ICT Support as a Strategy for Developing of Mathematical Thinking

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Abstract

Australasian research indicates that pre-service primary teachers have poor attitudes towards mathematics and lack confidence in teaching mathematics particularly problem solving. At the University of Western Sydney in Australia, students in both primary and secondary areas have expressed dissatisfaction over the lack of supervision by mathematics specialist lecturers during in-school professional experience sessions. This has occurred in a context of shrinking university budgets, where class sizes have risen and where in some cases, specialist lecturers have been replaced by much cheaper non-specialist casual staff and thus increased demand upon the remaining mathematics education specialists. This paper presents ICT activities and strategies used to cope with this increased workload. It also discusses the use of ICT to support and enhance the development of mathematical thinking of pre-service primary and secondary teachers in this environment. It has implications for both the teaching of mathematics in mathematics method subjects and the provision of support for in-school professional experience sessions.

Background

The context for this paper in the Australian state of New South Wales (NSW) is one of continuing reduction of support for teacher education while there is a looming shortage of teachers. The Australian Council of Deans (2001) stated that "teacher supply is projected to reach critical levels over the next five years" and that "the need to train more teachers is an urgent one" (p. 114). At the University of Western Sydney (UWS) mathematics education units are presented to both primary and secondary pre-service teachers. The aims of these units are to develop the mathematical thinking of the pre-service teachers while addressing the pedagogical issues associated with both the development of mathematical thinking of their potential students and the integration of ICTs (information and communication technologies). This paper will discuss attempts to use ICTs to combat difficulties due to the deteriorating level of support while enhancing the development of mathematical thinking of the pre-service teachers.

Mathematical thinking and attitudes

It has been a concern of Australasian researchers for some time that pre-service primary teachers hold negative views towards mathematics and these views influence their mathematical teaching (Grootenboer, 2003). Although it is well reported that New South Wales primary pre-service teachers have poor attitudes towards mathematics due to their past performance (Bobis & Cusworth, 1994, 1995), a key assumption of the UWS units is that everyone can do mathematics once they are engaged with the activity. The UWS units are informed by the considerable progress that has been made in activating learner's powers to think mathematically by paying close attention to the nature of learning (Mason, 2001). Problem solving is a focus of all units and the problems are chosen so that they permit multiple approaches and a variety of different levels of sophistication.

These problems and activities are selected upon their ability to foster and cater for diversity in learning in order that every pre-service teacher has access to the content contained within the problem. It is through successful and rewarding problem solving experiences that the attitudes of these pre-service teachers are changed. As English (2002) observed:

> "... research has shown repeatedly how numerous under-achieving students show exceptional abilities to deal with sophisticated mathematical constructs when these understandings are grounded in their personal experiences and are expressed in familiar modes of representation and discourse" (p. 105).

While the attitudes of the secondary pre-service teachers are not as negative as their primary colleagues, nevertheless the strategies outlined in this paper are also applied to units for this group.

Some hurdles to integrating ICTs in mathematics

The link between mathematical thinking and computer-based technologies has always been strong. However, the integration of ICT into the teaching and learning of mathematics has not been without significant difficulties. Schools in NSW have adopted various approaches and these greatly influence the beliefs and behaviour of pre-service teachers assigned to these schools for professional practice. The units at UWS seek to prepare the pre-service teachers to identify, cope and adapt the approach adopted at their assigned school.

A commonly adopted approach promotes ICT as a tool for use across the curriculum where the emphasis is on the development of ICT-related skills, knowledge, processes and attitudes (Russell & Finger, 2003, p. 3). A technocentic focus where educators expect that ICTs on their own will bring about a change (Salomon, 2000), and "promote the use of computers in the classroom as if using technology was an end in itself" (Downes, Fluck, Gibbons, Leonard, Matthews, Oliver, Vickers, & Williams, 2001, p. 23). UWS pre-service teachers are prepared by helping them to differentiate between what ICT can do with what it is doing and what it should be doing. By constant exposure and integration within all their units, the 'dazzle effect' tends to wear off, and the pre-service teachers can redirect their focus upon student learning.

