Educ Stud Math (2009) 71:299–317
DOI 10.1007/s10649-008-9177-6

Perceptions that may affect teachers' intention to use technology in secondary mathematics classes

Robyn Pierce · Lynda Ball

Published online: 16 January 2009

Abstract Technology is available and accessible in many mathematics classrooms. Adopting technology to support teaching and learning requires teachers to change their teaching practices. This paper reports the responses of a diverse cohort of 92 secondary mathematics teachers who chose to respond to an Australian state-wide survey (Mathematics with Technology Perceptions Survey) developed using a Theory of Planned Behaviour framework. The items discussed in this paper targeted mathematics teachers' perceptions of possible barriers and enablers to their intention to use technology in their teaching. The responses are varied but, overall, strength of agreement with enablers outweighed agreement with perceived barriers. However, it is clear that despite an overall positive attitude towards the use of technology for teaching mathematics, some perceived barriers to change are notable. It is, therefore, helpful if those responsible for professional development, promoting the use of technology, recognise and address these barriers as well as working to strengthening enablers.

Keywords Teachers' perceptions · Technology · Secondary mathematics · Theory of planned behaviour · Computer · Calculator

1 Introduction

An extensive range of sophisticated technology is now generally available to teachers. In particular, Mathematics Analysis Software (MAS) such as scientific calculators, function graphers, Computer Algebra Systems (CAS), lists and spreadsheets, statistical packages and geometry packages have become commonplace in many classrooms. Such MAS may be accessed either on computer or hand-held devices. Traditionally, mathematics teaching has been dominated by work with pen and paper. Given the diverse range of technologies available, it is useful to consider what affects teachers' intention to change from this

R. Pierce (✉) · L. Ball (✉)
Melbourne Graduate School of Education, The University of Melbourne, Level 7 Doug McDonell Bldg, Victoria, Australia, 3010
e-mail: r.pierce@unimelb.edu.au

traditional approach and to use technology in the teaching of mathematics. This paper reports and discusses the findings of a survey which asked mathematics teachers to respond to items relating to their background and to key attitudes and perceptions which may dispose teachers towards change and others that may create barriers to change.

The study reported in this paper presents teachers' perceptions from the position of a schooling system where the use of hand-held technology is expected in important end of school mathematics examinations. In the Australian state of Victoria, where this study was conducted, the government curriculum guidelines draw specific attention to what we call MAS, especially geometry packages, graphics calculators and CAS (VCAA, 2005a, b). These documents also indicate the privileged position of graphics, CAS and integrated software calculators (with symbolic, graphical, numerical and other features) which are permitted in the high-stakes examinations held in the final year of secondary schooling (VCAA, 2005b). As a result of their designated importance, such technologies promote most discussion among Victorian secondary mathematics teachers, and it is likely that teachers had at least some of these technologies in mind when responding to the survey. For this reason, most examples presented in the following sections refer to this range of technologies.

In the next section, we provide some background on the Theory of Planned Behaviour (which informed the design of this survey) and review literature related to mathematics teachers' perceptions of the role and value of technology for teaching mathematics. This is followed by a description of the methodology, the results and discussion, and finally conclusions and implications.

2 Studying intention to change

Teaching mathematics with technology requires a marked change in behaviour for practising mathematics teachers who have taught, and been taught, in traditional mathematics classrooms dominated by working with pen and paper. Behaviour change may be viewed in a number of ways. Some researchers choose to consider the individual's journey on the path of change. For example, Prochaska and DiClemente (1983) provide a classification of stages involved in behaviour change: pre-contemplation; contemplation; preparation for action; action and maintenance. An alternative perspective is brought to bear by Ajzen (1991) who focused on the pre-action stages and put forward the Theory of Planned Behaviour (TPB). This theory focuses on factors affecting a person's intention to change. The TPB considers attitudes and perceptions that may either enable or present barriers, to a person's intention to change. Ajzen (1991) summarises the theory as follows:

> The theory of planned behaviour postulates three conceptually independent determinants of intention. The first is the attitude toward the behaviour and refers to the degree to which a person has a favourable or unfavourable evaluation or appraisal of the behaviour in question. The second predictor is a social factor termed subjective norm; it refers to the perceived social pressure to perform or not to perform the behaviour. The third antecedent of intention is the degree of perceived behavioural control which, as we saw earlier, refers to the perceived ease or difficulty of performing the behaviour and it is assumed to reflect past experience as well as anticipated impediments and obstacles. As a general rule, the more favourable the attitude and subjective norm with respect to a behaviour, and the greater the perceived behavioural control, the stronger should be an individual's intention to perform the behaviour under consideration. The relative importance of attitude, subjective norm,

and perceived behavioural control in the prediction of intention is expected to vary across behaviours and situations. (p. 188)

In using the framework of TPB for this study, our concern was mathematics teachers' intention to change their teaching practice to incorporate the use of technology. We wished to explore teachers' attitudes toward teaching mathematics with technology (for example attitude based on the belief that such teaching will improve students' understanding); subjective norms with respect to teaching mathematics with technology (for example what they perceive other staff expect) and perceived control over teaching mathematics with technology (for example whether they perceive there is enough class time available for this new teaching). Ajzen (1991) suggests that such factors are usually found to predict behavioural intentions with a high degree of accuracy. He goes on to report that research tells us that a person's intentions, in combination with perceived behavioural control (especially if aligned with actual behavioural controls), can account for a considerable proportion of variance in actual behaviour.

The TPB is well established as a framework for research in the health and social sciences. Ajzen (n.d.) provides an extensive bibliography. Typical of these examples is the work of Pierce and Gunn (2007) who used TPB to understand limitations on the clinical use of Problem Solving Therapy for general practitioners (GPs) working with depressed patients. Such work has parallel with the behaviour change we wish to explore. In both cases, professionals (GPs and teachers) are being challenged to change their approach to developing patients' or students' new skills and enhancing patients' or students' understanding of depression or mathematics. TPB has not commonly been used as a framework for research in education but a literature search did find, for example, that Sugar, Crawley and Fine (2005) used TPB to assess teachers' attitudes to the integration of technology into their teaching, and they found TPB especially helpful in identifying social factors as part of the motivation for teachers to adopt the use of technology. In particular, Sugar et al. (2005) report that the teachers believed that their principal, school parents and students were keen for them to use technology. These perceived subjective norms acted as enablers, encouraging teachers to have a positive intention towards incorporating various new technologies into their teaching.

