Pedagogical Practices with Digital Technologies: Pre-service and Practicing Teachers

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In this paper the pedagogical practices of practising teachers and pre-service teachers when using digital technologies are described and compared. Data were collected by observation of presentations about using digital technology in mathematics by teachers and pre-service teachers and practising teachers were interviewed. Teachers generally used pedagogical approaches involving student-centred activity whereas pre-service teachers were more likely to use technology to teach concepts by demonstration and were not inclined to use the more student-centred approaches, though many used guided tasks. The study enabled some analysis and reflection upon the promoted action in the learning environments of pre-service teachers.

Numerous researchers have reported the limited use of digital technology in secondary and primary mathematics classrooms (Forgasz, 2006; Goos & Cretchly, 2004; Ruthven & Hennessy, 2002; Sinclair, 2006). The use of digital technology in senior secondary mathematics classrooms where the assessment of students permits or assumes the use of digital technology are notable exceptions around the world (Forgasz, Griffith, & Tan, 2006). Responding to studies that suggest that pre-service teachers will have limited opportunity to develop innovative pedagogical practices that include the use of digital technology, mathematics teacher educators have developed and evaluated technology enriched programs and practices in the education of pre-service mathematics teachers (e.g., Goos, 2005; Sinclair, 2006). The research reported in this paper has a similar genesis and purpose. The pedagogical practices with respect to the use of digital technology of three cohorts of pre-service secondary mathematics teachers are compared with those of a small sample of secondary school teachers who use technology relatively frequently in junior secondary mathematics classrooms.

Background

Ruthven and Hennessy (2002) reported that mathematics teachers in the United Kingdom used computers in mathematics to enhance the classroom ambience, assist tinkering, facilitate routine processes, and accentuate features of mathematics. In Queensland, teachers agreed that technology enabled students to perform calculations more quickly, receive dynamic feedback, study real life applications, and make links between numeric, graphic, and algebraic representations (Goos, 2004). These positive affective and cognitive affects of the use of technology in mathematics learning contribute to teachers' likelihood to use digital technology in their mathematics lessons (Forgasz, 2006; Norton & Cooper, 2001). Teachers' knowledge of software and pedagogical approaches and their beliefs about mathematics and the teaching and learning of mathematics also influence their use digital technology (Forgasz, 2006; Norton & Cooper, 2001). Goos and Cretchley (2004) argued that theoretical frameworks that focussed on identifying factors that encourage or hinder teachers' use of digital technology were too deterministic.

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Using Valsiner's zone theory, Goos (2005) theorised the development of professional identity of beginning mathematics teachers as the negotiation of the constraints and affordances of their learning and professional environment. She analysed the elements of the zones of proximal development (ZPD), promoted action (ZPA) and free movement (ZFM) of a pre-service teacher. Pre-service teachers' skills in using digital technology, pedagogical knowledge using digital technology for teaching and pedagogical beliefs constituted their ZPD. They were influenced by two zones of promoted action, the first that of the university lecturer and program and the second created by the mentor or supervising teacher in the practical component of the training program. The university program was described as "technologically rich" as pre-service teachers had access to graphics calculators that could be readily used in university classroom settings, activities specifically devoted to develop technical and pedagogical skills with technology, and one assessment task that required students to work in pairs and present a technology-based activity for a secondary program. Goos also promoted "mathematical thinking, real world applications and collaborative inquiry" (p. 42). The ZFM included the resources available in the school, curriculum program requirements, and the students of the pre-service teacher's classroom. The way in which this pre-service teacher negotiated this environment illustrated the dynamic nature of learning to teach mathematics.

Sinclair (2006) on the other hand used an ecological framework of complexity theory to reflect upon her practices as a mathematics teacher educator. In this framework the systemic conditions for learning include internal diversity, internal redundancy, distributed control, organised randomness, and neighbour interactions. In her pre-service course rather than setting a specific assessment task on the use of technology, she left the range of tasks more open allowing pre-service teachers to take more responsibility for their learning. As well as specialised workshops she worked on illustrating the diversity of digital use and developing shared understandings for meaningful communication by imbedding technology in every session, thereby modelling the use of technology as "an extension of self" (Goos, Galbraith, Renshaw, & Geiger, 2003). She observed that her pre-service teachers initiated the use of technology in the various assessment and teaching activities of their program.

Pre-service teachers' pedagogical practices with technology was not the particular focus of either of these studies, though others have observed that teachers use technology in ways that are consistent with their pedagogical practices. For example, Ng and Teong (2003) observed that mathematics teachers in Singapore most frequently used digital technology for demonstration of mathematics. Teachers in Singapore who used dynamic geometry most often used the software to prepare worksheets and test papers and to use dragging and animation of pre-designed templates or sketches to show geometrical properties and aid students' visualisation.

