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Learning to Teach Mathematics with Technology: A Survey of Professional Development Needs, Experiences and Impacts

Anne Bennison
The University of Queensland

Merrilyn Goos
The University of Queensland

The potential for digital technologies to enhance students' mathematics learning is widely recognised, and use of computers and graphics calculators is now encouraged or required by secondary school mathematics curriculum documents throughout Australia. However, previous research indicates that effective integration of technology into classroom practice remains patchy, with factors such as teacher knowledge, confidence, experience and beliefs, access to resources, and participation in professional development influencing uptake and implementation. This paper reports on a large-scale survey of technology-related professional development experiences and needs of Queensland secondary mathematics teachers. Teachers who had participated in professional development were found to be more confident in using technology and more convinced of its benefits in supporting students' learning of mathematics. Experienced, specialist mathematics teachers in large metropolitan schools were more likely than others to have attended technology-related professional development, with lack of time and limited access to resources acting as hindrances to many. Teachers expressed a clear preference for professional development that helps them meaningfully integrate technology into lessons to improve student learning of specific mathematical topics. These findings have implications for the design and delivery of professional development that improves teachers' knowledge, understanding, and skills in a diverse range of contexts.

The importance of using of technology to support mathematics learning is now widely recognised. In the 1990s mathematics curriculum policy in Australia began to promote the use of technology to support students' learning and develop their understanding of mathematical concepts (Australian Association of Mathematics Teachers, 1996; Australian Education Council, 1990). The intent of these national policy documents is reflected in various state and territory curriculum statements and syllabuses that now permit, encourage, or require the use of digital technologies in secondary school mathematics (e.g., Department of Education and Children's Services, 2005; Queensland Studies Authority, 2009a, 2009b; Victorian Curriculum and Assessment Authority, 2005). The use of information and communication technologies (ICT) is also embedded in professional standards published by teacher registration authorities (e.g., see Queensland College of Teachers, 2006) and the Australian Association of Mathematics Teachers (2006). These bodies also recognise the need for teachers to engage in continuing professional development to improve their knowledge, understanding, and skills in teaching and learning. In Queensland, the location of our research, participation in continuing professional development is voluntary with opportunities provided by professional associations, school sector authorities, and individual schools. These activities are generally offered outside normal school hours, on weekends, or during vacation periods.

We have recently reported on a state-wide survey of mathematics teachers' use of computers, graphics calculators, and the Internet in Queensland secondary schools (Goos & Bennison, 2008). In the latter paper we examined relationships between teachers' use of technology and their pedagogical knowledge and beliefs, access to technology, and professional development opportunities. In the light of current policies on the use of ICT and requirements for continuing professional development, it is appropriate to ask about the characteristics and needs of teachers who participate in professional development activities and whether there is any relationship between participation and changes in teachers' knowledge, understanding, and skills in teaching with technology. These are some of the issues we explore in the present paper, which takes a closer look at the technology-related professional development experiences of the teachers who participated in our survey. The theoretical background to our analysis draws on research into teacher learning and development, particularly in the context of technology integration in school mathematics.

Theoretical Background: Technology Integration and Teacher Learning

Although the potential for mathematics learning to be transformed by the availability of digital technologies such as computers, graphics calculators, and the Internet is well accepted, research in many countries has found that technology still plays a marginal role in mathematics classrooms and that curriculum mandates, access to technology resources, and institutional support are insufficient conditions for ensuring effective integration of technology into teachers' everyday practice (e.g., Cuban, Kirkpatrick, & Pack, 2001; Hoyles, Legrange, Son, & Sinclair, 2006; Ruthven & Hennessey, 2002; Wallace, 2004). Survey research carried out in Australasia over the past 10 years has investigated relationships between mathematics teachers' use of technologies and a range of factors that might facilitate or hinder use (Forgasz, 2002; Routitsky & Tobin, 1998; Thomas, 2006; Tobin, Routitsky, & Jones, 1999). This research found that although frequency of technology use is clearly related to access to computers, software, and class sets of graphics calculators, teachers' lack of skill and confidence and their uncertainty about the benefits of technology for students' mathematics learning were also important factors that discouraged greater use.

In our own research, which largely comprises longitudinal case studies of technology-related innovation, we have developed an adaptation of Valsiner's (1997) zone theory of child development to investigate interactions between teachers, students, technology, and the teaching-learning environment (e.g., see Goos, 2008, 2009). This framework extends Vygotsky's (1978) concept of the zone of proximal development (ZPD) to incorporate the social setting and the goals and actions of participants. Valsiner describes two additional zones: the zone of free movement (ZFM), which structures learners' interactions within the learning environment, and the zone of promoted action (ZPA), representing the actions of a more experienced or knowledgeable person to promote specific types of learning. When applying zone theory to teachers' professional learning, we interpret the ZFM as constraints within the school environment, such as student characteristics, access to resources and teaching materials, and curriculum and assessment requirements, while the ZPA represents opportunities to learn from preservice teacher education, colleagues in the school setting, and professional development. When teachers are the learners, the ZPD becomes a set of possibilities for development that are influenced by their mathematical and pedagogical knowledge and beliefs. This pedagogical knowledge must include knowledge of how to successfully integrate knowledge of content and knowledge of technology in order to promote mathematics learning. Thomas and Hong (2005) have called this pedagogical technology knowledge (PTK) and it has been suggested that PTK can be used as a framework by researchers investigating mathematics teachers' use of technology (Thomas & Chinnappan, 2008).