The application of TPB in the context of this study is not expected to reveal new factors affecting teachers' use of technology for teaching mathematics but rather to act as an organiser that draws attention to attitudes and perceptions which may act as barriers or enablers to teachers adopting this practice. Identification of these determinants along with some sense of their level of influence will inform those conducting professional learning programs for practising teachers.

A literature review informed the choice and design of survey items used in this study. In the sections that follow, we have organised pertinent reports from the literature according to TPB principles: common teacher attitudes towards the value of teaching mathematics with technology; teachers' subjective norms for the use of technology in their school and factors that teachers perceive as behavioural controls that either encourage or inhibit their use of technology for teaching mathematics.

2.1 Attitudes

TPB tells us that a person's attitudes may enable or create barriers to his or her intention to change. Attitude here refers to a favourable or unfavourable disposition towards an action according to whether they believe it to be beneficial or not. From the literature summarised below, it seems that for mathematics teachers considering the use of MAS in their teaching, their positive or negative attitudes relate to their views about four important areas: what it means to understand and learn mathematics; the contribution of MAS in the development of mathematical understanding; how MAS will impact on students' attitude towards learning mathematics and the role of the teacher and the role of the student in class lessons.

While Hennessy, Ruthven and Brindley (2005) conclude that teacher commitment to integrating technology relates to "recognising the educational value and believing in the transformative potential of the technology" (p. 185), the teachers in their study were concerned to use technology only where they believed it enhanced learning compared with other approaches. More specifically, a survey, reported by Routitsky and Tobin (1998), and further by Tobin, Routitsky and Jones (1999), investigated teachers' perceptions of the use of graphics calculators in secondary schools. Overall, most of these teachers believed that the graphics calculator would improve students' mathematical understanding and make a positive contribution to student learning. Such positive attitudes act as enablers for change.

On the other hand, in their research on teaching algebra, Cedillo and Kieran (2003) reported that their most experienced teachers, with strong mathematics backgrounds, were initially half-hearted about teaching with technology. Their negative attitude seemed to stem from a belief that using technology would not enhance student learning. Their views and practices changed markedly over time as they observed positive impact on their students' learning. Thomas, Tyrrell and Bullock (1996) also found that once teachers started using computers in their mathematics classrooms, there was a positive shift in their perception of the value of using computers. These initial negative attitudes would have acted as initial barriers to individual teachers' intention to change, but their attitudes slowly changed as a result of their experience.

Such studies show that teachers' positive or negative attitudes towards teaching with technology, specifically MAS, may depend on how they believe such teaching will impact on students' learning. Closely linked to this are the teachers' beliefs about what it means to understand mathematics. Teachers who believe that students learn best by working with pen and paper, or believe that in order to demonstrate understanding of mathematics, a student must be able to solve problems without the aid of technology, may have a negative attitude towards the use of technology in their mathematics classes. Herget, Heugl, Kutzler, and Lehmann (2000) challenged teachers to formulate a position about the pen and paper skills that are necessary for students to have when using a CAS that can perform algebraic manipulations automatically. They suggested that simple examples be performed with pen and paper and then technology be used for more difficult manipulations. The stage along the difficulty continuum at which students should be allowed to use technology is a point of contention. For example, Gardiner (2001) perceives that students need to do harder examples with pen and paper than those suggested by Herget et al. (2000). As a result, Gardiner urges caution about using technology too early, instead suggesting that practice of a variety of cases with small numbers is vital for developing students' understanding. Ball and Stacey (2005), who studied the trial of a new senior secondary mathematics subject for which CAS use was permitted in all assessment, describe an example of a teacher who believed that students learn best if they first use by-hand (pen and paper) skills for new procedures and then later move to using technology as the procedures increase in difficulty. Even though this teacher was an expert user of technology, she chose not to use technology to teach concepts as she perceived that pen and paper work would help students develop more understanding of mathematical techniques.

Teachers are not only concerned about students' understanding of mathematics but also about students' attitudes. Teachers' perceptions of students' attitudes towards mathematics are significant in determining whether they incorporate technology in their teaching. Mumtaz (2000), for example, found in her meta-study of teachers' use of technology that teachers need to be convinced that the use of technology will increase students' interest and motivation. This finding is supported by Forgasz (2006) who found that teachers are encouraged to use computers in secondary mathematics classroom if they perceive that this will increase students' motivation, enjoyment and confidence.

Not all students respond in the same way to the opportunity to work with technology. Ruthven and Hennessey (2002) found that technology led both to an improved attitude by students and a positive contribution to the ability of students, in particular lower achieving students, to undertake exploration in mathematics. However, some teachers believe that using technology will encourage boys but discourage girls. Some research data do raise awareness of this issue. Vale and Leder (2004) report that female secondary students were less positive than male secondary students about computer-based mathematics. The female students were more likely to be concerned about successful results in computer-based mathematics, while male students were more concerned about the relevance of the mathematics and their personal pleasure in using computers in mathematics classes. In contrast, Pierce, Stacey and Bartaksas' (2007) administration of the Mathematics and Technology Attitude Scale for middle secondary school students found female students were less confident than males about using technology but that this did not significantly affect the students' beliefs about the value of technology for learning mathematics.

Teachers' attitudes towards using technology for learning and teaching mathematics can also relate to the effect that they perceive this change may have on their classroom practice. Scrimshaw (2004), in a British study that aimed to identify factors which promote teachers' use of ICT, noted that technology can support teachers in implementing a 'student-centred' approach to learning, but he also commented that for teachers who prefer a 'teacher-centred' model, the belief that technology use promotes a 'student-centred' model may deter them from using technology. In the context of mathematics teaching, this may be viewed as the difference between a classroom where considerable individual student exploration using technology and student choice of methods is encouraged, and one where the teacher directs the use of technology, tightly directs classroom discussion and mandates particular solution methods.

2.2 Subjective norms

According to TPB, the second determinant of intention to change is the social factor termed subjective norms. It suggests that a teacher's intention to change their teaching practice will be influenced by how they perceive that using technology fits into the mathematics teaching culture of the school. For example, do the colleagues they respect think that teaching with technology is a good idea? Does the school principal or mathematics coordinator expect them to use technology for teaching mathematics? What do the students' parents expect?

2.2.1 Colleagues

Forgasz and Griffith (2006) conducted a survey in 2001 and 2003 which included an investigation of teachers' views about the impact of CAS on teaching and student learning in senior secondary school mathematics. Responses to the introduction of CAS were generally positive. In a sample of 47 teachers from ten schools, Forgasz and Griffith found that younger and older teachers tended to be more positive about the introduction of CAS than those of 35–45 years of age. This suggests that the age demographics of the teachers at a particular school may influence the perceived norm for using or not using CAS technology for teaching mathematics. If most of the mathematics teachers at a school hold negative attitudes towards teaching with technology, younger staff, for example, may feel constrained to limit their use of technology. The results from this study related to teachers' views of teaching with CAS contrasted with those reported by BECTA (2004) which found little evidence that age impacted on levels of ICT use, i.e. computer use. It might be that there are differences in views dependent on age when considering hand-held technology versus computer-based technology, and this warrants further investigation.