Russell and Finger (2003) pointed to other approaches "that attempted to change the orientation from teaching *about* computers to teaching *with* computers". Downes et. al., (2001) discuss a conservative position that uses integration in the sense of technologies being used by the teacher and students "yet the pedagogy remains much the same as in the past" (p. 26). ICT thus is a tool for enhancing students' learning outcomes within the existing curriculum and using existing learning processes (Russell & Finger, 2003). There is a "consistent tendency of the educational system to preserve itself and its practices by the assimilation of new technologies into existing instructional practices. It fits into the prevailing educational philosophy of cultural transmission, where there is a body of important knowledge that has to be mastered" (Salomon, 2000, p. 2). Generally the focus is upon mastery with a consequent development of drill and practice programs, and a " most powerful and innovative technology is taken and is domesticated ... Emasculated tools cannot do any harm, but they do not do any good either" (p. 2). Pre-service teachers are prepared by exposing them to the ways ICT can support learning and the building of knowledge in their units. Particular focus is directed towards the interactivity and multiple data representation capacity of ICT in assisting concept development.

Downes et. al. (2001) describe another approach where "students are actively engaged in gathering data, aggregating their data with those gathered by other students, and making meaning of their results" (p. 26). Here ICTs are integral to the pedagogy which will change not only *how* students

learn but *what* they learn (Russell & Finger, 2003). In terms of mathematics, it means the use of ICT in the teaching of mathematics moves beyond pointing to how ICT can support, improve, and provide new ways of teaching mathematics to how ICT changes the way mathematics is expected to be performed. This is an approach commonly adopted in the UWS mathematics education units where students are involved with mathematical modelling (also called Working Mathematically). Real data, arising from some problem, is analysed by the use of a mathematical model, which produces conclusions and inferences. The use of graphics calculators and the various probes allow data to be captured outside the classroom and to be transferred and analysed at a later time.

Finally Russell and Finger (2003) describe a radical position where integration is a component of the reforms that will alter the organisation and structure of schooling itself. "Among the diversity of school types will be virtual schools, where students spend part or all of their time working 'off-campus', for example, from home using an online computer" (p. 3). They cite over one hundred virtual schools already existing in the U.S.A. as evidence of this trend. Salomon (2000) is critical of this position pointing to the unintended and unknown effects and citing the example of high range internet users experiencing increased loneliness, depression, anxiety and poorer social relationships (Kraut, Patterson, Lundmark, Kiesler, Mukopadhyay, & Scherlis, 1998). Others claim that the internet is an isolating technology that reduces participation in communities (Nie & Erbring, 2000). He states that "not many students have the self-discipline or the sustained motivation to be distance-, virtual learners" (p. 4). So while Russell and Finger (2003, p. 9) conclude that "more sophisticated understandings of the implications of ICTs for reforms in curriculum, pedagogy and assessment are required", Salomon regards this approach as technocentrism in danger of yielding virtual results. If this is the future then UWS aims to prepare pre-service teachers in all their units by providing them with experiences and strategies for ICT to be more efficient and effective in producing independent thinkers, skilled in life-long learning, with sound social values and capable of intelligently handling complex problems.

Having considered some of the ways in which NSW schools have adopted ICT and the consequent pressures placed upon the pre-service teachers, in the following sections, an attempt will be made to convey the strategies used in UWS units to prepare pre-service teachers to meet these and other demands. Strategies that will assist them to identify, cope with and adapt current school approaches.

ICTs and developing mathematical thinking

In all mathematics education UWS units it is intended that all pre-service teachers are immersed in the efficient and effective use of ICTs in order to give them the confidence and the knowledge to incorporate ICTs in their own teaching. Changes are continually occurring to the way teachers operate and the way teachers see the world. So the UWS units seek to help the pre-service teachers make best use of the rapid development of ICTs, even while change is happening around them. They are given the opportunity to consider carefully the social and individual effects due to ICTs as their units progress. So while discussing the strategies used in the development of mathematical thinking their units will also address the questions, is it possible: to differentiate between what ICT can do with what it is doing and what it should be doing?; for ICT to support learning and the building of knowledge?; for ICT to contribute to the development of mathematical thinking?; and, for ICT to be more efficient and effective in producing independent thinkers, skilled in life-long learning, with sound social values and capable of intelligently handling complex problems? (Adapted from Solomon, 2000).