Previous research shows digital technology is most effective when students are actively engaged in the constructing of meaning through and with the technology (Goos & Cretchley, 2004). Effective pedagogical approaches therefore involve students using technology as a "partner", or as an "extension of self", where students utilise the affordances of the technology to develop understanding of mathematical concepts and solve problems, rather than using technology as a "servant" to perform mathematical operations uncritically (Goos et al., 2003).

Ng and Teong (2003) developed the framework shown in Table 1 as part of a professional development program for teachers on the use of Geometers' Sketchpad. The level of instruction in this framework varies from teacher demonstration, the most structured and teacher-centred activity, to student-centred open-ended tasks that Ng and Teong call "black box tasks". They identified the alternate student learning objectives related to geometry as teaching (or learning) a concept, consolidating the concept, developing an informal proof of a geometric property or theorem, and problem solving. The consolidation of concepts could be interpreted as providing students with a range of other experiences of the particular concepts previously introduced or developed. Alternately it could be interpreted as practice exercises or the application of geometric skills and concepts to routine geometric problems.

Table 1
A Framework for Teaching Geometry with GSP (Ng & Teong, 2003)

Level No.	Purpose of instruction/Level	Teach concept	Consolidate concept	Informal proof	Problem solving
1	Teacher demonstration				
2	Templates/pre-made sketches				
3	Guided exploration/construction tasks				
4	Black box tasks				

In this paper the pedagogical approaches developed by pre-service teachers and the learning purposes of using digital technology are investigated. These approaches are compared with teachers of mathematics. The aim of this study is to consider the way in which the promoted action of a pre-service teacher education program and that of teachers in schools is reflected in the pedagogical practices of pre-service teachers.

Methods

Eight teachers, ranging in experience from 1 year to 25 years, who teach in socially disadvantaged schools in the western region of Melbourne and who reported that they used digital technology regularly participated in the first study that is reported in this paper. These teachers were selected following telephone interviews of mathematics teachers to identify teachers who used technology in junior secondary mathematics more than twice per term. Four of these teachers had previously supervised or mentored a pre-service teacher. The practicing teachers were interviewed using as semi-structured interview protocol and their responses tape-recorded. During the interview the teachers were asked to describe a successful mathematics lesson that integrated the use of digital technology and to explain why they thought that it was successful. These teachers also participated in a whole day workshop on the use of digital technology and presented examples of mathematics lessons that they found to be successful to their peers as part of the workshop program. Field notes were taken of these presentations and digital copies of some of these activities were gathered later.

In the second study, pre-service teachers who were enrolled in the mathematics pedagogy subject of a secondary teacher education program (Graduate Diploma of

Education (Secondary)) in the years from 2004–2006 were participants. The number of pre-service teachers enrolled varied: 30 in 2004, 25 in 2005, and 10 in 2006. As part of the course pre-service teachers are required to work in schools under the supervision of an experienced teacher of mathematics. The pre-service teachers worked in one school for 1-day per week throughout the year and for two 4-week periods during the year.

During the course pre-service teachers participated in workshops on the use of digital technology. The purposes of these workshops were two-fold: firstly to provide pre-service teachers with the opportunity to develop some knowledge of the software and the technical skills to operate the software or hardware, and secondly to model innovative practices in the implementation of digital technology in the classroom. In each year students participated in a three-hour workshop on Geometer's Sketchpad (dynamic geometry software) and another three-hour workshop on graphics calculators where the focus was on teaching and learning functions. In 2005 and 2006 students also participated in a three-hour workshop on a CAS (computer algebra system) calculator. Students in 2006 also used graphics calculators during a further session on senior secondary chance and data curriculum. Many students in each year of the course were mature age students or educated overseas and had not had an opportunity through their own secondary education to develop technical skills in the use of graphics calculators and other mathematics specific software. Furthermore, it cannot be assumed that all pre-service teachers in the course will have used computer algebra or statistical software in their undergraduate studies of mathematics (Lavicza, 2006).

In each year students were required to complete a technology assignment to fulfil the assessment requirements for the mathematics curriculum and pedagogy subject. For this assignment pre-service teachers conducted some research into the use of digital technology in the teaching of mathematics and then presented a teaching and learning activity to the rest of the group. The specific requirements varied slightly from year to year. In 2004 and 2005 students worked in pairs on this task, though some students chose to complete this assignment individually. In 2006 the students worked individually on the task and were required to evaluate the use of the resource based on their experience of observing or using it during the practical program of the course (partnership placement).