We argue that our zone theory framework allows us to make sense of the different types of teacher knowledge, experience, and contexts that previous research has shown to be vital to effective integration of digital technologies into mathematics teaching and learning (e.g., Fine & Fleener, 1994; Forgasz & Prince, 2001; Manoucherhri, 1999; Simonsen & Dick, 1997; Walen, Williams, & Garner, 2003). Table 1 classifies these factors as elements of the zones of proximal development, free movement and promoted action.

Table 1
Factors Affecting Technology Use

Valsiner's Zones	Elements of the Zones
Zone of proximal development	Skill/experience in working with technology General pedagogical knowledge Pedagogical technology knowledge (technology integration) Pedagogical beliefs (technology; mathematics)
Zone of free movement	Access to resources (hardware, software, teaching materials, time) Support from colleagues (including technical support) Institutional culture Curriculum & assessment requirements Students (perceived abilities, motivation, behaviour)
Zone of promoted action	Preservice education (university program) Practicum and beginning teaching experience Professional development

We used the zone framework in the survey research mentioned earlier (Goos & Bennison, 2008) to analyse relationships between secondary mathematics teachers' use of computer and graphics calculator technologies and their pedagogical knowledge and beliefs (zone of proximal development), access to the respective technologies (zone of free movement), and professional development opportunities (zone of promoted action). We found that teachers who frequently used graphics calculators were more likely than others to agree that technology was beneficial to students' mathematics learning, to have good access to class sets of graphics calculators, and to have participated in graphics calculator professional development. Having good access to computer rooms was the most important factor related to frequent use of computers for mathematics teaching, but there was also some evidence that participation in professional development was related to computer use.

In a review of recent Australasian research on mathematics teachers' professional learning and development, Anderson, Bobis, and Way (2008) found that most research in this area focused on the identification of features of effective professional development. In such research it is common to find the claim that changing teachers' beliefs is a necessary prelude to changing teaching practice (Cooney, 2001). However, the relationship between professional development, teaching practice, and teacher beliefs is a complex one. Some researchers claim that beliefs have an impact on classroom practice (e.g., Barkatsas & Malone, 2005), while others investigate apparent inconsistencies between beliefs and practice (Raymond, 1997). Beswick (2007) argues that beliefs and practices develop together and so the relationship between them is more likely to be dialectic than linear or directional.

Some of this complexity is captured by Guskey's (1986, 2002) model for teacher change. His model looks at how the three major outcomes of professional development – changes in teachers' classroom practices, changes in student learning outcomes, and changes in teachers' attitude and beliefs – are linked. Initially he proposed a linear model that begins with participation in professional development. According to this model, teachers then incorporate what they have learned into their classroom practices, leading to changes in student learning outcomes both in terms of achievement and affective characteristics. The crux of Guskey's argument was that it is only after student learning has changed that teachers change their attitudes and beliefs. Nevertheless, Guskey acknowledged that relationships between the three outcomes of professional development are complex. He later conceded that this model might over simplify teacher change processes that are more likely to be cyclic than linear (Guskey, 2002). For example, Rogers (2007) modified Guskey's original (1986) model to propose the alternative, cyclic model of teacher change shown in Figure 1 as a result of her investigation of the professional learning of a primary school teacher who worked with a "mathematician in residence" acting as an external critical friend.

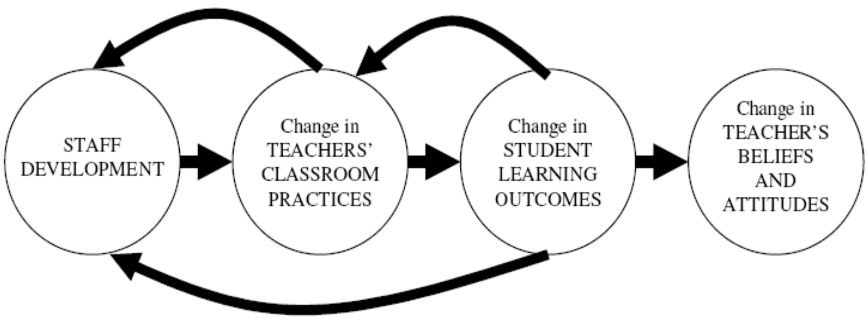

Figure 1. Cyclic model of the process of teacher change (Rogers, 2007).

Changes in classroom practice are often associated with participation in professional development as teachers try a new teaching approach such as the integration of technology into their classroom practice. Evidence is emerging that teachers now need more than "show and tell" workshops that provide information and raise awareness of particular technologies, such as graphics calculators (Chamblee, Slough, & Wunsch, 2008). Instead, they want to know how to teach specific mathematics topics using technology, with an emphasis on their personal management of the technology in the classroom and its impact on student learning. In this regard, Guskey (1986) claimed that teachers wanted "practical ideas that directly relate to the day-to-day operation of their classrooms" (p. 6) and retained practices that work while abandoning those that do not. He proposed three guiding principles for effective professional development that results in teacher change:

- recognise that change is a gradual and difficult process for teachers;
- ensure that teachers receive regular feedback on student learning; and
- provide support and follow up including technical assistance, time to experiment, and opportunities to work collaboratively with colleagues.