If major change to teaching practices is expected, this requires careful management and leadership to provide structures and support to encourage and enable teachers. A key finding of Coffland and Strickland (2004), who report a study of factors related to teacher use of technology in secondary geometry instruction, was the effect of the school principal's attitude. Teachers' attitudes towards computers were found to be directly related to principals' attitudes. If the principal had a positive attitude, so did the teachers. Baylor and Ritchie (2002), who stressed the importance of the school leadership in fostering integration of technology into teaching and learning, also emphasised the influence of a supportive environment and teacher professional development.

The impact of a subjective norm is not always consistent. Teachers' perceptions of positive expectations and support by a principal, or of having the use of technology imposed, evoke different responses. This result may not be surprising given the autonomous nature of teaching. Hennessy et al. (2005) point out that a top-down approach may lead to critical questioning of the value of technology instead of a sense of ownership, while Veen's (1993) early study found that principal and institutional support for the incorporation of technology into teaching practice may be an important factor for some teachers, but the degree to which it motivates individual change may vary from teacher to teacher. Teachers' beliefs about the value of technology for learning and their perceptions of their own technology skills were more central to the integration of technology into their teaching than school factors such as a positive attitude to technology by the school principal.

We anticipate that in an environment where schools compete to attract students, teachers' perceptions of parents' views on the use of technology for teaching mathematics may influence at least the school leadership's perceptions of its value. However, we have found no results related to this in the literature. Thomas, Hong, Bosley and Santos (2006) comment that quite a lot has been said, "often in the media by parents and others, about the possible negative effects of calculator use in the mathematics classroom" (p.232). If parents are opposed to the use of technology for teaching mathematics, then this may well be perceived by teachers as a barrier.

2.3 Perceived behavioural controls

The third determinate of intention to change recognised by TPB is a person's perceived behavioural controls. This encompasses a person's subjective views of limitations that may prevent them taking the action in question. From the literature (see for example, Scrimshaw, 2004) it seems that for using technology in teaching mathematics, teachers' perceptions of their own knowledge and technology skills; the extra time needed for both teachers and students to learn adequate technology skills; the extra expense of purchasing technology and other external constraints will be key in determining their intention to change their teaching practice.

In considering factors which may present barriers to teachers' intentions to use technology, one influence, identified in the literature, is teachers' perceptions of their own technological knowledge; for example, if they feel they will be able to cope with unexpected problems (BECTA, 2004). In addition, their perceptions of the costs for both themselves and their students in terms of time and money may also influence their intention to use technology.

The development of technological pedagogical content knowledge (TPCK) has been identified as essential for good teaching with technology (Mishra & Koehler, 2006). TPCK encapsulates the specific knowledge that a teacher needs to teach well with technology in the context of the content that they are trying to teach. If a teacher perceives that they lack TPCK, then they may be reluctant to use technology.

Additional time needed to integrate technology into teaching practice is an important consideration and possible barrier to implementation by many teachers (see for example, Mumtaz, 2000). Coffland and Strickland (2004) found that teachers perceived that teaching with technology required more time both in preparation and in class than their traditional teaching. The perceived effort involved in learning technology, and changing practice was highlighted by the teachers who commented that the "technology required more time to learn and implement than they had available or were willing to give" (p. 358). This included a perception that if they used technology, they would not have time to finish the course.

A teacher may perceive that learning to use technology will be an extra burden or distract mathematically weak students from core mathematical learning. An example of the impact of such thinking is described by Kendal and Stacey (2002) who report the observations of the same teacher with two different cohorts of year 11 calculus students in two consecutive years. His choices about the use of CAS calculators were dependent on his perceptions of the mathematical ability of his students. When teaching the first cohort, the teacher made use of the symbolic, graphical and numeric representations of CAS. However, he chose to make less use of technology in the second year because he considered that this second group was mathematically 'weaker'. He did not use the tables and spreadsheets facilities of CAS for introductory calculus in the second year as he thought this would only be an additional burden on students. In this case, the teacher's knowledge of several different approaches to teaching calculus, along with his perception of the students' mathematical ability, were key in influencing his decisions about if, when and how to use technology.

Some studies comment that access to technology actually enables less-able students to participate in exploration (Ruthven & Hennessey, 2002), and others perceive that the technical overhead, when learning new technological features, may be an additional burden (Tynan, 2003).

External constraints commonly have a negative impact on adoption of technology; for example, if the technology is not easily available or its use is not permitted in examinations, then it is highly unlikely to be used in mathematics classes. In such circumstances, teachers may be expected to restrict use of technology in their classes (Macintyre & Forbes, 2002). In contrast, the state-wide Victorian curriculum documents (VCAA, 2005a, b) for years 7–12 encourage the use of a range of technology for learning mathematics at all year levels (VCAA, 2005a) and at year 12, technology is permitted for most mathematics assessment, including in externally set mathematics examinations. In such circumstances, teachers may be expected to encourage the use of technology in their classes.

Faced with the general introduction of new technology for mathematics, teachers may be concerned that students from lower socio-economic groups may have less access to expensive tools. A survey reported by Routitsky and Tobin (1998), and again by Tobin et al. (1999), investigated teachers' perceptions of the use of graphics calculators in Victorian secondary schools. The timing of this survey coincided with students being permitted to use graphic calculators in year 12 examinations. Results showed that teachers were generally positive about the use of technology. However, there was a common perception that the cost of technology, such as graphics calculators, raises serious access and, therefore, equity issues.

The various studies cited above draw attention to specific aspects of teaching with technology. From these studies, we have extracted details relating to attitudes, subjective norms and perceived behavioural controls that have influenced teachers' use of technology for teaching mathematics. Based on the principles of TPB, analysis of these factors was used to inform the development of items for the Mathematics with Technology Perceptions Survey (MTPS). It was expected that, by organising information in a new way, the results of the MTPS would highlight both barriers and enablers to teachers' intentions to use technology.