Due to financial constraints, all units are presented using a combination of lectures and tutorials. Students have access to a web site for each unit, which are located on the WebCT platform of the

University's server. The unit web sites support the development of mathematical thinking using a variety of means. The most basic involves the provision of information as all lecture notes, tutorial material and copies of overheads used in the classes are available to students to down-load and read *before* the classes. Students who are unable to attend are able to minimise their loss by having access to the notes. This removes the drudgery for students in copying and allows them time to think and respond to what is being presented. Thus the lecturer is able to conduct an interactive question and answer style of session. There is time for students to engage in problem solving during the lectures and they are encouraged to conjecture and explore their thinking. The lecturer assists the students to deepen their understanding by making connections to previous learning.

Tutorials are very practical and involve the students in activities to develop their thinking and to develop strategies for teaching mathematics with a problem solving perspective. The development of mathematical thinking relies on students being immersed in rich mathematical problem solving tasks. These tasks sometimes involve web-based simulations or applets. All students are required to have a mathematics problem solving exercise book. Every tutorial begins with a problem which each student attempts individually before sharing with a partner, and then with the other students at their table. Finally the strategies for solving the problem and the pedagogical implications are discussed in a whole class setting. Students are encouraged to reflect upon their thinking and to make regular written journal entries of their progress. Some problems become on-line discussions, where the material expands and progresses til the end of semester. The problem, solutions and lesson strategies are recorded in the front of the workbook and become a great resource for the pre-service teachers to use with their classes. The back of the tutorial workbook is taken up with a number of extended investigations that use a theme (mathematics of sport) as a context for a number of small related investigations. Thus the tutorial workbook becomes an instrument to monitor cognitive and metacognitive processes of the learner.

The tutorial includes other activities linked to the teaching of topics chosen from the syllabus. These activities are chosen from a range of 'best practice' publications. Students are also expected to purchase a Tutorial resource book produced by the lecturer which contains material that has been found to be useful over a long period of time and in a variety of situations. While in many cases the activities can be considered ‘best practice’, they do not constitute a ‘magic’ or ‘fool-proof’ prescription for teaching. The material within this book could be seen as contributing to the knowledge required of professional teachers of mathematics. As professionals, teachers are always searching for and collecting good ideas and activities that promote the thinking and learning of their students.

During the lectures and tutorials, other ICTs are introduced, demonstrated and used by the pre-service teachers, such as spreadsheets, internet activities, CD-roms, and databases. The secondary pre-service teachers are loaned a graphical calculator that they return at the end of the year. There is an expectation that pre-service teachers will BOOST (By Out Of School Time) their skills on certain technologies. Take home activities are planned and assigned to develop this expectation such as becoming familiar with the keyboard of a graphics calculator. Web-based simulations and applets are also very useful as take home activities.

Earlier research by Gerber, Shueld, and Harlos (1998) reported that prospective teachers regarded the internet mainly as a source of information and communication. However, the UWS units also stress the processes involved in the construction of knowledge. Salomon (2000) points to a growing emphasis in society upon the access to information, and the processes of selection and integration that it implies. He highlights an important distinction between access to information and the knowledge that guides and results from it, and argues that the information accessed is not the same

as the knowledge constructed on its basis. Thus the information highway and the information age are not the same as the knowledge highway or the knowledge age. To support his argument he lists the differences between the two concepts as:

- "Information is discrete; knowledge is arranged in networks with meaningful connections between the nodes.
- Information can be transmitted as is; knowledge needs to be constructed as a web of meaningful connections.
- Information need not be contextualized; knowledge is always part of a context.
- Information requires clarity; the construction of knowledge is facilitated by ambiguity, conflict and uncertainty.
- Mastery of information can be demonstrated by its re-production; mastery of knowledge is demonstrated by its novel applications" (p. 4).

The process of transforming information into knowledge is a demanding and purposeful process that requires both instruction and a community of learners. In each UWS unit, attempts are made to form communities of learners and to use ICT to support these communities. At the very beginning of the unit, students are given one week to register on the discussion board by leaving a short message about themselves. This is a check that all students have access and the necessary computer knowledge and skills. In the first week, students are divided into communities of learners. Each community is given a private chat room on the discussion site. Thus discussions that are begun during tutorials can be continued via the chat room. The use of a community of learners linked via the web assists the pre-service teachers to gradually build and refine their ideas as the unit progresses.