In their research review, Anderson et al. (2008) identified gaps in recent Australasian research on mathematics teacher development in relation to questions about *which* teachers participate in professional development activities and what teachers perceive to be their professional development *needs*. In one of the few local studies in this area, Pannizon and Pegg (2007) compared the professional development needs of teachers in metropolitan, regional, and remote areas of Australia and found that teachers in rural and remote areas were more likely to experience lack of opportunity to participate in professional development and have lower access to ICT resources than their metropolitan colleagues.

This brief review of literature on technology integration and teacher learning has identified a number of key issues concerning the effectiveness of professional development in bringing about changes in teacher beliefs and practices, and about teachers' professional development needs and opportunities. In the present paper we investigate some of these issues by revisiting data collected in our survey of technology use by mathematics teachers in Queensland schools. Our investigation is framed by the following research questions:

1. What are the technology-related professional development experiences and needs of Queensland secondary mathematics teachers?
2. What are the professional and demographic characteristics of

teachers who participate in technology-related professional development?

3. What relationships exist between participation in technology-related professional development and teachers' confidence in their technology skills and their pedagogical beliefs about using technology to teach mathematics?

Research Design and Methods

We provide here a brief summary of the survey methodology, which has been reported in full elsewhere (Goos & Bennison, 2008).

School Technology Surveys and Teacher Technology Surveys were sent to the Heads of Mathematics Departments in all 456 secondary schools in Queensland in September 2002, together with Reply Paid envelopes for return of completed surveys. This was the first year of implementation of revised senior secondary mathematics syllabuses that made it mandatory to incorporate "higher technologies" (computers or graphics calculators) into a school's learning and assessment programs (Queensland Board of Senior Secondary School Studies, 2000a, 2000b). Thus in 2002 the revised syllabuses were to be implemented for year 11 students, and in the following year for year 11 and 12 students.

We designed the two surveys based on instruments used in previous Australasian studies and on international research on factors known to influence mathematics teachers' use of technology (as described previously). The School Technology Survey collected information on school context while the Teacher Technology Survey investigated individual teaching contexts and practices. The Teacher Technology Survey sought information with respect to three types of technology: *computers* (software packages, both general and mathematics specific), the *Internet*, and *graphics calculators*; under the general headings of *Use*, *Access*, *Experience*, *Attitudes*, and *Professional Development* (19 items; 18 asked for a response from the choices provided and one was open ended). Demographic information such as gender, tertiary qualifications, years of teaching experience, years experience in teaching with the three types of technology, and current mathematics teaching assignment was also collected.

Altogether 89 School Technology Surveys were returned (20% response rate) from schools in 31 of the 33 Education districts in the state. There were 485 Teacher Technology Surveys returned by teachers in 127 schools (28% response rate). The same response rates were recorded for both surveys in government and non-government schools. The response rate is acceptable for a mail survey with no pre-notice or reminder follow up to non-respondents (Kaplowitz & Hadlock, 2004) and comparable to that achieved by Thomas (1996) in a similar census survey of New Zealand secondary schools. The distribution of responses by education sector and geographical region gives us confidence that the sample is representative of schools and teachers throughout the state, although this self-selected sample may have over-represented mathematics teachers who were interested in technology. Responses to questions on frequency of technology use and attitudes towards technology give us confidence that this was not the case. The majority of teachers who claimed to use technology frequently were those teaching senior mathematics classes where the use of technology was mandatory and many teachers who responded to the survey were undecided about some of the benefits of using technology to support mathematics learning. This has been reported in detail previously (Goos & Bennison, 2008).

Results

We begin our discussion of the findings by summarising responses to survey items that asked teachers about their professional development experiences and needs (research question 1). This is followed by an analysis of the professional and demographic characteristics of teachers who had participated in technology-related professional development (research question 2). We then examine relationships between participation in professional development and teacher confidence and pedagogical beliefs about using technology (research question 3).

Professional Development Experiences and Needs

Overall 400 teachers (82.5%) reported that they had participated in professional development on using technology to teach mathematics. We have previously reported that 126 of these teachers (26.0%) indicated they had participated in professional development related to computers, the Internet, and graphics calculators, and that participation in professional development in the use of graphics calculators (344 teachers, 70.9%) and computers (308 teachers, 63.5%) was approximately double that in the use of the Internet (162 teachers, 33.4%) (Goos & Bennison, 2008).

Responses to the open-ended question "What do you see as your current needs for professional development in this area?" were offered by 392 teachers (80.8% of the sample). A content analysis resulted in identification of nine response categories. Three of these categories referred to the type of technology (computers; Internet; graphics calculators), one to a perceived lack of any need for professional development (PD), two to constraints that detracted from the value of PD (time and access), and three to the desired focus for PD (how to use specific software or hardware; how to meaningfully integrate technology into mathematics learning experiences;

how to design assessment tasks that meaningfully integrate technology). Because teachers were free to write whatever they wanted to, the content of their responses could fall into more than one category.

