematics, as students became less convinced that mathematics is something that is either right or wrong, best learned progressing through a step-by-step sequence and practice on lots of problems. Thus students' mathematical and pedagogical beliefs, as elicited through questionnaires, seemed to be conducive to the use of technology for developing conceptual understanding.

However, quite a different picture emerged from the students' Technology Surveys of their practicum schools. Eighteen students completed the first practicum session: 13 were placed in government schools, two in independent schools, and three in Catholic schools. Fourteen schools were in the Brisbane metropolitan area, and four in regional or remote locations. Fifteen students used the Survey instrument and/or course bulletin board to provide information on availability, access, and observed use of computer and graphics calculator technologies in mathematics lessons.

While all schools had computer laboratories, most of the pre-service students noted that access was difficult due to frequent use by non-mathematics classes and the need to book the laboratories some weeks in advance of a lesson. Nine of the 18 BEd students saw no use of computers in mathematics lessons during the seven week practicum, and a further three reported observing their use only two or three times in this period. All but two schools had graphics calculators – the exceptions being a P-10 school in far western Queensland and a new school with only Years 8 and 9 students. Year 11 and 12 students in non-government schools were usually required to buy their own calculators, while in government schools classes had to share a small number of class sets. Apart from the two students placed in schools with no graphics calculators at all, a further nine reported observing little or no use (i.e., less than two or three occasions) during the practicum.

Taken together, these findings concerning pre-service students' beliefs and practicum contexts might lead to the conclusion that they had little hope of incorporating technology into their mathematics teaching in ways consistent with the inquiry-based views of teaching and learning promoted by the BEd methods course. However, this analysis does not take account of the highly contextualised nature of beliefs and the negotiation by individuals of relationships between their beliefs, actions, and teaching environment. The following section considers these relationships in a case study of one pre-service student (Lizzie) whose responses to the Mathematical Beliefs Questionnaire and Technology Survey were typical of the BEd group.

Table 1
Representative Pre- and Post-Course Responses to Mathematical Beliefs Questionnaire

		Score Totals	
	Questionnaire Item	Pre	Post
(+)	9. In mathematics there are often several different ways to interpret something.	**45**	**53**
(-)	2. In mathematics something is either right or it is wrong.	**39**	**31**
(+)	7. Doing mathematics involves creativity, thinking, and trial-and-error.	54	52
(-)	14. Solving a mathematics problem usually involves finding a rule or formula that applies.	41	37
(+)	17. The role of the mathematics teacher is to provide students with activities that encourage them to wonder about and explore mathematics.	52	55
(-)	23. Good mathematics teachers only teach what is important for mathematics tests.	24	21
(+)	20. Good mathematics teaching involves class discussion in which students share ideas and negotiate meanings.	**47**	**53**
(-)	26. Good mathematics lessons progress step-by-step in a planned sequence towards the lesson objectives.	**47**	**38**
(+)	30. Calculators can assist mathematics learning by serving as tools for exploration and consolidation of ideas.	46	48
(-)	37. Students who have access to calculators learn to depend on them and do not learn computational skills properly.	36	34
(+)	33. Use of physical objects and real life examples to introduce mathematics ideas is an essential component of learning mathematics.	55	54
(-)	40. Doing lots of problems is the best way for students to learn mathematics.	**44**	**37**

Note. Item totals are sums of scores for the 12 students who completed the questionnaire pre-course and post-course. Strongly Agree = 5, Agree = 4, Undecided = 3, Disagree = 2, Strongly Disagree =1.

Case Study: Beliefs-In-Context

Lizzie's responses to the Mathematical Beliefs Questionnaire at the start of the course were similar to the pattern displayed by the BEd group as a whole, and in some cases her beliefs tended to be even less procedural and teacher-centred. In particular, for the items displayed in Table 1, she *disagreed* with the negatively phrased statements in Items 2, 14, and 37 whereas the class as a whole was somewhat undecided about these at the start of the year. Her practicum placement was in a government school in an outer Brisbane suburb, attended by approximately 600 students, where she was assigned to teach a Year 9 Mathematics extension class and a combined Year 11/12 Mathematics C class. (Mathematics C is a specialist subject usually taken by high achieving and well motivated students). Although the school had four computer laboratories, Lizzie reported it was difficult to gain access due to high use by other non-mathematics classes. The four Year 11 and 12 mathematics classes that had access to graphics calculators shared two class sets; however, Lizzie had rarely seen these used during her practicum. Nevertheless, she incorporated graphics calculators into both the Year 9 and Year 11/12 lessons observed during a visit to the school near the end of the second practicum session. Observations and interviews associated with the former lesson are analysed here.

