MANIPULATING VIRTUAL MATERIALS AND USING "OFFICE" SOFTWARE TO DEVELOP PRIMARY MATHEMATICS CONCEPTS

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This paper describes a mathematics teaching approach which uses PowerPoint to replicate traditional non-computer teaching by manipulating virtual copies of real materials (Baturo, 2000). It reports on three case studies of primary teachers who admitted to having computer technophobia as they attempted to integrate learning technology in their classrooms even though they had undergone an extensive school-based computer skilling program. The results show that the generic software approach is a powerful way to encourage teachers to use computers in mathematics teaching, manipulating virtual mathematics materials facilitates learning, and teacher mathematics pedagogy knowledge is the determining factor in enhancing learning through computers. It is much easier to provide computer expertise than mathematics pedagogy knowledge.

Technological change is expected to transform teaching and learning. For example, the Department of Education Queensland (1995) has argued that computer technology will change the nature of student learning, the roles of both teachers and students, and "support and enhance the achievement of educational goals across the P-12 curriculum" (p.3). However, many teachers who have not grown up with computer technology have developed high levels of stress (technophobia) when faced with a teaching future that appears to be inexorably leading to the integration of learning technologies (e.g., Morton, 1996). As Eraut (1994) conceded, "using an idea in one context does not enable it to be used in another context without considerable further learning taking place" (p. 33).

According to Reilly (1997), successful teaching with computers tended to focus on knowledge-construction activities that actively engaged students in solving problems both as individuals and as members of a team. These types of activities tended to change, quite significantly, students' conceptions about the nature and discourse of the subject-matter being studied (Clements, 1994) with accompanying qualitative changes to students' mental models of the phenomena being studied (Woodruff & Meyer, 1997). As McRobbie, Nason, Jamieson-Proctor, Norton and Cooper (2000) argued, understanding of mathematics in computer related activities is dependent on the following: (1) *degree of difficulty* – computer activities have to be carefully chosen so that the mathematics being taught is within the students' zone of proximal development (Vygotsky, 1978) or the students will be unable to make the leap to the new knowledge; (2) *links to non-computer activity* – activities should integrate on and off computer activities (Kaput & Rochelle, 1997); (3) *scaffolding* – the mathematics behind an activity needs to be fully understood by teachers so that they can provide the necessary scaffolding to assist students' construction of knowledge from the computer activities (Bagley & Hunter, 1992); and (4) *reflection* - opportunities should be provided after computer activities for students to discuss and reflect on what they have done and learnt (Davis & Rimm, 1998).

In Australia, current pedagogy believes that mathematics understanding is best constructed by each child through a combination of: (1) work with materials (concrete then pictorial); and (2) discussion and reflection with peers and teacher (e.g., Booker et al., 1999). Most activity with real or concrete materials in number and space involves *sliding, joining, separating, grouping, ungrouping, partitioning, turning* and *flipping* actions. All of these actions are available on computer through mouse movements and images of the materials ("virtual materials") using the commonly available generic "office" software (e.g., *MicroSoft* Office, *ClarisWorks*) (Baturo, 2000). Real materials are multisensory (i.e., they can be seen, smelt, moved, picked up, touched, weighed) whereas virtual materials are bisensory (seen and moved) so virtual materials are more abstract than real materials. Therefore, real materials may develop a more detailed memory structure (schema) than virtual materials. However, on the other hand, mathematising is about refinement and abstraction so that the multisensory nature of real materials may actually hinder the abstraction process as the child may not know which are the salient features to focus on.

Some actions are neither as overt as they are with concrete representations nor as covert as they are with pictorial representations. For example, with respect to *numeration processes*, grouping virtual base-10 materials will require the child to activate a "selection" tool, hold down the left mouse key as s/he "draws" a box around the objects to be grouped, go to the Draw menu on the Drawing toolbar, and then select "Group" from the menu. Thus, there is indirect physical manipulation through the mouse but the regrouping process will require much more dexterity than the direct physical manipulation. Furthermore, the grouping process has to be known but held in memory as the child performs the sequence of operations that will make the transformation from ones to tens. Similarly, but slightly less difficult, actions are required for the ungrouping process, namely, select the object to be ungrouped by clicking n it, going to the Draw menu, and selecting "Ungroup" from the menu. Figure 1 shows that, from this analysis, virtual materials should provide a conceptual bridge from concrete to pictorial representations.