Teachers who were specific about the type of technology for which they needed professional development mentioned computers (144; 36.7% of those who responded to this question; 29.7% of the sample) and graphics calculators (117; 29.8% of those who responded to this question; 24.1% of the sample) about twice as often as the Internet (65; 16.6% of those who responded to this question; 13.4% of the sample). A small proportion (29; 7.4% of those who responded to this question; 6.0% of the sample) stated that they required no professional development. Access to computers appears to be a significant problem for many teachers (79; 12.0% of those who responded to this question; 9.7% of the sample), and time was an issue for 20.0% of teachers who responded to this question (Goos & Bennison, 2008).

Many of the teachers who *had participated* in technology-related professional development expressed a desire for more (86, 27.9% of those who had participated in PD on computers; 35, 21.6% of those who had participated in PD on the Internet; 109, 31.7% of those who had participated in PD on graphics calculators). Very few of these teachers wanted to learn more about how to use these forms of technology (5, 1.6% of those who had participated in PD on computers; 2, 1.2% of those who had participated in PD on the Internet; 5, 1.5% of those who had participated in PD on graphics calculators). Instead, their main desire was to learn how to effectively integrate technology into their classroom practice (87, 28.2% of those who had participated in PD on computers; 31, 19.2% of those who had participated in PD on the Internet; 103, 30.4% of those who had participated in PD on graphics calculators). As one teacher pointed out "It is useful to know what software applications are available and have the ability to use them but overall I think PD on the integration of technology within the individual school work programs is definitely necessary." Others said they were interested in planning "activities that combine technology with mathematical concepts" in order to "improve learning outcomes" or to "enhance learning."

Of the 81 teachers who *had not participated* in any technology-related professional development, 68 (84.0%) responded to the question asking about their professional development needs. The distribution of responses across the nine content categories was similar to that of teachers who had participated in professional development. A selection of their comments related to constraints such as opportunity, time, and access is shown in Table 2.

Table 2
Examples of Professional Development Needs (Teachers who had not participated in Technology-Related Professional Development)

Teacher	Comment
103	Time!! To explore various application and develop teaching strategies relating to technology.
207	Nil – it's time and access that causes restrictions, especially when the school computer network is slow due to much use at once and can't be relied upon to work properly.
208[a]	It is hard to do professional development. Usually technology in-service is expensive and we have to travel. Budget constraints restrict this.
258	Obviously – all technology especially graphics calculators – it's more about time to learn than opportunities.
308[a]	I have recently been awarded a transfer to a larger state high school on the grounds of professional development. I have not had any professional development in maths teaching since graduating in 1998. I rely on my instinct and how I was taught when I went to high school.

[a] These teachers are located in rural or regional areas outside south-east Queensland.

The findings from our survey indicate that, although the majority of respondents had undertaken some technology-related professional development, these teachers were looking for further opportunities to learn how to effectively integrate technology into their teaching and assessment practices (cf Chamblee et al., 2008). Consistent with Guskey's (1986, 2002) model of teacher change, many survey respondents justified the personal investment in changing their classroom practice in terms of improving students' learning. However, time and access to technology (i.e., elements of teachers' school environment, or zone of free movement) were seen to be a significant hindrance.

Characteristics of Teachers who Participate in Technology-Related Professional Development

Our second research question is concerned with the professional and demographic characteristics of survey respondents who had participated in technology-related professional development. Table 3 shows the data sources for each set of characteristics and the nature of responses.

Table 3
Data Sources – Professional and Demographic Characteristics of Teachers who Participate in Technology-Related Professional Development

Teacher characteristics	Data sources from Survey	Response categories
Professional characteristics	Preservice curriculum specialisation	Mathematics vs. non-mathematics
	Current teaching assignment	Mathematics only vs. mathematics + other subjects
	Years teaching experience	<5, 5-9, 10-14, 15-19, ≥20
	Years experience using technology in teaching mathematics	<1, 1-2, 2-5, 5-10, >10
Demographic characteristics	School size	Small (<500 students), Medium (500-999), Large (≥1000)
	School sector	Government, Catholic, Independent
	Geographical region	SE Qld vs. rest of Qld

Relationships between participation in professional development and these characteristics were analysed by conducting chi-square tests of the frequency distributions obtained by cross-tabulating responses to items asking teachers whether they had experienced professional development on how to use computers, the Internet, and graphics calculators in teaching mathematics with responses to the two sets of items listed in Table 3. As most teachers had participated in professional development on using computers and/or graphics calculators in teaching mathematics we focus our analysis on these forms of technology. Results are presented in Table 4.