3 Methodology

Data were collected from mathematics teachers in a wide range of schools by means of an emailed survey with two sections. The items (comprising the MTPS) reported in this paper focus on mathematics teachers' attitudes and perceptions and formed Section 1 of the emailed survey. In Section 2 of the survey (the 'Mathematics with Technology Use' Survey—not reported here), teachers were asked to answer a series of questions in relation to the class with which they had made greatest use of technology in the past year. They were asked to identify the technology they had used and to indicate whether they, or their students, used it to support doing or learning mathematics. Only the data related to responses to the MTPS are reported in this paper. However, it is important to note that scientific, graphics and CAS calculators and lists or tables or spreadsheets, were the most commonly used technologies, and teachers' responses should be interpreted with this in mind.

A convenient but reasonably representative (see Table 2) sample of teachers was obtained. The aim was to take a census approach by emailing all Victorian secondary schools, but it proved difficult to locate correct addresses for all schools. After several rounds of corrections, approximately 200 secondary schools were emailed without error. The email to the schools asked that the letter be forwarded to the school's mathematics coordinator. The details of the study were explained in this letter, and coordinators were asked to volunteer to complete and return the emailed survey and ask other staff teaching mathematics to do the same.

TPB underpins the design of the MTPS reported in this paper. The purpose of these items was to ascertain the prevalence of key attitudes and perceptions creating barriers or enabling teachers' intentions to change their practice and to teach mathematics with technology. The 12 items targeting attitudes, subjective norms and perceived behavioural controls were based on the literature and distilled from a 57-item pilot survey given to teachers from four different schools. The pilot survey was designed following the guidelines for TPB questionnaires provided by Francis et al. (2004). The wording of the MTPS items was influenced by teacher views that we had heard commonly expressed at professional development sessions and in research meetings. In restructuring the survey to collect information about teachers' attitudes and perceptions related to using technology for teaching mathematics as part of this study, we noted that Francis et al. (2004) suggested that the TPB framework may be explored using as few as 12 items. We chose to take this option because we wanted a brief survey that would not be a burden for teachers. Guided by the TPB, six of the items in the MTPS summarise perceptions which are likely to encourage or enable a teacher to adopt the use of technology (E), while the other six statements presented likely barriers (B). Note that disagreeing with a 'barrier' statement does not mean that that factor is an 'enabler'; however, disagreeing with an 'enabler' may create a 'barrier'. Table 1 shows this classification of items as enablers or barriers along with a tag to indicate whether the item relates primarily to:

- an attitude towards teaching mathematics with technology (AT)
- a possible subjective norm, i.e. perception of the value which others, who are professionally significant to teachers, may place on the use of technology for teaching mathematics (SN)
- condition which the teacher may perceive as behavioural controls, i.e. barrier that makes using technology for teaching mathematics difficult and would, therefore, discourage a teacher from choosing to adopt this practice (BC).

In addition to the attitude and perception items, demographic data were collected on gender, years of teaching, geographical location and school system affiliation. Years of teaching was then grouped to identify those who were likely to have trained since 2000, in an era when the use of graphics calculators in senior secondary mathematics has been assumed in this state; those who trained prior to 1980, when access to MAS other than simple arithmetic calculators was unusual; and the middle group. Geographical location

Table 1 MTPS items with codes and percentage of respondents for each option

	Codes		Mathematics with technology perceptions survey item	SD	D	N	A	SA
1	AT	E	If I use more technology, my students will be more motivated to work on their math	3	9	30	50	8
2	AT	B	Students don't understand math unless they first do it by hand	4	48	24	18	5
3	BC	B	If there are unexpected problems caused by technology this will be very difficult for me	16	45	17	17	4
4	AT	E	Technology can be used to help students gain a deeper understanding of math than is possible in a by-hand classroom	2	8	12	59	20
5	SN	E	The math co-ordinator (or principal) expects me to use technology in my math classes	2	5	13	51	28
6	SN	B	My colleagues think that when my students use technology for math they are 'just pressing buttons' and not really learning math	12	52	21	14	1
7	SN	E	My students' parents think more technology should be used in math classes	1	23	60	15	0
8	BC	B	If I use more technology I won't have time to cover the course	14	47	15	22	2
9	BC	B	Technology is too expensive for my students to access	9	39	20	26	6
10	AT	E	Using technology makes math more enjoyable for my students	0	2	11	62	25
11	BC	B	Learning to use new technology for my math classes will encroach too much on my personal time	11	56	17	10	5
12	AT	E	Technology can be used to allow my students to engage with more real world problems	2	4	9	61	24

n=91 for items 1 and 7; n=92 for all other items; for ease of comparison, percentages have been displayed rather than frequencies. Similarly, percentages have been rounded to whole numbers; therefore, not all sets add to exactly 100. This had no effect on the pattern of responses. Responses were scored from SD=1 to SA=5.

AT attitude, *SN* subjective norm, *BC* perceived behavioural control, *E* enabler, *B* barrier, *SD* strongly disagree, *D* disagree, *N* neutral, *A* agree, *S* strongly agree was recorded by asking the name of the government designated, education department region to which their school belongs. These were recoded as metropolitan (Greater Melbourne area) and non-metropolitan. School system affiliation was classified as Government and Non-government. This distinction may be of importance because each is funded differently and accesses professional development in different ways.

4 Results and discussion

4.1 Demographics

Ninety-two teachers responded to the MTPS. To preserve anonymity, teachers were not asked to disclose their name or their school but we do know that cohort of teachers, who chose to respond, was diverse in each of the demographics dimensions canvassed. The composition of this cohort is summarised in Table 2.

The numbers of teachers in each sub-category of the sample was reasonably reflective of the equivalent proportions in the population of mathematics teachers in Victoria, Australia. Accurate population data were not available; however, based on recent reports (Harris & Jenz, 2006; DEECD, 2007), it is estimated that two-thirds of mathematics teachers had more than 10 years experience; 60% of Victorian secondary teachers were female, but more males tended to teach mathematics at senior level; 60% of Victorian secondary students attended government schools and 40% attended non-government schools (over represented in our sample) and finally, approximately 70% of the total Victorian population lived in the metropolitan area.

With regard to the teachers' use of technology, there was also diversity. While 18 teachers did not indicate the year level at which they made most use of technology, of those who did, 19% said grade 7 or 8; 30% grades 9 or 10 and 51% grade 11 or 12. Individual teacher's use of technology varied from those who only used the CD that accompanied the set text book or only used graphs and spreadsheets through to a few who made use of a wide range of technologies including the use of digital images and data loggers. Again, some teachers (this varied from four to seven) did not respond to these items.