Descriptive accounts (field notes) of the pre-service teachers' presentations were kept by the researcher, who was also the lecturer for this subject, in each of these years. Digital copies of the materials that students' presented were collected for most students, especially in 2005 and 2006.

Data were analysed using an adapted version of the Ng and Teong's (2003) Framework to apply more generally to other areas of the mathematics curriculum and the range of digital resources that teachers of mathematics may choose to use. The purposes and objectives of teaching and learning were redefined and expanded to include practise and the application of mathematics to real world situation. The levels of teacher direction in the design of instructional activities were also re-interpreted. The category "templates and pre-made sketches" was modified to also include interactive learning objects. Many of the resources available on the Internet are in the form of interactive learning objects. "Black-box" tasks were re-labelled as "open-ended tasks". An additional category was added: "research project" for semi-structured tasks or assignments that involved student inquiry.

Findings

The digital learning activities that teachers reported in the interview or presented to peers during the workshop are categorised in Table 2. A letter identifies each teacher in the study. These data show that each teacher used either one or two pedagogical approaches. They used approaches of varying levels of student-centredness: templates or learning objects, guided tasks, or research projects. Teachers also used digital technology for a range of learning purposes, though informal proof was the least likely to be reported. In a previous paper I presented a more detailed analysis of one of these teacher's pedagogical practice (Vale, 2006). Here I provide a brief description of some of the activities reported by teachers.

Table 2
Teachers' use of Digital Technology

Purpose of instruction/Level	Teach/learn concept	Consolidate concept	Informal proof	Problem solving	Application
Teacher demonstration					
Templates/ interactive learning objects	G, H	A, E, F, H		A, C, F, G	
Guided exploration/ tasks	A, B, F, H		H		A, E
Research project Open-ended task	C, D, G	C, G			C, G

Teachers prepared templates for students to record results of investigations and to learn concepts such as π, and they used games and online interactive learning objects to practice number skills, consolidate understanding of the relationship between algebraic and graphic representations of linear equation, and develop skills such as estimation. They claimed that these activities enabled students to work at their own pace. Templates and interactive learning objects were also used for problem solving.

Guided tasks were also popular and used by teachers for exploring geometric properties and measurement concepts and learning about box-plots and statistics. At least two of the teachers who used this teaching approach were adamant these activities were most successful when students were provided very clear "step-by-step" instructions. These instructions were concerned with learning to use the tool but also helped students to focus on what to observe and scaffolded mathematical interpretation of dynamic visual media. Although two of these teachers preferred to provide students with guided tasks for the application of mathematically skills, such as presentation of data, others preferred to use integrated curriculum research projects where students worked collaboratively to use the Internet to gather data or information and to use digital tools to analyse or present their work. Teachers using this approach observed peer assistance, tutoring, and mentoring.

Over the 3 years in which pre-service teachers completed the technology assignments 35 presentations were analysed. In each year at least one pair of pre-service teachers chose to base their presentation on the use of technology to design assessment tasks and these presentations were not included in the data presented in Table 3. Also a few pre-service teachers did not complete the task or records of their presentation were not retained. The 35 presentations analysed and reported in Table 3 were the work of 53 pre-service teachers. Table 3 shows the percentage and number of pre-service teacher technology presentations in each category. Many of the activities presented by pre-service teachers were ones that they had used or observed during their practical experience in schools, though data on this was not always recorded for pre-service teachers in 2004 and 2005.

Table 3
Pre-service Teachers' use of Digital Technology

Purpose of instruction/Level	Teach/ learn concept	Consolidate concept	Informal proof	Problem solving	Appl'n	Total
Teacher demonstration	14 % (5)	6% (2)				20% (7)
Templates/ ILOs	6% (2)	11% (4)		3% (1)	3% (1)	23% (8)
Guided exploration/ tasks	31% (11)	6% (2)		6% (2)	9% (3)	51% (18)
Research project					3% (1)	3% (1)
Open-ended task					3% (1)	3% (1)
Total	51% (18)	23% (8)		9% (3)	17% (6)	100% (35)

The data in Table 3 show that pre-service teachers were most likely to present a technology-based learning activity that was a guided exploration or task (51%) and they were also most likely to use digital technology to teach or learn a concept (51%). Moreover, the pre-service teachers were most likely to use a guided task to teach or learn a concept (31%). Typically these presentations involved the use of a function-grapher (graphics calculator, Excel, Geometers' Sketchpad, or Graphmatica) to investigate the effect of parameters in symbolic expressions on the graphs of functions (such as linear, quadratic, or exponential functions). The pre-service teachers were thus focussed on the interaction of symbolic, graphic, and numeric representations of concepts and, in particular, the use of visualisation of graphic images or numeric patterns to learn about a mathematical concept. A closer analysis of materials presented however found that one-third of these guided activities did not include questions that required students to compare and contrast graphic or numeric data or to require students to conduct further exploration through the use of "what if" type questions. The guided tasks were in essence designed for students to learn to use the tool to generate graphs or tables of data.