Table 4

Analysis of Relationships Between the Participation in Technology-Related Professional Development and Teachers' Professional and Demographic Characteristics

	Participation in professional development			
	Computers		Graphics calculators	
Teacher characteristics	χ^2	p	χ^2	p
Professional characteristics				
Pre-service curriculum specialisation	12.63[a]	**< 0.001**	29.31[a]	**< 0.001**
Current teaching assignment	31.67[a]	**< 0.001**	17.01[a]	**< 0.001**
Years teaching experience	27.50[c]	**< 0.001**	13.20[c]	**< 0.001**
Years experience using technology in teaching	39.55[c]	**< 0.001**	66.15[c]	**< 0.001**
Demographic characteristics				
School size	16.64[b]	**< 0.001**	13.39[b]	**0.001**
School sector	1.29[b]	0.525	18.93[b]	**< 0.001**
Geographical region	57.73[a]	**< 0.001**	12.16[a]	**< 0.001**

[a]df = 1, [b]df = 2, [c]df = 4

For *computers*, the hypothesis of independence between participation in professional development and teacher characteristics was rejected for all characteristics except school sector. Inspection of the relevant contingency tables (Tables 5 (a) and 5 (b)) comparing observed with expected cell frequencies and proportions suggested the following relationships. Teachers who had participated in professional development on computers in teaching mathematics were more likely than others to have specialised in mathematics in their preservice program and be teaching only mathematics. They were more likely than others to have been teaching for more than 20 years and have used technology in teaching mathematics for more than 5 years. These teachers were also more likely than those who had not participated in professional development on computers to be teaching in large schools in south-east Queensland. Teachers from all school sectors (government, Catholic and independent) had participated in computer-related professional development on computers in expected proportions.

Table 5 (a)

Contingency Tables for the Analysis of Relationships Between the Participation in Technology-Related Professional Development and Teachers' Professional Characteristics

Professional Characteristic	PD Participation – Graphics calculators		PD Participation – Computers	
	Yes	No	Yes	No
Preservice curriculum specialisation				
Mathematics (row %)	295 (77.2%)	87 (22.8%)	260 (67.5%)	125 (32.5%)
Non-mathematics (row %)	45 (48.9%)	47 (51.1%)	45 (47.9%)	49 (52.1%)
Total (row %)	*340 (71.7%)*	*134 (28.3%)*	*305 (63.7%)*	*174 (36.3%)*
Current teaching assignment				
Mathematics only (row %)	180 (80.7%)	43 (19.3%)	172 (76.8%)	52 (23.2%)
Mathematics + other subjects (row %)	159 (63.6%)	91 (36.4%)	132 (52.0%)	122 (48.0%)
Total (row %)	*339 (71.7%)*	*134 (28.3%)*	*304 (63.6%)*	*174 (36.4%)*
Years teaching experience.				
< 5 (row %)	37 (53.6%)	32 (46.4%)	29 (41.4%)	41 (58.6%)
5 – 9 (row %)	47 (72.3%)	18 (27.7%)	36 (54.5%)	30 (45.5%)
10 – 14 (row %)	47 (72.3%)	18 (27.7%)	41 (62.1%)	25 (37.9%)
15 – 19 (row %)	41 (68.3%)	19 (31.7%)	38 (62.3%)	23 (37.7%)
≥ 20 (row %)	168 (78.1%)	47 (21.9%)	160 (74.1%)	56 (25.9%)

Total (row %)	*340 (71.7%)*	*134 (28.3%)*	*304 (63.5%)*	*175 (36.5%)*
Years experience using technology in teaching mathematics				
< 1 (row %)	37 (44.0%)	47 (56.0%)	27 (39.1%)	42 (60.9%)
1 – 2 (row %)	54 (65.9%)	28 (34.1%)	28 (49.1%)	29 (50.9%)
2 – 5 (row %)	122 (83.0%)	25 (17.0%)	92 (66.7%)	46 (33.3%)
5 – 10 (row %)	97 (88.2%)	13 (11.8%)	82 (71.3%)	33 (28.7%)
≥ 10 (row %)	18 (100.0%)	0 (0.0%)	75 (81.5%)	17 (18.5%)
Total (row %)	*328 (74.4%)*	*113 (25.6%)*	*304 (64.5%)*	*167 (35.5%)*

Note. Interpretation of the outcome of the chi-square test involves comparing, within each column, each proportion (row %) with the others and with the expected proportion shown at the bottom of each section of the table (Total row %).

Table 5 (b)

Contingency Tables for the Analysis of Relationships Between the Participation in Technology-Related Professional Development and Teachers' Demographic Characteristics

Demographic Characteristic	PD participation – Graphics calculators		PD participation – Computers	
	Yes	No	Yes	No
School size				
Small (< 500 students)	36 (53.7%)	31 (46.3%)	35 (51.5%)	33 (48.5%)
Medium (500 – 999 students) (row %)	151 (76.6%)	46 (23.4%)	115 (57.5%)	85 (42.5%)
Large (≥ 1000 students) (row %)	157 (73.4%)	57 (26.6%)	158 (73.5%)	57 (26.5%)
Total (row %)	*344 (72.0%)*	*134 (28.0%)*	*308 (63.8%)*	*175 (36.2%)*
School sector				
Government (row %)	179 (64.4%)	99 (35.6%)	175 (62.3%)	106 (37.7%)
Catholic (row %)	116 (82.3%)	25 (17.7%)	96 (67.6%)	46 (32.4%)
Independent (row %)	49 (83.1%)	10 (16.9%)	37 (61.7%)	23 (38.3%)
Total (row %)	*344 (72.0%)*	*134 (28.0%)*	*308 (63.8%)*	*175 (36.2%)*
Geographical region				
SE Queensland (row %)	212 (78.2%)	59 (21.8%)	191 (69.5%)	84 (30.5%)
Rest of Queensland (row %)	132 (63.8%)	75 (36.2%)	117 (38.0%)	191 (62.0%)
Total (row %)	*344 (72.0%)*	*134 (28.0%)*	*308 (52.8%)*	*275 (47.2%)*

Note. Interpretation of the outcome of the chi-square test involves comparing, within each column, each proportion (row %) with the others and with the expected proportion shown at the bottom of each section of the table (Total row %).