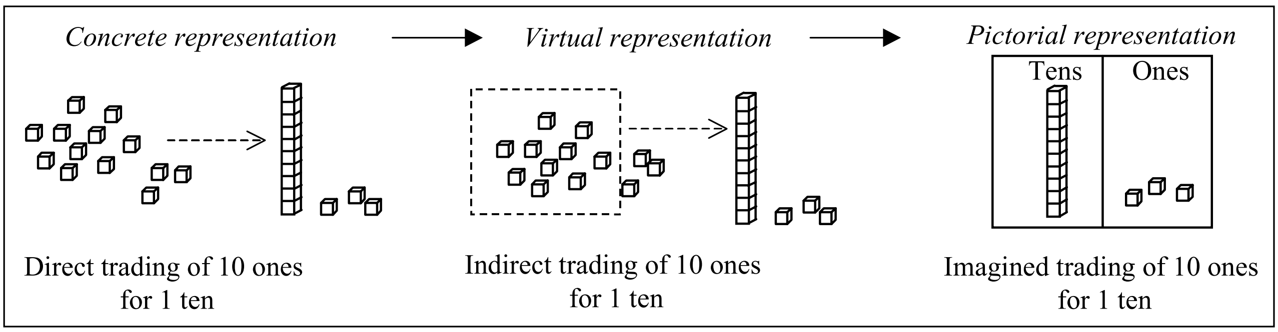

Figure 1. The role of virtual representations in developing whole-number concepts and processes.

Some actions are indirect. For example, for *spatial processes* (see Figure 2), the sliding actions requires the child to select the shape by placing the mouse on the shape and clicking, then to s/he simply slide the shape to a new position. For flipping actions, the child selects the shape by clicking, activates the Draw menu, selects Rotate or Flip, and then selects Flip Horizontal or Flip Vertical. For rotating actions, the child selects the shape, activates the Draw menu, selects Rotate or Flip and then selects any of the Rotate options (Free Rotate, Rotate Left, Rotate Right). Tessellations and tangrams (which require sliding, flipping, rotating actions) are spatial activities that are enjoyed by all age groups. However, assembling a class set of real materials is time-consuming. Virtual materials require only one template which can be downloaded for individual student's use. The students themselves can then quickly copy the shapes required and, with respect to tessellations, have access to a variety of colours to enhance the final product.

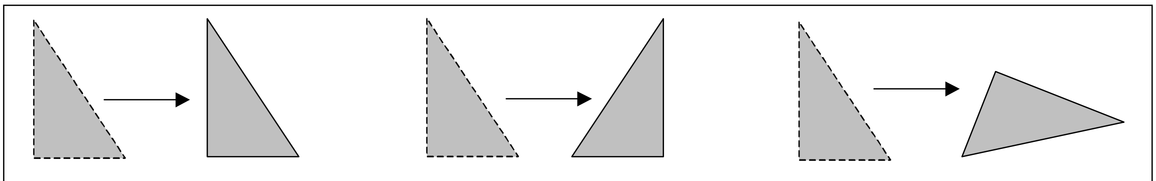

Figure 2. Spatial actions (sliding, flipping, turning) undertaken on virtual shapes.

The project

The study used a combination of action research (Kemmis & McTaggart, 1988) and teaching experiment (Romberg, 1992) approaches in which the mentors worked with three volunteer teachers (Monica, Andrea, and Janice) in the development, implementation, and evaluation of a sequence of mathematics lessons taught with computers. Data gathered was predominantly qualitative.

Subjects. *Monica* – a Year 5 teacher with 20 years teaching experience; *Andrea* – a Year 4 teacher with 5 years experience; *Janice* – a Year 2 teacher with 12 years experience. The three teachers had been trained to use computers to support their teaching (e.g., preparing worksheets, publishing a newsletter for parents) but not as part of their teaching. All three teachers said they were severely technophobic before this training. At the start of the project, they rated their confidence in computer skills at about 4 on a 5-point scale but their confidence in teaching with computers between 0 and 1.

