INVESTIGATING MATHEMATICS EDUCATION USING MULTIMEDIA

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In 1830, Warren Colburn gave this advice to teachers wishing to teach children arithmetic: "It is necessary rather to furnish occasions for them to exercise their own skill in performing examples, than to give them rules. They should be allowed to pursue their own method first, and then they should be made to observe and explain it, and if it was not the best, some improvement should be suggested ... Examples of any kind upon abstract numbers, are of very little use, until the learner has discovered the principle from practical examples" (Colburn, 1830/1970, p. 15-16).

In 1991, the National Council of Teachers of Mathematics (NCTM) suggested that mathematics teachers be proficient in such things as:

- selecting mathematical tasks to engage students' interests and intellect;
- providing opportunities to deepen their understanding of the mathematics being studied and its applications;
- orchestrating classroom discourse in ways that promote the investigation and growth of mathematical ideas;
- seeking, and helping students seek, connections to previous and developing knowledge (p. 1).

Surprisingly, these visions of mathematics teaching, although over 160 years apart, display very similar sentiments which emphasize the need for student-centered approaches to learning mathematics. In the majority of schools across the world the reality is quite different. In classrooms, students are seated individually, they are required to listen passively and to observe the teacher demonstrating rules and then they spend extensive time practicing these rules. It is apparent that views about teaching mathematics are resistant to change and require restating generation after generation. The answer may lie in the methods through which new teachers become aware of and develop their pedagogical knowledge, skills and attitudes.

For many teachers of mathematics, knowledge about teaching develops from observing and imitating the way their teachers taught the subject (Ball, 1994; Lampert & Ball, 1990). Knowledge of teaching gained from tertiary institutions plays a secondary role. Here knowledge is often transmitted in the form of abstract theories generally unrelated to the contingencies of real classrooms. Where real experiences in classrooms are encountered through, for example, a teaching practicum, preservice teachers are often faced with the admonitions from their more experienced colleagues to put aside their book-learned theories and adopt traditional approaches more in line with their own school experiences. Being able to observe teachers and students working in situations that reflect the views expressed by Colburn and NCTM was, for some, a lucky encounter. However, with the use of current technologies a wide range of experiences can become a part of all student teachers' developing knowledge of ways in which mathematics can be taught and learned with understanding.

Multimedia appears to be an environment that supports aspects of observation, discussion and collaborative activity developing teachers' knowledge. The use of a technology which provides unrestricted access to large amounts of video, graphical, audio and textual material appears to be one way of exposing students to a learning environment. In this environment, students can experience aspects of classroom teaching various perspectives, and view a multitude of important ideas and representations of knowledge.

The purpose of this paper is to provide a description of interactive, self-paced and instructor-supported learning modules that can provide preservice teachers with a more complete range of mathematics teaching and assessment strategies. These modules would provide:

- an understanding of the purpose of each strategy;
- an awareness of the particular strengths and weaknesses of each;
- instances of where each could be usefully employed, and
- an inclination and willingness to employ these strategies in their own classrooms.

The design of the multimedia project was based on a theoretical framework of learning whose focus was on

developing knowledge that was transferable to real situations. This framework of situated learning has the potential to provide the forms of learning outcomes demanded of teacher education programs.

Situated Cognition

Until the invention of schools, nearly all formal knowledge and skill was transferred through apprenticeships (Collins, 1988). Agricultural skills, trades, medicine, law and the arts were all taught by the master who handed on the required skills to the apprentice (Collins, Brown, & Newman, 1989). In the mid-to-late nineteen eighties, teachers and researchers in education began to investigate the notion of apprenticeships and to try to distinguish those characteristics which were critical to its success. Their aim was to begin the process of developing a theoretical perspective for successful learning based on the apprenticeship model, that cognitive science had, to date, not been able to explain.

Brown, Collins and Duguid (1989) were the first to use the ideas to produce a proposal for a model of instruction that has implications for classroom practice. In their model of situated cognition (or situated learning), Brown et al. (1989) argue that meaningful learning will only take place if it is embedded in the social and physical context within which it will be used. Collins (1988) defines situated learning as "the notion of learning knowledge and skills in contexts that reflect the way the knowledge will be useful in real life" (p. 2). The situated learning model is constantly evolving and recent contributions of various theorists and researchers, including the original authors of the model, have expanded and refined the notion to a much more comprehensive and far-reaching framework for classroom application. Many of these authors and theorists believe that useable knowledge is best gained in learning environments which feature the following characteristics (Herrington & Oliver, 1995):

- Authentic context that allows for the natural complexity of the real world
- Authentic activities
- Access to expert performances and the modeling of processes
- Multiple roles and perspectives
- Collaboration to support the cooperative construction of knowledge
- Coaching and scaffolding which provides the skills, strategies and links that the students are initially unable to provide to complete the task
- Reflection to enable abstractions to be formed
- Articulation to enable tacit knowledge to be made explicit
- Integrated assessment of learning within the tasks

Situated learning, as defined in these characteristics, has implications not only for classroom practice but also for the design of interactive multimedia. Not all these elements can be discretely included in a software program, but they can be provided for in a learning environment by considering the ways in which the program will be implemented and evaluated. These characteristics have been incorporated into a learning environment designed to provide a situated learning context in which students can investigate teaching and assessment strategies in mathematics education.