4.2 Overview

Statements classified as 'enablers' describe perceptions or attitudes that may encourage a teacher to use, or have their students use, technology for teaching or learning mathematics. In the MTPS, this descriptor applied to items 1, 4, 5, 7, 10 and 12 with modal scores of 4

Table 2 Percentage of teachers in key demographic dimensions

	$Y<7$ Likely trained since 2000	$7\leq Y<27$	$Y\geq 27$ Likely trained pre-1980
Years of teaching	30	56	15
Gender	Male 45		Female 55
School Type	Government 44		Non-government 56
Location	Metropolitan 75		Regional 25

except for item 3 with mode 3 (see Table 1). This suggests a generally positive response to views that would enable teachers to have a positive intention towards the use of technology in teaching mathematics. Only the mode for item 7 indicated fewer positive responses; in fact, 60% were neutral and only 24% negative: many teachers did not perceive any pressure from their students' parents to incorporate more use of technology in their mathematics teaching practice, with only 15% perceiving this expectation.

Statements classified as 'barriers' describe perceptions or attitudes that might discourage a teacher from using, or having their students use, technology for teaching or learning mathematics. In the MTPS, this descriptor applied to items 2, 3, 6, 8, 9 and 11. Overall, the response to barriers was not as clearly positive or negative as the response to enablers. The items were framed so that agreement means that the teacher held a belief, attitude or perception that could pose a barrier to their intention to use technology in teaching mathematics. The modal response to each of these six items was 2 (see Table 1), but overall, the level of disagreement with barrier items was not as strong as the overall agreement with enabler items. However, most teachers agreed or strongly agreed with one or more of the barrier items.

Following Table 3, we consider attitudes, subjective norms and perceived behavioural controls items separately.

4.2.1 Attitudes

Items 1, 2, 4, 10 and 12 describe attitudes as defined earlier in 2.1. Most teachers agreed that using technology would make students more motivated (item 1, 57%), make math more enjoyable (item 10, 86%), assist them to gain deeper understanding (item 4, 79%) and work with real world problems (item 12, 84%). There was a similar response pattern to attitude and belief items 4, 10 and 12 (see Table 1) with item 10, *using technology makes math more enjoyable for my students*, receiving the strongest and most positive response of all items on the MTPS. Eighty-six percent of respondents either agreed or strongly agreed with this statement, only 2% of respondents disagreed and 0% strongly disagreed. It is interesting, therefore, that despite expecting students to enjoy the experience of learning with technology, engage in more real world problems and gain a deeper understanding, only 57% of teachers were positive that this would result in students having increased motivation to learn mathematics (item 1).

Twenty-three percent of teachers agree or strongly agree that *students don't understand math unless they do it by hand first* (item 2). Teachers holding this view may be more restrained in their use of technology; they might support its use for speed and accuracy if its use is permitted in examinations but not explore its use for learning mathematics.

4.2.2 Subjective norms

Most of the teachers clearly felt that their mathematics coordinator or principal expected them to use technology in their teaching (item 5, 79% agree or strongly agree) but most did not feel pressure from their students' parents to increase use (item 7, 15% agree, 60% neutral).

While technology is now widely accepted across education in the state in which these teachers work, 15% of the teachers still agreed that their *colleagues think that when my students use technology for math, they are* '*just pressing buttons*' *and not really learning math* (item 6). On the other hand, 64% of respondents disagreed with this statement. Disparaging views of colleagues may either make the adoption of technology difficult or heighten a teacher's resolve to prove them wrong.

Table 3 Full set of results for statistical tests of association between items

	Years Teaching	Gender	School Affiliation	Location	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11
Item 1	5.386	**6.125**	1.013	0.189											
	0.229	***0.050**	0.602	1.000											
Item 2	5.679	0.575	5.075	1.288	1.350										
	0.221	0.778	0.079	0.526	0.891										
Item 3	2.219	**11.376**	2.404	2.316	5.514	4.530									
	0.721	***0.003**	0.292	0.304	0.229	0.332									
Item 4	3.734	0.127	3.594t	2.497	6.694	2.457	5.528								
	0.422	1.000	0.152	0.317	0.108	0.691	0.208								
Item 5	**11.065**	1.926	0.904	**6.666**	**16.752**	1.676	3.309	**12.025**							
	***0.012**	0.470	0.654	***0.028**	***0.001**	0.823	0.489	***0.008**							
Item 6	2.546	0.709	2.473	0.566	2.361	5.177	2.639	1.169	4.088						
	0.662	0.730	0.286	0.729	0.707	0.264	0.640	0.917	0.364						
Item 7	3.152	3.472	3.196	**6.065**	2.790	3.209	5.915	**11.313**	4.801	1.892					
	0.551	0.172	0.199	***0.049**	0.611	0.531	0.196	***0.011**	0.269	0.778					
Item 8	2.937	1.863	0.927	2.296	2.659	**14.497**	3.090	2.892	2.801	2.622	**9.357**				
	0.587	0.407	0.681	0.306	0.637	***0.004**	0.546	0.595	0.598	0.640	***0.042**				
Item 9	0.811	0.806	4.135	2.704	4.927	7.815	0.856	3.281	6.192	**9.276**	1.931	4.868			
	0.960	0.720	0.128	0.253	0.291	0.093	0.956	0.522	0.150	***0.047**	0.764	0.302			
Item 10	5.867	0.460	1.401	1.451	**12.098**	4.836	5.059	8.547	6.573	2.285	5.074	7.601	6.752		
	0.139	0.873	0.582	0.569	***0.005**	0.286	0.216	0.055	0.128	0.732	0.225	0.054	0.078		
Item 11	1.556	0.464	3.896	1.899	0.913	7.338	5.936	3.024	1.182	8.337	4.224	**14.839**	7.742	6.999	
	0.861	0.811	0.156	0.461	0.946	0.113	0.195	0.565	0.942	0.063	0.376	***0.003**	0.093	0.091	
Item 12	2.314	0.606	1.463	4.500	**8.635**	5.480	6.017	5.200	7.634	1.190	1.579	3.032	2.556	**11.453**	6.927
	0.720	0.750	0.619	0.085	***0.040**	0.203	0.129	0.164	0.066	0.956	0.874	0.564	0.663	***0.015**	0.082

Fisher's Exact test statistic p value. For consistency, Fisher's exact test is used throughout since the assumptions for Chi-square are violated in almost all cases. Statistically significant results at $p=0.05$ are indicated in bold and asterisked

4.2.3 Perceived behavioural controls

The strongest agreement with a barrier statement was with item 9, concern that *technology is too expensive for my students to access*; 32% of teachers agreed with this statement. Concern about the cost of technology was also one of the strongest findings in the study reported by Routitsky and Tobin (1998). Their study focused on hand held calculators and since this is still the predominant technology used for mathematics in Victorian secondary schools it is reasonable to surmise that the same concern persists a decade later and would seem to warrant further investigation.