A similar picture emerges from the chi-square analysis for *graphics calculators*. In this case, however, the hypothesis of independence between participation in professional development and teacher characteristics was rejected for all characteristics, including school sector. Inspection of the relevant contingency tables (Tables 5 (a) and 5 (b)) suggested similar relationships as those found for computers in terms of preservice curriculum specialisation, mathematics-only teaching assignment, years of teaching experience, and location in south-east Queensland. Teachers who had *not* participated in graphics calculator professional development were more likely than others to have used technology in teaching mathematics for less than 2 years, and to be teaching in small schools and in Government schools rather than in the Independent or Catholic sectors.

Several observations can be made after examining the results of this analysis for computers and graphics calculators. First, survey respondents whose current teaching load included other subjects in addition to mathematics were less likely than those teaching only mathematics to have participated in technology-related professional development. It may be that schools offer the former teachers fewer mathematics professional development opportunities than specialist mathematics teachers or that these teachers have a more substantial commitment to their other curriculum area(s) and are unable to devote time to developing skills they may feel are not essential.

Second, less-experienced survey respondents (both in years of teaching and experience with technology) are less likely than others to have participated in technology-related professional development. In one sense this is not surprising, as recently qualified teachers have not been working in schools for long enough to have experienced substantial professional development opportunities. Workload pressures in the early stages of their careers may also prevent them from participating in professional development. It is possible that these teachers feel adequately prepared by their preservice program and as a result do not see an immediate need for technology-related professional development.

A third observation is that survey respondents outside south-east Queensland were less likely to participate in technology-related professional development than their colleagues close to Brisbane (e.g., see comments by Teachers 208 and 308 in Table 2). This observation echoes the findings from Pannizon and Pegg's (2007) study and suggests a need to investigate more effective ways of engaging teachers in regional and rural areas in professional development on computers and graphics calculators.

Professional Development, Teacher Confidence and Pedagogical Beliefs

Previous research has identified teachers' confidence in their technology skills and beliefs about the role of technology in enhancing student learning as facilitators or hindrances to technology use. As professional development often attempts to bring about changes in teacher beliefs and teaching practice (Cooney, 2001; Guskey, 1986, 2002), we were interested in investigating relationships between survey respondents' participation in technology-related professional development (zone of promoted action), confidence in their technology skills (zone of proximal development), and pedagogical beliefs expressed as attitudes towards technology (zone of proximal development). On the basis of our analysis of the attitudes section of the survey (Goos & Bennison, 2008), we selected as indicators of key pedagogical beliefs about the role of technology in learning mathematics a set of four items about advantages of using technology that attracted the highest proportion of Uncertain responses from teachers. Table 6 shows the data sources for each of these factors and the nature of responses.

Table 6
Data Sources - Professional Development, Confidence, Pedagogical Beliefs

Factors related to technology use	Data sources from Survey	Response categories
Participation in professional development (ZPA)	Have you had any professional development on the use of computers/graphics calculators/the Internet in teaching mathematics?	Yes, No
Confidence in technology skills (ZPD)	How confident do you feel in using these technologies in teaching mathematics?	Not confident, Confident, Very confident[a]
Pedagogical beliefs (ZPD)	Technology helps students to understand concepts. Technology makes sophisticated concepts accessible to students. Technology helps students explore unfamiliar problems. Technology improves student attitudes towards mathematics.	Disagree, Undecided, Agree[b]

[a] Teachers were asked to rate their confidence with technology using a 5-point Likert-type scale where a score of 1 was labelled Not confident, 3 Confident, and 5 Very confident. To simplify analysis and presentation of results, scores were combined as follows: 1 or 2 = not confident, 3 = confident, 4 or 5 = very confident.

[b] Teachers were asked to indicate the extent to which they agreed with statements on the advantages and disadvantages of using technology using a 5-point Likert-type scale based on scores of 1 (Strongly disagree), 2 (Disagree), 3 (Undecided), 4 (Agree), and 5 (Strongly agree). To simplify analysis and presentation of results, scores were combined as follows: 1 or 2 = disagree, 3 = undecided, 4 or 5 = agree.

Relationships between participation in professional development, teacher confidence, and pedagogical beliefs were analysed by conducting chi-square tests of the frequency distributions obtained by cross-tabulating responses to items asking teachers whether or not they have participated in technology-related professional development on computers and graphics calculators with responses to survey items about confidence and attitudes shown in Table 6. As most teachers had participated in professional development on using computers and/or graphics calculators in teaching mathematics our analysis addresses only these forms of technology. Results are presented in Table 7.