Monica wanted to use computers in mathematics, have the children and herself develop computer skills and have children use computer skills to learn mathematics; *Andrea* wanted to further her knowledge and use/application of technology in the classroom; and become more confident when teaching use of technology in the classroom; while *Janice* wanted to access information/ideas on how to transfer my "new" computer skills into learning situations for my class, isolate and define particular computer skills that can be taught and assessed in whole class to small group activities, and "have a go" and continue to learn about mathematics and computing.

Mentors. The three mentors consisted of the research team and *Greg*. Greg was a Year 4 teacher with expertise in the use of computers in the classroom who acted as liaison between the research team and the 3 teachers, providing "just in time" technical support when needed. The school's administration gave Greg half-time release from teaching duties for the duration of the project (6 weeks).

Procedure. There were four main stages built into the project, namely, *skilling, planning, implementing*, and *evaluating*. For the *skilling* stage, two inservice sessions (each 1-day) were undertaken with the three teachers to introduce the MS Office program, PowerPoint. The teachers' originally associated PowerPoint with high-quality presentations and high levels of computer expertise so were skeptical about their ability to acquire the skills that would be needed. For the *planning* stage, the teachers prepared a mathematics unit of four sequential lessons. The project team (mentors and teachers) then met for half a day to refine the plan, to discuss classroom management techniques with respect to computers, and to begin the construction of the computer activity in PowerPoint. Activity construction was to be done predominantly by the teacher but mentoring by the researchers was available when needed. For the *implementing* stage, the teachers conducted the computer activities in their own classroom or in the school's Year 7 mini laboratory of 8 computers. Each lesson was video-taped and all mentors were available for help if needed during implementation. For the *evaluation* stage, the research team met with the teachers and Greg to evaluate the activities in terms of effectiveness in promoting learning, and in terms of personal professional development. The three teachers were then asked to complete a questionnaire whilst Greg was asked to write a report on his role in the project in terms of the type and amount of "just in time" support, and the quality of the mentoring component. The results of the meeting and questionnaire are reported in this paper.

Cases

Monica. For her Year 5 class, *Monica* planned a sequence of lessons using tangram activities to introduce flips, slides, and turns (transformations). To this end, she developed a series of PowerPoint tasks in which tangram pieces were combined to form shapes and prepared a program that integrated on and off computer activities. The students were introduced to the virtual materials in the first week as a whole class with the use of a data projector. The students then worked on paper tangram activities and, when these were completed, went on to virtual activities (replicates of the paper activities). They were rotated through the computer activities, 6 students at a time. The classroom had three computers that were kept in a small room at the back of the class.

The students enjoyed the challenge of the paper tangram activities and were motivated to continue by the promise of computer time. With respect to the computer tangram activities, the students were highly motivated by the colourful pieces and the clear, succinct directions were easy to follow. They worked collaboratively on the computers and were soon personalising the pieces by using their own colours and exploring "what would happen if …". During the computer session, where three pairs of students were working collaboratively on the three computers, the following conversation was overheard: *These are easier than the paper ones to see where they go* (John). *I reckon the paper ones are easier 'cos you can pick them up* (Allison). Both points of view were supported by other students nearby.

Monica herself was also motivated and encouraged by her ability to develop the virtual materials that the students used. She successfully introduced the necessary understandings of PowerPoint and the school's network structure to enable the students to retrieve, manipulate (flip, slide and turn) and save the tangram activities. However, some students experienced difficulty solving the tangram puzzles and the tangram activities were not explicitly connected to transformations.

The tangram activities were not sequenced; they did not move from simple to complex, increasing the number of tangram pieces and providing increasingly less detailed templates. They did not differentiate between puzzles that involve flips (more difficult) and those that did not (less difficult). The on and off computer activities were also at different levels of difficulty. The paper tangram activities had solutions provided on their templates, the computer activities did not. Finally, there was no explicit teaching of the role of flips, slides and turns in the formation of the puzzles. The result of this was that a section of the class needed support to solve any problems and the achievement of the students was less than expected.