Elements of the Multimedia Learning Environment

Drawing upon the characteristics of a situated learning environment and the requirements of the content area of mathematics, each program was designed to comprise two elements.

(1) A CD-ROM on the issues of teaching or assessment strategies in mathematics education, each incorporating:

- Video clips of teachers using various techniques within their classrooms, with original sound;
- Video clips of teachers reflecting and discussing the strengths and weaknesses of the approach;
- Video clips of children discussing their feelings and thoughts;
- Interviews with experts in the field providing theoretical perspectives;
- Reflections by preservice teachers on the approach;
- Text descriptions of each approach;
- Teacher and student work samples;
- A problem-based notebook providing a variety of tasks within which to examine the resource.

(2) A manual for users and facilitators on how to implement the resource, which would also provide advice on the situated learning elements which were not included in the resource itself (such as collaboration and articulation).

Twenty three categories of assessment and twenty eight teaching strategies were selected as relevant to K-12 mathematics classrooms. This was done by conducting a review of the literature on teaching and assessment and from the reading of current issues in the field. Assistance was provided by two visiting scholars, one with experience in multimedia development in mathematics education, the other knowledgeable in the area of assessment in mathematics. Figure 1 shows the interface of the assessment multimedia program and its constitutive elements.

Videos

By clicking on the video cassette objects under the television screen, preservice teachers can view a short video sequence of either the scene in the classroom where the teacher demonstrates the use of the technique (*Scenario*), the teacher's comments on the use of the technique (*Teacher*), or a student's comment (*Student*).

Filing Cabinet Resources

Descriptions

By clicking on the top filing cabinet drawer, students can read a description of the strategy which includes advice on how to implement the strategy effectively in the classroom.

Samples

By clicking on the second drawer students can examine samples of school children's work or teachers' records. These samples were collected from the schools at the time of filming the segments and then digitized and imported into the program.

Reflections

The third drawer of the filing cabinet contains advice given by a preservice teacher on his or her experience of using the strategy on professional practice in schools.

Interview

Clicking on the bottom drawer of the filing cabinet gives students access to an expert commentary on the use of the strategy. Apart from providing valuable advice on methods of implementing the strategies in the classroom, the expert's comment is important because it allow students to compare their own level of thinking on the issue with the expert's. This is critical to the kind of reflection students might engage in as they use the program.

Notebook

Clicking the notebook on the table allows students to use the electronic notepad and also gives them access to the authentic activities of the program. The first tab, *Notes*, enables students to write their own reflections and ideas as they explore the various elements provided, and also to cut and paste text from three of the resources provided in the filing cabinet drawers: the description of the strategy, the preservice teachers' advice and the expert's comment. At the end of a work session, students can save copies of their notes to their own disks, then format them using their regular word-processing program.

The *Investigations* tab takes students to a series of authentic activities which replicate the kind of task a school teacher might be faced with in real life. The tasks are presented to the student realistically, such as in a memo or letter, rather than simply a list of possible activities, and they include genuine constraints such as deadlines and time allowances. Activities assume that students will be working in pairs or small groups, and require them to examine the resource over an extended period of time, and from a variety of perspectives.