Twenty-four percent of teachers agreed or strongly agreed with the statement, *if I use more technology, I won't have time to cover the course* (item 8). At a time when teachers were being encouraged by the system to increase their use of technology, most respondents did not perceive this to be a problem. However, for almost one in four teachers, *time to cover the course* was a perceived behavioural control on their use of technology for teaching mathematics. It may be that those who agreed or strongly agreed with this statement thought that they made sufficient use of technology already or perhaps they are trying to teach their mathematics courses in a traditional manner primarily with pen and paper and view teaching technology skills and learning to do mathematics with technology as a time-consuming addition.

There was also evidence of negative perceptions by some teachers about learning new technology. Fifteen percent thought that the learning process would *encroach too much on my personal time* (item 11), and 21% felt that *if there are unexpected problems caused by technology this will be very difficult for me* (item 3). We know that learning to use and teach with new technology requires a time commitment from teachers. It is encouraging to see that 67% of respondents disagreed with the statement about this learning encroaching too much on personal time.

These results confirm that while a majority of these respondents held positive attitudes and perceptions in relation to the use of technology for teaching mathematics, many also perceived barriers.

4.3 Associations between attitudes, perceptions and demographic factors

In the following sections, we consider items where there is a statistical association with one or more demographic factors. In most cases, the low-powered Fisher's exact test results are reported as the skewed nature of much of the data meant that the assumptions for the more common Chi-squared test were not met. While Fisher developed his test for 2×2 contingency tables, this was extended by Freeman and Halton (Mehta & Patel, 1996). For this study, calculations were performed using the statistical software, SPSS 15, and the results may be interpreted in a similar way to those of the Chi-squared test. A summary table for Fisher's exact statistics and associated p values for all items is included as Table 3. Results with a p value less than 0.05 have been identified by use of a bold font. In this discussion, 'expected' refers to the frequency expected if the two factors referred to were independent. We considered the association between each of the statement items and gender; geographical location; years of teaching and school system affiliation.

4.3.1 Differences with gender

Analysis of the MTPS results set out in Table 3 showed evidence of an association between gender and the teachers' views of the motivational value of using technology. Evidence of this difference was demonstrated in teachers' responses to item 1, *if I use more technology, my students will be more motivated to work on their math*. Overall, only 57% of the respondents agreed or strongly agreed with this first statement. However, this response was from 67% of the male teachers compared to 49% of the females, and more female teachers than what we might have expected if the two factors were independent gave a neutral response (Fisher's Exact Test 6.125; p=0.050).

For barrier item 3, *if there are unexpected problems caused by technology, this will be very difficult for me* (Fisher's Exact Test 11.376; p=0.003), the pattern of association with gender was reversed, but the pattern is still the same; males were more positive about technology. Thirteen percent of males and 31% of females agreed or strongly agreed with the statement. If we also consider that those who gave a neutral response were not very confident about working with technology, the result is even stronger: a total of 20% for males and 56% of females.

These results suggested that female teachers may be less confident than males about using technology. However, a majority of both groups see value in using technology for teaching mathematics: 79% of both males and females agreed or strongly agreed that *technology can be used to help students gain a deeper understanding of math than is possible in a by-hand classroom* (item 4). Perhaps this lack of confidence by female teachers may have some impact on female students or be due to the same underlying cause. The results are consistent with those reported for research on students by Pierce et al. (2007) who administered the Mathematics and Technology Attitude Scale to a large group of 15–16-year-old students who were using a range of hand-held and computer-based software for mathematics, but seem partly contrary to Vale and Leder (2004) who reported more negative findings suggesting female secondary students were generally less positive than male secondary students about computer-based mathematics.

Even though this finding was related to students, the result suggests that an important consideration in planning technology-based professional development of teachers is having an awareness that some female teachers may be more likely to perceive themselves as less competent technologically. Presenters need to provide experiences that both increase teachers' confidence as well as their technology skills.

4.3.2 Difference with region

There were minor differences in the response patterns for those teachers who worked beyond the metropolitan area at regional or rural schools. These teachers were more likely than expected to disagree or strongly disagree with item 5, *the math co-ordinator* (*or principal*) *expects me to use technology in my math classes* (Fisher's Exact Test 6.666, p=0.028). The importance of this finding is unclear, and further research is required to explore the reasons for this trend. In more metropolitan schools, there was the perception that school leadership expected technology to be used. Eighty-six percent of metropolitan teachers agreed or strongly agreed with item 5 as compared to 63% of teachers from regional or rural schools.

4.3.3 Differences with years of teaching

Surprisingly, there was a lack of association between years of teaching and most items. Some mathematics teachers, now entering the profession, used technology in their own secondary education and brought personal experience of learning mathematics with technology to their decisions about how to incorporate technology use into their teaching practice. It was expected that these teachers would be less likely to be perturbed by possible barriers; therefore, differences with years of teaching would be evident. However, the only item where there was evidence of association with years of teaching was with item 5, *the math co-ordinator* (*or principal*) *expects me to use technology in my math classes*. Teachers' perceptions of what their school leadership expected of them varied with years of teaching. Those who have been teaching for between 7 and 27 years were more likely to agree or strongly agree with item 5 (91%) than either recent graduates (60%) or those with a very long teaching career (83%) (Fisher's Exact Test 11.065, p=0.012). While based on literature, such as Forgasz and Griffith (2006) who report an earlier survey of a similar but smaller sample, we might conjecture that attitudes to technology relate to age and, therefore, years of teaching experience, it is interesting to note that a breakdown by years of teaching in our study suggested no significant effect on other items.

4.4 Associations between items

There were few statistically significant associations between items 1 to 12. These associations were investigated using Fisher's Exact Tests (see Table 3 for full summary of results) on the count data for 3×3 contingency tables which combined the counts for *strongly disagree* with *disagree* and, similarly, *agree* with *strongly agree*. The lack of association was not surprising as the 12 items were selected to represent key attitudes, subjective norms and perceived behavioural controls, and these items were not intended to form a scale. Four interesting statistical associations did, however, emerge.

It seems that if teachers did not feel that the school leadership (mathematics coordinator or principal) expected them to use technology, then they were less likely to believe that technology use will motivate students. This is evident as responses to items 1 and 5 are not statistically independent. Fewer teachers than expected were either positive or neutral in their response to item 1, *if I use more technology*, *my students will be more motivated to work on their math*, and also disagreed with the statement: *the math co-ordinator* (*or principal*) *expects me to use technology in my math classes* (item 5). More teachers than expected both disagreed that they were expected to use the technology and disagreed with the claim that it will motivate their students (Table 3: Fisher's Exact Test 16.752, p=0.001).