Table 7
Analysis of Relationship between Participation in Technology-Related Professional Development and Teacher Confidence and Pedagogical Beliefs

	Participation in professional development			
	Computers		Graphics calculators	
Factors affecting technology use	$\chi2(2)$	p	$\chi2(2)$	p
Confidence	6.97	**0.031**	72.57	**< 0.001**
Attitudes towards technology:				
Technology helps students to understand concepts.	2.39	0.303	10.03	**0.007**
Technology makes sophisticated concepts accessible to students.	5.76	**0.056**	5.95	**0.051**
Technology helps students to explore unfamiliar problems.	2.47	0.291	1.94	0.380
Technology improves student attitudes towards mathematics.	4.62	**0.099**	16.48	**< 0.001**

For *computers*, the hypothesis of independence of classification was rejected for confidence and attitude statements related to accessing concepts and student attitudes towards mathematics. Inspection of the relevant contingency tables (Tables 8 (a) and 8 (b)) revealed that survey respondents who had participated in professional development on computers were more likely than others to be very confident in using computers in teaching mathematics. Teachers who had *not* participated in this professional development were more likely than others to be undecided about whether technology makes sophisticated concepts accessible to students or improves student attitudes towards mathematics.

Table 8 (a)
Contingency Tables for the Analysis of Relationship between Participation in Technology-Related Professional Development and Teacher Confidence

	PD Participation – Graphics calculators		PD Participation – Computers	
Confidence level	Yes	No	Yes	No
Not confident (row %)	61 (45.5%)	73 (54.5%)	50 (55.6%)	40 (44.4%)
Confident (row %)	85 (73.3%)	31 (26.7%)	99 (60.4%)	65 (39.6%)
Very confident (row %)	197 (87.2%)	29 (12.8%)	159 (69.7%)	69 (30.3%)
Total (row %)	*343 (72.1%)*	*133 (27.9%)*	*308 (63.9%)*	*174 (36.1%)*

Note. Interpretation of the outcome of the chi-square test involves comparing, within each column, each proportion (row %) with the others and with the expected proportion shown at the bottom of each section of the table (Total row %).

Evidence of dependent relationships between participation in professional development and teacher confidence and attitudes appears to be even greater for *graphics calculators*. The hypothesis of independence of classification was rejected for all factors except the attitude statement related to exploring unfamiliar problems. Inspection of the relevant contingency tables (Tables 8 (a) and 8 (b)) showed that survey respondents who had participated in professional development on graphics calculators were more likely than others to be very confident in using them to teach mathematics. Teachers who had *not* participated in professional development on graphics calculators were more likely than others to be undecided about the statements that technology helps students to understand concepts and makes sophisticated concepts accessible to students, and to be undecided about or disagree with the statement that technology improves student attitudes towards mathematics.

Table 8 (b)

Contingency Tables for the Analysis of Relationship between Participation in Technology-Related Professional Development and Teacher Pedagogical Beliefs

	PD Participation – Graphics calculators		PD Participation – Computers	
Attitude towards technology	Yes	No	Yes	No
Technology helps student to understand concepts				
Disagree (row %)	18 (72.0%)	7 (28.0%)	15 (57.7%)	11 (42.3%)
Undecided (row %)	73 (60.8%)	47 (39.2%)	70 (58.8%)	49 (41.2%)
Agree (row %)	253 (76.0%)	80 (24.0%)	223 (66.0%)	115 (34.0%)
Total (row %)	*344 (72.0%)*	*134 (28.0%)*	*308 (63.8%)*	*175 (36.2%)*
Technology makes sophisticated concepts accessible to students.				
Disagree (row %)	16 (76.2%)	5 (23.8%)	17 (77.3%)	5 (22.7%)
Undecided (row %)	75 (63.6%)	43 (36.4%)	65 (55.6%)	52 (44.4%)
Agree (row %)	253 (75.1%)	84 (24.9%)	225 (65.8%)	117 (34.2%)
Total (row %)	*344 (72.3%)*	*132 (27.7%)*	*307 (63.8%)*	*174 (36.2%)*
Technology helps students to explore unfamiliar problems.				
Disagree (row %)	19 (67.9%)	9 (32.1%)	16 (57.1%)	12 (42.9%)
Undecided (row %)	64 (67.4%)	31 (32.6%)	56 (58.3%)	40 (41.7%)
Agree (row %)	259 (74.0%)	91 (26.0%)	234 (65.9%)	121 (34.1%)
Total (row %)	*342*	*131*	*306*	*173*

	(72.3%)	*(27.7%)*	*(63.9%)*	*(36.1%)*
Technology improves student attitudes towards mathematics.				
Disagree (row %)	14 (50.0%)	14 (50.0%)	19 (65.5%)	10 (34.5%)
Undecided (row %)	102 (65.0%)	55 (35.0%)	89 (57.1%)	67 (42.9%)
Agree (row %)	228 (78.4%)	63 (21.6%)	199 (67.2%)	97 (32.8%)
Total (row %)	*344 (72.3%)*	*132 (27.7%)*	*307 (63.8%)*	*174 (36.2%)*

Note. Interpretation of the outcome of the chi-square test involves comparing, within each column, each proportion (row %) with the others and with the expected proportion shown at the bottom of each section of the table (Total row %).