In the Year 9 lesson, which came at the end of a unit on linear equations, Lizzie introduced students to graphics calculators for the first time to help them see how changing the values of m and c in the formula $y = mx + c$ changed the appearance of the graph. This involved using an activity she had created and presented in a BEd workshop for an assignment earlier in the year. She distributed paper tangram pieces and asked students to work in pairs to position the pieces on grid paper so as to reproduce the picture of a sailing boat she displayed on an overhead transparency. Students then had to record the coordinates of the vertices of each tangram piece, transfer these into lists in the graphics calculator, and produce a scatterplot that resembled a dot-to-dot picture of the boat. The task was then to estimate equations of the straight lines forming the sides of each tangram piece, enter these into the calculator's Y= editor (with suitable specification of the domain), and graph the equations over the scatterplot to make a finished picture that matched the tangram construction. Intelligent adjustment of gradient and intercept to produce lines of better fit was integral to the task.

This lesson represented a significant departure from the teaching style Lizzie had felt obliged to adopt during the practicum, which she described in the following terms:

> Come in, put a few questions on the board, get them started and settled down. Then I might introduce a new concept or a new way to do something, just introduce that in a few examples, they copy those into their books. Do a set from the textbook and go through and correct them. Generally I show them the way to do it and then they just practise and rehearse it over and over again.

Although she admitted that the prospect of the research visit had been partly responsible for her using the graphics calculators, she clearly treated this as an opportunity to experiment with more interactive teaching approaches incorporating technology as a means of achieving deeper understanding of concepts:

> I would love to have more lessons like that, more sort of interactive where they are working with somebody else (...) rather than just sitting there and doing their individual work. (...) It's just better than giving an equation and saying "what's this gradient? what's this y-intercept?" It's sort of embedding what an actual gradient is and what a y-intercept is. It's a deeper knowledge rather than just the surface stuff which they are quite capable of doing.

In the post-lesson interview, Lizzie identified several constraints within her teaching environment that might have stood in her way in using technology in this lesson: the students' previous lack of access to (and hence experience with) the calculators; pressure to "cover" content before the test at the end of the unit; and models of teaching that emphasised learning by practising on textbook exercises. Rather than preventing her from attempting a different teaching approach, these contextual factors were mediated by Lizzie's non-rule-based beliefs about mathematics teaching and learning and how technology might play a role in motivating learning and aiding visualisation of concepts. Consequently, she was able to interpret some aspects of her situation as *affording* her use of technology. First, this group had worked through the equations unit more quickly than other Year 9 classes and time was therefore available to try a different type of activity; second, the infrequent use of the class sets of calculators by Year 11 and 12 classes made it relatively easy to obtain them for this lesson; finally, she had already developed and trialed the activity with her pre-service BEd colleagues. In the absence of pedagogical models of technology use within her practicum school, Lizzie drew on her own beliefs about teaching and learning together with ideas and experiences from the pre-service course to take advantage of specific features of her teaching environment and try out a technology-based lesson.

Discussion and Implications

This paper has reported on some initial findings of a three-year longitudinal study of the professionalisation of beginning teachers of secondary school mathematics, where the focus is on how participants integrate technologies such as computers and graphics calculators into their pedagogical repertoires. Whereas previous research in this area has tended to identify features of the school and classroom context as constraints that can run counter to beliefs and interfere with practices, the present study is investigating relationships between beliefs and the contexts in which they are elicited and enacted. Lerman (2001) argues that teachers' beliefs are contextualised to both the data gathering situation and the specific teaching setting. This point was illustrated via contrasting analyses of pre-service students' mathematical and pedagogical beliefs and their practicum experiences in technology integration. Information gained from questionnaires and surveys, while useful in providing an overview of students' beliefs and teaching conditions in their schools, cannot on its own explain how beliefs are related to practice. For this reason an analysis was presented of the experiences of one pre-service student in her teaching context – the social setting in which beliefs and practices come together to produce new elements of a pedagogical identity.

Lizzie did not consider herself an expert with graphics calculators – she noted, for example, that she still consulted the calculator manual and continually searched the Internet for additional teaching ideas. Nevertheless, because of her exposure to technology through the BEd course she was regarded as an expert by other teachers in the school. She also mentioned that, unlike these other teachers, she was willing to take risks in using unfamiliar calculator features with a class, and felt comfortable in admitting mistakes or accepting help from the students in her classes. For Lizzie, learning to teach with technology appeared to be part of the process of developing her identity as a teacher, whereas for other teachers it may have represented a threat to the pedagogical identities they had already established. Lizzie's experience raises the question of whether successful experimentation with technology-based lessons could provide the impetus for beginning teachers of secondary school mathematics to persist with the student-centred teaching approaches typically promoted by pre-service methods courses. That is, a beginning teacher's technology expertise could anchor forays into innovative teaching territory and help avoid the familiar problem of reversion to the teaching styles used by their own school teachers or modelled during the practicum. These and other issues will be investigated as the study follows Lizzie and her peers into their first years of teaching.

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