Andrea. For her Year 4 class, *Andrea* developed a unit of work on polygons. She had taught the mathematical properties of polygons earlier and the computer activities were viewed as a means of assessing the extent to which the students understood the concepts. The first activity provided a range of 1-D, 2-D, and 3-D shapes (see Figure 3) and the students were required to sort them into Polygons/Not Polygons. Later activities involved students constructing their own polygons. The students worked in pairs; half the class at a time, on 8 computers in a small laboratory while the teacher with whom Andrea shared a double teaching space supervised the other half of the class. .

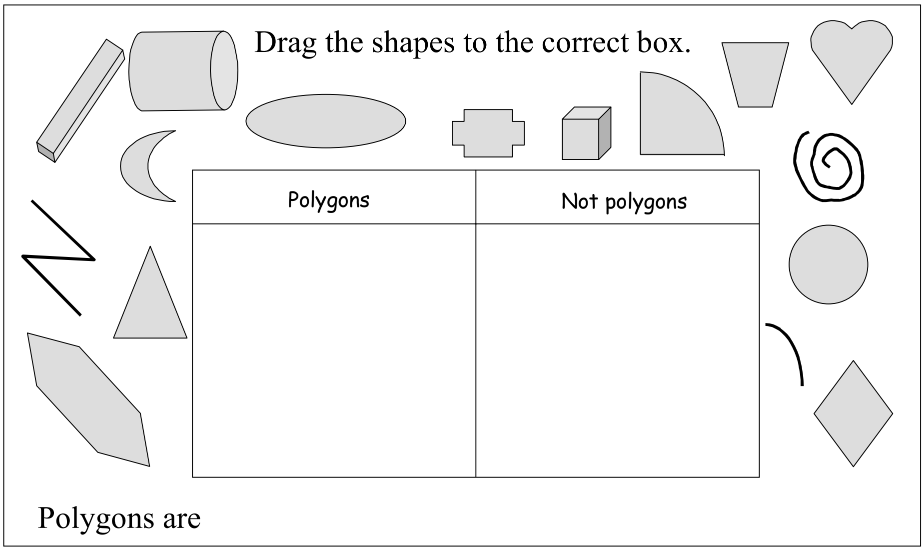

Figure 3. A polygon assessment activity designed by Andrea (Lesson 1).

Andrea tried to direct the activities so that all students listened to her and then did part of the activity. She was very structured (scaffolded) in the way she implemented the lessons because, unlike Monica, she was teaching the mathematics concepts and requisite technology skills simultaneously. These skills consisted of knowing how to retrieve and save files, and how to use “click and drag”, text boxes, and the Draw, AutoShape and colour features of PowerPoint. She also was at pains to ensure both students in each partnership had time on the computer and that there was a period at the end of each activity where students reflected on what they had learnt. They were required to type these reflections into text boxes, an activity that revealed that the students had acquired the appropriate knowledge and language.

Although Andrea's initial lessons did not allow time for students to explore the enhancing features of PowerPoint (e.g., colouring lines and shapes; playing with different fonts), students nevertheless did so. One student showed his group how to change the colours of the lines and the enclosed space and before long all students were exploring the Format feature. This activity highlighted the motivational power of the computer, the collaborative nature of student learning when engaged on a task, and the need to let students explore first and learn later.

Andrea realised that this aspect of her lessons needed attention in her review. She stated that there was not a lot she would change except have smaller groups and more investigation in the mini-laboratory situation ("I used a similar teaching style as in the classroom - very structured and controlled - perhaps give children more experimentation time at the end of lessons").

Janice. In her Year 2 class, *Janice* developed materials to introduce and reinforce two-digit numeration. She used the data projector to introduce simple "click and drag" PowerPoint skills and then rotated the children through activities on three computers where they moved virtual base-10 blocks to form two-digit numbers or numbers and words to label pictures of base-10 blocks. She also taught the children to open folders and save the results of the manipulations. Although there were some difficulties with the computer hardware, the students were so highly motivated that they kept coming back to the activities during their free time (lunch and before school).