The results of this analysis for computers and graphics calculators suggest that survey respondents who had participated in professional development on the use of technology in teaching mathematics were more confident in their technology skills than non-participants and more positive about the benefits of these technologies for students' learning of mathematics. Although dependent relationships between variables do not imply causality, it is at least plausible to speculate that professional development might have some effect on teachers' confidence and pedagogical beliefs, where this effect is mediated by changes in classroom practice and changes in student learning outcomes (as indicated by the model of teacher change shown in Figure 1).

Discussion

In this paper we have reported on our research investigating the technology-related professional development experiences and needs of mathematics teachers in Queensland secondary schools. Questions about the effectiveness of such professional development activities and the characteristics of teachers who participate in them need to be addressed at a time when continuing professional learning is increasingly becoming a requirement for renewal of teacher registration in many parts of Australia.

Our first research question asked about teachers' participation in professional development and their perceived professional development needs. Although the majority of teachers who responded to the survey had participated in professional development in at least one of the three targeted types of technology (computers, Internet, graphics calculators), a significant number (almost one-fifth) had not undertaken any professional development on the use of technology in teaching mathematics. Lack of time and access to technology appeared to be significant constraints that prevented teachers from participating in both formal and informal professional development. In terms of our zone theoretical framework, elements of these teachers' zone of free movement (i.e., constraints in their school environments) diminished any potential impact of the zone of promoted action that might be opened up by professional development. According to Guskey (1986), time and access factors are crucial if professional development is to result in the types of changes to classroom practice that many survey respondents desired. These changes reflected emerging professional learning needs identified by Chamblee et al. (2008) in that they involved more effectively integrating technology into teaching and assessment practices, especially in the context of the syllabus or the school's work program, in order to improve students' learning. This highlights the need for professional development activities to be targeted at developing mathematics teachers' pedagogical technology knowledge (Thomas & Chinnappan, 2008) if the potential for using technology to support mathematics learning is to be fully realised.

The second research question sought to address a gap in Australasian research on mathematics teacher development (Anderson et al., 2008) by identifying professional and demographic characteristics of survey respondents who participated in professional development on computers and graphics calculators. The finding that participants were most likely to be experienced, specialist mathematics teachers working in medium- to large-sized schools in south-east Queensland should raise concerns about how education systems and professional development providers can best meet the needs of less-experienced, non-specialist teachers and those who work in smaller regional and rural schools where staff turnover is highest and most difficulty is experienced in filling secondary mathematics teaching positions (Pannizon & Pegg, 2007).

The third research question identified relationships between participation in technology-related professional development (i.e., a zone of promoted action) and survey respondents' confidence in their technology skills and their pedagogical beliefs about the role of technology in mathematics teaching and learning, both of which we conceptualise as elements of teachers' zone of proximal development. Although the analysis cannot provide evidence of causal relationships, the findings were clear in showing that professional development participation is related to greater confidence with technology and more positive beliefs about technology use being beneficial for students' learning of mathematics. As we have previously reported that participation in professional development is also related to higher frequency use of computers and graphics calculators by survey respondents (Goos & Bennison, 2008), these findings, taken together, provide support for models of teacher change that link professional development with changes in classroom practice and changes in teacher beliefs (Guskey, 1986, 2002). While we have not investigated the nature and direction of the links between professional development, changes in teachers' classroom practices, and changes in attitudes and beliefs it is clear that participation in professional development plays a crucial role in whether and how technology is used in mathematics classrooms.

The findings from our survey research, although representing only 28% of Queensland secondary schools, are consistent with previous Australasian survey research that reported relationships between computer and graphics calculator use, teacher beliefs about the benefits of technology for students' learning, and participation in professional development (Forgasz, 2002; Thomas, 2006; Tobin, Routitsky, & Jones, 1999).

Our survey of Queensland secondary school teachers' use of technology for teaching mathematics was a fairly "blunt" instrument for investigating the questions that interested us, especially those questions about factors influencing technology use where causal relationships cannot be inferred. Nevertheless, the analysis presented here provides a rare and demographically representative snapshot of practice across the state that highlights issues of concern around technology integration and teacher professional development. The zone theory framework, in categorising and synthesising the range of factors known to influence technology integration, allowed us to "fill in" the zone of promoted action with teachers' professional development experiences and needs as well as to examine the role of professional development in relation to elements of teachers' zone of proximal development (confidence in technology skills, pedagogical beliefs) and zone of free movement (environmental constraints such as time and access to technology resources). As many other researchers have argued (e.g., Cooney, 2001; Guskey, 2002; Rogers, 2007), these factors interact in complex ways to facilitate or hinder teacher change.

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Authors

Anne Bennison. Teaching and Educational Development Institute, The University of Queensland, St Lucia Qld 4072. <a.bennison@uq.edu.au>.

Merriyn Goos. Teaching and Educational Development Institute, The University of Queensland, St Lucia Qld 4072. <m.goos@uq.edu.au>.