To further encourage reflection by the pre-service teachers, at the end of each week of classes, one or two questions are displayed on the unit web site. The communities of learners are asked to consider and discuss how to answer these questions. This helps the pre-service teachers to focus their thinking on the key ideas for that week. One component of the unit assessment is a 2 hour end of semester extended reflection activity paper (taken under examination conditions) that consists of 5 questions designed to test knowledge and understanding of the content and methodology covered during the unit. These questions are taken from those displayed each week. One of the gains from this assessment strategy is that the stress from fear of the unknown in examinations is removed or at least greatly reduced. Another gain is revealed in the quality of the answers, which exhibit a deeper understanding of the issues as a result of the prolonged thinking and reflection. And not surprisingly, research involving the extended reflections paper and the pre-service teachers revealed that they did not use pre-prepared and memorised answers as they reported doing in other examinations.

On the discussion site is also a space for the lecturer to answer student questions. It is a rule that questions concerning assignments, examinations or unit material will only be answered via this space. While this ensures that every student has equal access to the information, it also saves the lecturer a great deal of time and effort as questions need only to be answered once. Also, the lecturer advertises the times when he will be on-line and this reduces the expectation by students that they will receive an immediate reply. This also discourages them from asking trivial questions. Often a question will be answered by another student, and the lecturer needs only to add a brief supporting statement. An unintended benefit is that the better students through their questions and enthusiasm greatly influence the pace and quality of the unit. The more relaxed students are intimidated into greater effort by the thoughtful questions and responses from the keener students.

Thus the UWS unit web sites are supportive of claims that the internet can promote more collaborative forms of teaching and learning (Jefferies & Hussain, 1998).

ICTs, developing mathematical thinking and professional experience

Research conducted with the pre-service teachers (White 2002) indicated their dissatisfaction with the degree of specific mathematics support. The secondary group reported their greatest frustration was having a tertiary supervisor who did not have a mathematics teaching background. In UWS because of various constraints methods lecturers are assigned to a couple of schools and supervise all the students in that school. This includes students from all the key learning method subjects such as English, Science and so on. Due to financial pressure upon universities in Australia, casuals are replacing lecturers as a cheaper option. For professional experience, these casuals are usually retired teachers from across all key learning areas and a student is fortunate to have a supervisor with a mathematics background. Thus there was a problem in getting assistance when a situation becomes difficult. The primary pre-service teacher responses were similar to the secondary group. Students wanted access to advice when needed that was independent of the school.

As a consequence of these surveys and inspiration from other research (Herrington, Herrington, & Omari, 2000) another site was constructed and is now on the University's WebCt platform. The site is called MAPS (Mathematics Assistance to Practicum Students) and a detailed discussion of this site and how the students used it can be found in White (2002).

Conclusion

Koblitz (1996) wondered whether more could be achieved by putting resources into simple materials that would stimulate students to think more and to develop their imagination and creativity. There is little doubt that without the use of ICTs in the UWS environment, the quality and presentation of mathematics education units at their current level would suffer. To maintain the current quality without ICT would place too great a demand on staff, time and money. For UWS in the near future it is unlikely that there will be an increase in the funding or resource allocation, so the challenge then becomes how to work creatively within the current limitations. There is no going back to a simpler time, ICTs are a reality in UWS, so the challenge translates to finding the most effective and rich ways they be used to further enhance the thinking and to find ways to challenge the beliefs and attitudes of the pre-service teachers.

This paper has discussed some of the ways ICTs have enhanced the conduct of units in developing mathematical thinking as well as facilitating access to expert and quick mathematical pedagogical advice to pre-service teachers. The success has been overwhelmingly positive if measured against the formal and informal feedback received from the pre-service teachers. It is an aim of all units that by:

> "... supporting learners in developing and refining their powers to think mathematically it is possible to go some way to, if not guarantee, at least make more likely that learners will construe through doing, know through construing, and know to act (to do) through knowing to use their developing powers to think mathematically" (Mason, 2002, p. 156).

Thus the challenge for our UWS learning community, the lecturer and the secondary and primary mathematics pre-service teachers, is to strive

" ... to attain new goals such as the ability to ask smart questions, to work in teams, to acquire life-long-learning skills, to construct higher order knowledge and perhaps above all, to be able to tackle new, complex problems in intelligent and creative ways" (Salomon, 2000, p. 6).

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