Pre-service teachers also showed a propensity to use templates or interactive learning objects (23%) or incorporate the use of technology through teacher demonstration (20%). Pre-service teachers were also likely to use technology to consolidate concepts or practice skills (23%) and for application to real world situations (17%). Activities for consolidating concepts and practising skills included online quiz and game sites, game software, and teacher designed games using spreadsheets. One presentation involved the uncritical and routine use of spreadsheet templates for presenting data.

Most of the teacher-centred demonstration methods occurred in 2006. It is not clear why this was the case. These demonstrations typically concerned instruction on the technical skills needed to use software for a particular task. For example, one of these demonstrations involved teaching students to use Excel for the calculation of statistics (mean, mode, and median). In other presentations pre-service teachers used software tools or authentic data to demonstrate a concept. For example one pre-service teacher used Excel to demonstrate an application in financial mathematics and another pre-service teacher used TinkerPlots as part of a PowerPoint presentation to demonstrate correlation. Perhaps because pre-service teachers worked individually they did not benefit from collaboration with peers that may have involved them in more pedagogical discussions of how to best use the material and resources available. In two of these cases, the presenters drew upon data and methods of using technology from their previous professional occupations.

The use of digital technology for problem solving or applications was more likely to be the focus of the presentation for pre-service teachers in 2005 and 2006. Pre-service teachers typically made use of commercially available learning objects and template for problem solving. Student surveys and other forms of data collection were typical application tasks. The only open-ended task involved the use of drawing software to explore and create tessellated designs.

Discussion and Conclusion

Pre-service teachers adopted the practice of guided tasks, popular with teachers to demonstrate their understanding of the role of technology in mathematic learning. However, the execution of these tasks indicated that rather than indicating a propensity to involve the use of technology as a "partner" for students in mathematics classrooms, the practice of pre-service teachers suggested they were more likely to use digital technology as a "servant" in mathematics classrooms. As the data gathered from practising teachers relied on self-report data that were not always accompanied by copies of material it is possible the pre-service teachers are observing guided instruction on the development of technical skills. This finding indicates that I need to work with pre-service teachers on planning structured inquiry with technology and in particular on the framing of questions that will scaffold and focus students' learning. Some very good resources exist and these need to be shared with mentors and supervising teachers in partnership schools.

Teachers in the study were more likely than pre-service teachers to use research projects as a way of integrating technology in mathematics learning. These tasks provided for internal diversity, meaningful communication among students, collaborative inquiry and shared responsibility for learning (Sinclair, 2006). It would seem however that this form of learning activity is not commonly modelled in the range of schools in which pre-service teachers undertake their practical training. Effective models of this kind of task need to be incorporated into the pre-service program.

Pre-service teachers used demonstration whereas the teachers in the study did not. Indisputably this is a common and successful element of teachers' pedagogical practice and pre-service teachers need to develop the communication and instructional skills required to use technology successfully for demonstration in their teaching too. However this finding suggests that the teachers in the study are more amenable to innovative practices than many of the pre-service teachers, and probably many of their peers who use digital technology less regularly, or rarely, in their teaching of mathematics. It suggests some differences in pedagogical beliefs or that pre-service teachers have not had sufficient opportunity to develop diverse pedagogical practices when using technology.

This project has provided me with information about the nature of "promoted action" with respect to the use of technology in secondary mathematics classrooms and to analyse and reflect upon pre-service teachers' developing pedagogical practice with technology. Although many pre-service teachers were afforded the opportunity to observe or practise the use of technology in mathematic teaching, others would appear to have less experience in classroom settings. Some mentor teachers encourage pre-service teachers to trial activities using digital tools and materials whereas others are constrained by the lack of encouragement or resources or by the curriculum requirements set by the supervising teacher. I need to model more regularly the various ways in which technology may be imbedded in mathematics teaching and to work with school colleagues to provide pre-service teachers with further opportunities for collaborative inquiry in university or school settings.

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