Janice had been fearful that her Year 2 students would not be able to save, retrieve and "click and drag". This proved unfounded; the children quickly acquired computer skills. Where Janice needed support from the researchers was in developing activities that appropriately sequenced numeration development and which ensured all connections between materials, language and symbols were made.

Reviewing the study

In the review of the study, three findings became evident. First, for technophobic teachers, the replication of traditional mathematics activities via PowerPoint provided a bridge from the acquisition of computer skills to the implementation of classroom activities.

Reflecting on her achievements, *Monica* stated, "Well, I'm now a PowerPoint junkie". She said she was confident in using her computer skill with the class and that she hoped that her children realised the value of computers in mathematics. She proudly said, "They liked my PowerPoint creations!" *Andrea* also indicated that she had become a lot more confident overall and had tackled projects and basic teaching activities that she would not have previously. She stated, "I feel more able to tackle using technology to integrate other subject areas". *Janice* simply cried, "MORE!!!" She described how she used the multimedia projector and prepared tasks involving specific computer skills ("click and drag, copy and paste") in PowerPoint. As she said, I developed an understanding of "where I've come from" to "where I want to go". At the end of the study, *Monica* was very positive, "I am confident to use PowerPoint in my preparation and implementations of my program"; *Andrea* described how she was very stressed at first but gained confidence as the lessons went better than expected; while *Janice* described how she was initially concerned, learnt to have confidence in her own planning, and was "most impressed with the eagerness of the children to access computers and work folders in their own time and to complete mathematics and computer tasks".

Second, where there were no mathematics-education difficulties associated with sequencing or activity type, the virtual materials provided a powerful medium for mathematics learning. Both the weaknesses and strengths of the cases reinforced the importance of ensuring activities: (1) were within students' *zone of proximal development* (Vygotsky, 1978) – the jump to complete set tangram puzzles was too difficult for some students in Monica's class; (2) integrated *on and off computer* tasks (Kaput & Rochelle, 1997) – the links between real and virtual base 10 blocks and between the paper and virtual tangrams were a source of understanding for students in Monica's and Janice's students; (3) were appropriately *scaffolded* and *reflected upon* (Bagley & Hunter, 1992; Davis & Rimm, 1998) – this strength of Andrea's activities appeared to be the reason for her success in the concept of polygon.

Third, teachers' mathematics pedagogic knowledge remained a major determining factor in enhancing learning when computers are integrated into the mathematics classroom. The study showed that learning is maximised when instruction takes account of: (1) *sequencing* and *connections* – this was a particular problem for Monica and the tangram activities; (2) *interpretation* and *construction* – Janice needed support to ensure her virtual base-10 blocks activities exhibited both these; (3) *sharing* and *recording* findings – this was needed by Monica to go beyond the puzzles to flips, slides and turns; and (4) *creative extension* – Andrea found she had to add this to her activity sequences. In the study, the teachers believed they lacked expertise in using computers to teach mathematics but not in teaching mathematics itself. Therefore, they were more receptive to advice regarding technology than mathematics instruction. This was particularly evident in the response of Monica when asked what she would do differently if they were to attempt the same project again. She stated that she would learn the features of PowerPoint well beforehand and practise it more ("I would spend more time with giving skill lessons to children, then I'd move slowly through the activities over a longer time").

Becker (1994) claimed that difficulty in accessing suitable software (time spent searching, getting it funded through the school) has contributed to many teachers' reluctance to incorporate computer learning in their mathematics programs. However, Sarama, Clements and Jacobs-Henry (1998) argued that teachers' beliefs about computer learning were of more concern. Their research showed that if teachers believe that mathematics cannot be taught effectively with computers, then they will resist attempts to incorporate them in their classrooms. Thus, there is a need to provide mathematics computer activities that teachers feel are easy to develop, do not require specialist software, and will promote positive learning outcomes. The manipulation of virtual materials described in this paper meets this need. There were difficulties particularly with respect to sequencing of mathematics content but no problems with confidence in using the computers.

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