Teachers responded positively to the perception that use of technology can allow students to engage in more real world problems, make mathematics more enjoyable and make students more motivated. This is evident in their responses to items 1, 10 and 12. Here, we see that more teachers than expected agreed or strongly agreed that technology makes mathematics more enjoyable, their students will be more motivated and that the technology will allow students to engage in more real world problems (Table 3: Items 1 and 10 Fisher's Exact Test 12.098, p=0.005, Items 1 and 12 Fisher's Exact Test 8.635, p= 0.040, Items 10 and 12 Fisher's Exact Test 11.453, p=0.015). While the association of these items and item 4, *technology can be used to help students gain a deeper understanding of math than is possible in a by-hand classroom*, is not statistically significant at the 0.05 level, Fisher's Exact is a low-powered test and so it is worth at least noting that the test of association between items 4 and 10 (more enjoyable) yielded a Fisher's Exact Test value of 8.547 with p=0.005. There was some evidence that teachers associated students' increased enjoyment of mathematics with increased understanding or perhaps it is the increased understanding that leads to increased enjoyment—an issue worth investigating further.

There was evidence that those teachers who perceived that students must learn mathematics by-hand (pen and paper) first may see teaching students to use technology as an extra, time-consuming task. They may see using technology as an addition to the previous curriculum that has already occupied all of the allotted class time. The perception that *students don't understand math unless they first do it by hand* (item 2) was strongly associated with the belief that *if I use more technology, I won't have time to cover the course* (item 8; Table 3: Fisher's Exact Test 14.497, $p=0.004$).

Not having time to cover the course (item 8) was also associated with disagreeing with item 7, *my students' parents think more technology should be used in math classes* (Table 3: Fisher's Exact Test 9.357, $p=0.042$) and strongly positively associated with item 11, the belief that *learning to use new technology will encroach too much on my personal time* (Table 3: Fisher's Exact Test 14.839, $p=0.003$). A general concern that learning to use technology will take too much time both in and out of class is an important barrier to be addressed. Teachers' decisions about when and how to use technology for teaching mathematics will take into account their perceptions of this time factor.

The results of this study show similarities to those of Forgasz (2006) who surveyed grades 7 to 10 teachers' views on the use of computers for teaching mathematics. She identified teachers' lack of access, confidence, computer skills and time as factors which create barriers to teachers' use of computers in mathematics, while easy access, teacher's confidence, along with student motivation and enjoyment, were encouraging factors. Forgasz's survey was more narrowly focused in terms of both sampling and technology than the study described in this paper, but the common barriers and enablers identified add weight to their importance.

5 Conclusions and implications

The MTPS, framed by the Theory of Planned Behaviour, proved to be a quick and effective instrument for gathering data on mathematics teachers' perceptions. Such perceptions influence a teacher's intention to use technology in the classroom. The items cover a balance of enablers and barriers while, at the same time, targeting teachers' perceptions of the value of technology for teaching mathematics, its acceptance in the school culture, and factors which inhibit or encourage its use. The MTPS could be used in any setting and easily be adapted to focus on particular software or technologies of interest. The key value of the MTPS is that, while it is brief and simple, it provides sufficient information to allow researchers or educational leaders to gauge the degree of acceptance of technology as an integral part of the mathematics classroom. Results from the MTPS highlight the importance to teachers of the barriers and enablers previously identified by the researchers.

The teachers surveyed for this study work in an education system where there is an expectation that technology is incorporated in teaching and learning and used by students in assessment. Regardless of years of teaching experience, perceptions of technology seemed positive: teachers recognised the potential benefits of technology. Most teachers perceived that their school leaders expected them to use technology for teaching mathematics. The MTPS could be used to monitor change in teacher perceptions over time, providing useful information for strategic planning for teaching with technology.

Despite acknowledging that technology may be used to improve students' learning across a number of dimensions, a considerable number of teachers also perceive a variety of barriers to the use of technology. Importantly, the issue of cost still remains. Many teachers are concerned that the cost of purchasing the technology typically used for mathematics teaching is still not affordable for their students. This has equity implications as the perceived advantages of this technology to support students' learning or for use in examinations may not be equally available for all students. Individual teachers are mixed in their responses to the value of technology, for example anticipating that its use may increase students' motivation and enjoyment but concerned that there will not be time to cover the course.

The responses to this survey confirm that professional development for teachers needs to address attitudes and perceptions as well as technological skill development. Presenters need to capitalize on enablers and present strategies for dealing with barriers. For example, in the cultural context of the respondents to this survey, presenters should be mindful that females are almost three times more likely, than males, to be concerned by unexpected problems with technology. Other barriers may be addressed by incorporating findings from the accumulated evidence of research studies and informal reports of classroom experience. This evidence may equip teachers to formulate an informed position on the role of technology in the teaching and learning of mathematics. Such background information is important to enable discussion with colleagues, including those who suggest that mathematics with technology is merely button pushing. Research on the use of technology in teaching mathematics has not produced unanimously positive results. An informed position will acknowledge barriers and enablers and so form a basis on which to make sound teaching decisions about when and how to use technology.

Transition from a traditional mathematics classroom to one where technology is used as an integral part of teaching requires teachers to be prepared to change and to make a commitment to learning to use the technology in an effective manner. In this study, the Theory of Planned Behaviour has provided a framework that helps to draw attention to attitudes and perceptions that either enable teachers or present barriers to their intention to change. Those educators responsible for providing either pre-service or in-service mathematics teachers with training in teaching with technology, along with school leaders, need to build on enablers and address likely barriers if changed teaching practice is to actually take effect in the classroom.

Acknowledgement The authors wish to thank the reviewers for their detailed constructive comments and direction to additional literature.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*, 197–211. doi:10.1016/0749-5978(91)90020-T.

Ajzen, I. (n.d.) The theory of planned behavior bibliography. Retrieved 22nd April 2008 from http://people.umass.edu/Ajzen/tpbrefs.html.

Ball, L., & Stacey, K. (2005). Teaching strategies for developing judicious technology use. In W. J. Masalski, & P. C. Elliott (Eds.), *Technology-supported mathematics learning environments (2005 National Council of Teachers of Mathematics Yearbook)* (pp. 3–15). Reston: NCTM.

Baylor, A. L., & Ritchie, D. (2002). What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms? *Computers & Education*, *39*, 395–414. doi:10.1016/S0360-1315(02)00075-1.