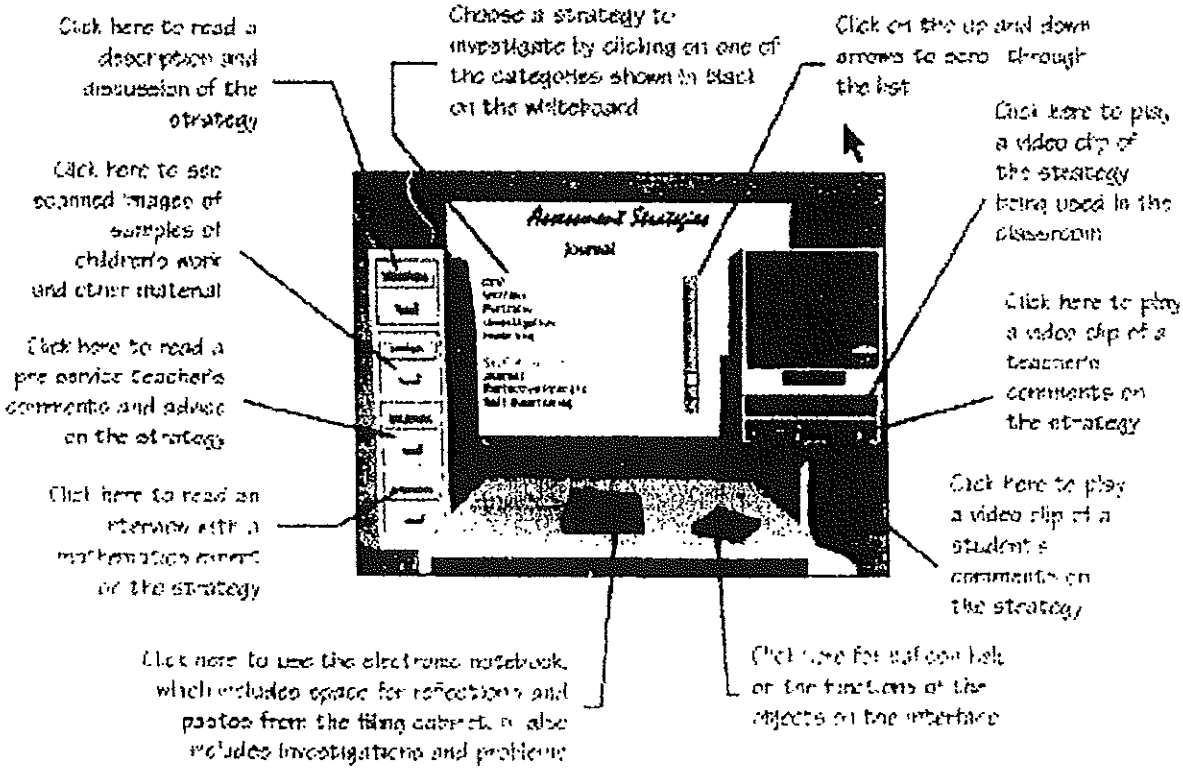

Figure 1. The Program Interface Showing Constitutive Elements.

Clicking on the *Problem Solving* tab gives students access to short problems which are more narrowly focused and require less time to solve. Such problems do not necessarily conform to the situated learning model proposed for the program, but were included to allow lecturers a broader range of approaches and to add versatility to the resource as a marketable item. The problems could be attempted in a single work session rather than the extended period of time recommended for the investigations.

The Manual

The manual provides educators and students with a list of optimum implementation conditions which are all based on the situated learning model used for the development of the program, and acknowledges the position that not all the critical elements of this model can be incorporated into the program itself. Some of necessity must be provided by the educator, and some by the students themselves. This list of optimum conditions is given below:

- The resource is best examined in depth, from a number of different perspectives.
- The resource is best used over a sustained period of 2-3 weeks rather than for a single session.
- The resource is best used by students working in pairs or small groups around each computer, rather than individually.
- The resource is best used when the lecturer is initially present during use to provide 'scaffolding' and support.
- The resource is best used when the lecturer demonstrates the resource by thinking-aloud as an investigation is modeled. Students then choose an investigation from those provided, or their own choice.

The manual also provides educators and students with a description of the theoretical framework on which the program was based, summaries of each of the strategies, and ways in which educators can assess students' use of the resource.

Requirements To Use the Programs

The large amount of multimedia used in the programs necessitated the use of CD-ROM technology as a storage and delivery medium. The resource was developed using Macromind Director, an application well suited to developments of this nature, which also enables cross-platform delivery. The resource has been developed with a mid-range delivery platform in mind. Then programs run on most multimedia compatible computer systems, such as a dual speed CD-ROM with 12Mb RAM, either Windows or Macintosh.

Implementation

Two similar but slightly different methods have been employed to trial the materials with teacher education students. The program on assessment strategies was used with classes of preservice secondary and primary mathematics teachers. In this situation, the lecturer was present and organized all the students to use the computer laboratory at the same time. The other method of no lecturer present (the lecturer-free method) and student nomination of time was used with Graduate Diploma primary and third year Bachelor's of Education students. In this case the lecturer was available on demand after the initial briefing of the workings of the resource and the requirements of the course had been explained.

In both cases students were asked to work in small collaborative groups of three or four members. They were required to select or were given one of the investigations from the program to consider. The activity needed the students to assume the identities of new teachers to a school or the mathematics coordinating committee of a school. They were then given the task to prepare a report on assessment or teaching procedures to be relayed to the rest of the staff (in reality the rest of their class) in a verbal presentation and also in a written form.