British Educational Communications and Technology Agency. (2004). A review of the research literature on barriers to the uptake of ICT by teachers. Retrieved July 28th, 2008 from http://partners.becta.org.uk/upload-dir/downloads/page_documents/research/barriers.pdf.

Cedillo, T., & Kieran, C. (2003). Initiating students into algebra with symbol-manipulating calculators. In J. T. Fey, A. Cuoco, C. Kieran, L. McMullin, & R. M. Zbiek (Eds.), *Computer algebra systems in secondary school mathematics education* (pp. 219–240). Reston: NCTM.

Coffland, D., & Strickland, A. (2004). Factors related to teacher use of technology in secondary geometry instruction. *Journal of Computers in Mathematics and Science Teaching*, *2*(4), 347–365.

DEECD.(2007). Department of Education and Early Childhood Development Annual Reports 2006-2007. Retrieved 10th July 2008 from http://www.education.vic.gov.au/about/publications/annualreport/annual2007.htm.

Forgasz, H. (2006). Factors that encourage or inhibit computer use for secondary mathematics teaching. *Journal of Computers in Mathematics and Science Teaching*, *25*(1), 77–93.

Forgasz, H. J., & Griffith, S. (2006). Computer algebra system calculators: gender issues and teachers' expectations. *Australian Senior Mathematics Journal*, *20*(2), 18–29.

Francis, J., Eccles, M., Johnston, M., Walker, A., Grimshaw, J., Foy, R., et al. (2004). *Constructing questionnaires based on the theory of planned behaviour: A manual for health services researchers*. Newcastle-upon-Tyne: University of Newcastle.

Gardiner, T. (2001). Education or castration? *Micromath*, *17*(1), 6–8.

Harris, K.-L., & Jensz, F. (2006). The preparation of mathematics teachers in Australia. The University of Melbourne: Centre for the Study of Higher Education, Retrieved 10th July 2008 from http://www.cshe.unimelb.edu.au/pdfs/Prep_Math_Teach_Aust.pdf.

Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution and change. *Journal of Curriculum Studies*, *37*(2), 155–192. doi:10.1080/0022027032000276961.

Herget, W., Heugl, H., Kutzler, B., & Lehmann, E. (2000). Indispensable manual calculation skills in a CAS environment. *Micromath*, *16*(3), 8–17.

Kendal, M., & Stacey, K. (2002). Teachers in transition: Moving towards CAS-supported classrooms. In E. Schneider (Ed.), *Zentralblatt für Didaktik der Mathematik*, *34*(5), 196–203.

Macintyre, T., & Forbes, I. (2002). Algebraic skills and CAS—could assessment sabotage the potential. *International Journal of Computer Algebra in Mathematics Education*, *9*(1), 29–56.

Mehta, C. R., & Patel, N. R. (1996). *SPSS Exact tests 7.0 for Windows*. Chicago: SPSS Inc.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054. doi:10.1111/j.1467-9620.2006.00684.x.

Mumtaz, S. (2000). Factors affecting teachers' use of information and communications technology: a review of the literature. *Journal of Information Technology for Teacher Education*, *9*(3), 319–342.

Pierce, D., & Gunn, J. (2007). GP's use of problem solving for depression: a qualitative study of barriers to and enablers of evidence based care. *BMC Family Practice*, *8*, 24. doi:10.1186/1471-2296-8-24.

Pierce, R., Stacey, K., & Bartaksas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers & Education*, *48*(2), 285–300. doi:10.1016/j.compedu.2005.01.006.

Prochaska, J., & DiClemente, C. (1983). Stages and processes of self-change of smoking: towards an integrative model of change. *Journal of Consulting and Clinical Psychology*, *51*, 390–395. doi:10.1037/0022-006X.51.3.390.

Routitsky, A., & Tobin, P. (1998). A survey of graphics calculator use in Victorian secondary schools. In C. Kanes, M. Goos, & E. Warren (Eds.), *Teaching Mathematics in New Times. Proceedings of 21st Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 484–491). Sydney: MERGA.

Ruthven, K., & Hennessey, S. (2002). A practitioner model of the use of computer-based tools and resources to support mathematics teaching and learning. *Educational Studies in Mathematics*, *49*, 47–88. doi:10.1023/A:1016052130572.

Scrimshaw, P. (2004). *Enabling teachers to make successful use of ICT.* Coventry: BECTA.

Sugar, W., Crawley, F., & Fine, B. (2005). Critiquing theory of planned behaviour as a method to assess teacher's technology integration attitudes. *British Journal of Educational Technology*, *36*(2), 331–334. doi:10.1111/j.1467-8535.2005.00462.x.

Thomas, M. O. J., Hong, Y. Y., Bosley, J., & Delos Santos, A. G. (2006). Use of calculators in the mathematics classroom. *The Electronic Journal of Mathematics and Technology*, *2*(2), 229–242.

Thomas, M. O. J., Tyrrell, J., & Bullock, J. (1996). Using computers in the mathematics classroom: the role of the teacher. *Mathematics Education Research Journal*, *8*(1), 38–57.

Tobin, P., Routitsky, A., & Jones, P. (1999). Graphics calculators in Victorian secondary schools: Teacher perceptions. In J. M. Truran, & K. M. Truran (Eds.), *Making the difference. Proceedings of 22nd Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 502–506). Sydney: MERGA.

Tynan, D. (2003). Student caricatures in a CAS classroom. In B. Clarke, A. Bishop, R. Cameron, H. Forgasz, & W. T. Seah (Eds.), *Making mathematicians. Proceedings of the 40th Annual Conference of the MAV* (pp. 311–319). Melbourne: Mathematical Association of Victoria.

Vale, C., & Leder, G. (2004). Student views of computer based mathematics in the middle years: Does gender make a difference? *Educational Studies in Mathematics*, *56*(3), 287–312. doi:10.1023/B:EDUC.0000040411.94890.56.

VCAA. (2005a). Victorian Essential Learning Standards. Retrieved December 7, 2007 from Victorian Curriculum and Assessment Authority Web site: http://vels.vcaa.vic.edu.au/downloads/vels_standards/velsrevisedmathematics.pdf.

VCAA. (2005b). VCE mathematics study design. Retrieved December 7, 2007 from Victorian Curriculum and Assessment Authority Web site: http://www.vcaa.vic.edu.au/vce/studies/mathematics/mathstd.pdf.

Veen, W. (1993). How teachers use computers in instructional practice: Four case studies in a Dutch secondary school. *Computers & Education*, *21*(1/2), 1–8. doi:10.1016/0360-1315(93)90041-G.