Evaluation

Initial evaluation of the resource was done by observation of the classes using the program, by interview with two students who were videotaped during their investigation of the activity and by assessment of the learning shown in the presentation and written report. The interview investigated students' perceptions of the elements of situated learning which had been incorporated into the design of the materials, the design aspects of the interface, the style of working and the quality of their learning.

The response to the interface was positive with students being able to conceptualize the layout of various resources and contents very quickly. They appreciated the classroom context and there was no hint that they felt patronized by the use of pictures in the interface design. One student commented:

> It was set up in a fun way, like it was a classroom. You had a video sitting there, you didn't just have the word 'video' and it didn't have the word 'filing cabinet' there. It was all there with pictures and you could relate to it.

Students generally found the interface and navigation system were logical in their layout and very easy to use, even for those students who were 'not very good with computers'. The non-linear nature of the system also found favor with the students as they were able to access the information in the order of their own choosing. Generally students did not recognize they were learning in a complex environment—each package contains over sixty video clips and over eighty documents—as they referred to the simplicity of the program. Of all the features only the television screen for the video clips was disliked as it was deemed by some students to be too small.

The students valued most the context and real-life relevance of the material they were using. Frequently, they drew contrasts between the authentic context presented in the program and the decontextualised approach often used in their teacher education course.

> Instead of just showing us the theory, it also showed the scenario inside the classroom so we can do that when we go on prac. It gave practical examples which I think the course is lacking a lot of.

There were, however, minor irritations for some of the students with certain personalities on the video clips for example a student commented negatively on the teaching style of one teacher while another noted the variation in the quality of teacher and child interview responses.

The approach established with the program involved, for many, a change in role and expectation both for themselves and the lecturer. For the student, it involved collaboration and thinking, often in a context of uncertainty. Responsibility for when to learn and what to learn was placed with the group of students. Hogan (1996) noted the crucial nature of this change of emphasis as she reflected on her role as lecturer:

> I was struck by the irony that I did an enormous amount of reading and thinking about education in order to prepare my lectures, plan effective workshops and select readings and texts for my students, while the students did relatively little. I was the most active learner in my classes - because I had total responsibility for what was learned and how it was presented for consumption. (p. 79)

The extra flexibility offered in this approach meant that students not only had to decide what the task was, but also decide the steps that would enable them to complete the task. The freedom was a positive feature for some as they could organize their many commitments, domestic, social as well as academic, and find better or more convenient times to work but for others the temptation to procrastinate often resulted in rushed and ill-prepared work.

As was noted earlier, two models of teacher role were used. Both roles attempted to activate the principles of situated learning namely supporting, coaching, clarifying and scaffolding the development of learning. Generally assistance was procedural on both content and software. While the 'lecturer-free' method allowed flexibility of time and was established to interact with the student group as the need arose, this was not always possible due to other commitments or the late evening use of the materials. Often, however, scaffolding or clarifying was done by another member of the group.

Collaborative aspects of the material were seen as crucial to higher quality learning of the main issues related to assessment and teaching. In a minority of cases students allocated aspects of the task to individuals who accessed them on their own and then brought this information back to the group for the presentation. This generally resulted in a qualitatively lower standard of presentation where each aspect of assessment or teaching was briefly sketched by the person who researched it. No overall or deeper knowledge of the issue was established; no argument was presented. The majority, however, worked together to clarify the issue or problem and to develop their response through joint planning and collaboration. In these cases the learning was richer and at a deep level. Students saw the value of collaboration as it aided their understanding both as a result of having someone explain aspects to them or, in the reverse of the case, having to justify or clarify their idea. A student noted:

> When we were doing our notes, it would be like 'What does that mean?' and you would have to explain exactly what you meant. You'd have to explain and explaining always clarifies no matter what you're doing.

Students articulated their understanding of assessment or teaching strategies in two ways: the formal reporting to the staff meeting and in their discussions with their partners as they used the program. One student noted that the capacity of the audience (the staff/class) to respond and question the findings of the report meant that the presenter could not merely copy large amounts of text and present that as a report. The possibility exists in this situation that further explanation will be necessary and understanding of the material is therefore essential. This is a very different form of learning for many students who are experienced at learning and repeating the notes of their lecturer. This depth of understanding established through cooperative work on the issue resulted in many students becoming highly knowledgeable in the areas of teaching and assessment.

The multimedia programs described in this paper, provide a different approach to learning, one that recognizes the importance of making connections to real-life situations, in this case real classroom experiences. The motivation to learn from these experiences has resulted in student teachers developing self-directed strategies that have resulted in quality learning. Ongoing research will determine whether such learning nurtures and promotes the kind of classroom practice envisioned by Colburn and NCTM.

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