THE USE OF TECHNOLOGY PRACTICE FOR THE ENHANCEMENT OF STUDENTS' PERCEPTIONS OF MATHEMATICS

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Australia is experiencing a resources boom that has created an increased demand for expertise in the hard sciences including mathematics, science, technology and engineering which is not being met. Part of the problem is the low participation rates in prerequisite school subjects. Not enough students are showing interest in mathematics, science and technology and have reported that this is because they find it hard and uninteresting. Since attitude formation occurs early in students' lives, an integrated teaching intervention was implemented in a primary school to probe students' initial perceptions about the nature of mathematics in particular, and chart those perceptions over the life of the intervention. The intervention featured the teaching of mathematics and science in a technology practice environment. The students reported a broader and more applied understanding of the nature of mathematics, a belief that the integrated study gave mathematics greater purpose and helped with their understanding of it. They also demonstrated a high level of interest and engagement. The findings inform the design of curriculum associated with integrating the teaching of the hard sciences and point to ways in which students can further perceive their engagement in the hard sciences as interesting and useful.

The ever increasing demands of the 21st-Century require that all people should be mathematically, scientifically, and technologically literate because they are increasingly being asked to make judgments about matters that require reasoning and understandings that are underpinned by mathematics, science knowledge, or technological capability. (Australian Academy of Technological Science and Engineering (ASTEC), 2002; Australian Association of Mathematics Teachers (AAMT), 1997). Unfortunately, the requirement that citizens become more mathematically, scientifically, and technologically literate is not reflected in student participation rates in Mathematics, Science, Engineering and Technology (MSET) subjects. It is well documented that mathematics is a gatekeeper subject for the hard sciences and that the proportion of students taking advanced mathematics has declined from 14.1% in 1996 to 11.7% in 2005 and intermediate mathematics participation has fallen from 27.2% to 22.6% since 1995 (Barrington, 2006). A possible reason for the drop in numbers may be students' attitudes to studying the mathematics. Indeed a number of authors have pointed out that attitude formation occurs early in students' lives, and if they develop perceptions that the mathematics in particular but the hard sciences in general are boring or too hard they are not likely to pursue the study of them beyond the compulsory years (e.g., Boaler, 1997; Eccles, & Wigfield, 1995).

De Bono (2004, p. 15) has defined perception as "how we look at the world. What things we take into account. How we structure the world." Perceptions include likes and dislikes, anxiety, beliefs about self-efficacy and self-concepts. De Bono (2004, p. 5) has noted that "Outside of highly technical matters, perception is the most important part of thinking." Unfortunately, for many there is a perception that the teaching of mathematics has been decontextualised (e.g., Corte, 2004). Some of the critical issues that have led students to see mathematics this way include an over reliance on textbook work with a procedural focus, teacher dominated discourse, and closed learning activities that result in a lack of capacity to transfer knowledge (Hollingsworth, Lakan, & McRae, 2003). Repeatedly, students report that they neither understand important mathematical concepts nor appreciate why they are worth the effort of learning, or they see mathematics as a way to entering further study, rather than acknowledging mathematics has intrinsic value in itself (Watt, 2005). Student perceptions that they fail to understand mathematics and that it is a hard subject are linked to the image they have that mathematics is an abstract collection of rules (Townend, 2001), in particular, rules associated with number manipulations (Thompson, 1992). Students rarely associate mathematics with creativity or innovative thinking.

Previous research indicates that there is some urgency in designing new models of teaching mathematics and different pedagogic models are needed to cater for different student groups. For example, there has already been extensive research in the fields of gender inclusive mathematics curriculum (e.g., Walkerdine, 1988) and feminist pedagogies (e.g., Brady & Dentith, 2001). However, the application of key principles (students' experiences as central, safe places, development of student voice, understanding of power and agency, recognition of difference) as they apply to mathematics education in particular, but MSET more broadly have been less well documented.
Concerns about poor student perceptions of mathematics learning is reflected in broad curriculum reform. In mathematics, as well as science and technology education there has been a shift towards emphasising thinking skills. The National Council of Teachers of Mathematics (NCTM) (2004) standards statement has encapsulated this trend world wide by giving pre-eminence to five process standards: problem solving; reasoning and proof; connections; communication; and representation. This shift in curriculum approach towards communication of reasoning and contextual problem based learning has found expression in attempts to integrate technology and science with mathematics. For example, the Connected Mathematics Project (National Science Foundation, 2005), New Basics curriculum documents (Education Queensland, 2001) and the Victorian Essential Learning Curriculum initiative (Victorian Curriculum & Assessment Authority, 2005) have a strong emphasis on integration across curricular learning through authentic tasks. However, many teachers have found it difficult to integrate mathematics, in particular, into authentic and open-ended tasks and many tasks are such that it is difficult for teachers to generate abstraction which is crucial to the development of mathematics and science concepts, principles and processes (Cooper, Nuyen & Baturo, 2003).

This background is set against the introduction of a Technology syllabus in Queensland (Queensland Studies Authority (QSA), 2003) that has recently become mandatory. A key aspect of the Technology Syllabus is Technology Practice. Technology Practice embodies the actions of investigation (identifying the problem and gathering information and data), ideation (planning and designing), production (creating and making), and evaluation (testing, judging and refining) (QSA, 2003). Other strands are Information, Materials, and Systems. Information focuses upon understanding the nature of information and techniques used to work with information. The Materials strand is concerned with understanding the nature of materials and techniques to manipulate materials. The Systems strand focuses upon understanding the nature of systems and techniques for assembling and controlling systems. With its focus on planning including the transformation of ideas and information, producing, and judging and evaluating products, Technology Practice affords opportunities to integrate the teaching, learning and application of mathematics and science. It is against this background the study has the following aims:

1. To investigate a pedagogic model in which mathematics and technology learning are integrated, and examine the effect of this model upon student perceptions and learning of mathematics.

2. To draw inferences from the data with respect to the effect of the pedagogic model applied and make judgments about the usefulness of Technology Practice as a learning environment to teach mathematics.

Approach and Methodology

Design

The overall design is a "design-based research" approach. Design experiments were developed as a way to carry out formative research to test and refine educational designs based upon principles derived from prior research (Collins, Joseph & Bielaczyc, 2004). Design-based research blends empirical research with theory-driven design of learning environments, and it is useful in understanding how, when and why educational innovation works in practice (Design-Based Research Collective, 2003). A number of scholars have recommended this approach to understanding innovative learning experiences since it enables the intertwining of research and practice (e.g., Bell, 2004). Further, the approach enables the researcher to adopt an interventionist, transformative stance that offers the opportunity to promote and sustain innovation (e.g., Bell, 2004).

Subjects

The participants in this study were the principal of a small independent primary school and her 12 students in a composite Years 1 to 7 class. The principal Ann (pseudonym) was an experienced classroom teacher. The names of students referred to in the paper are also pseudonyms.

Data collection

Data were collected during an integrated teaching intervention which ran for a term lasting 18 weeks. Data collection included audio and videotaping of interviews including student conducted interviews, Likert survey pre and post intervention tests, classroom interactions, field notes, collection of teacher
planning drafts and student work. In analysing the data, Bernsteins' theories (Daniels, 2001) of pedagogic discourse which include notions of instructional (negotiated rules for selecting and organising instructional content) and regulatory discourse (pedagogic relations that underpin learning activities). These discourses set up subject positions with respect to perceptions and attitudes (Singh, 2001).

**Description of Integrated Teaching Intervention and Results**

**Design Projects**

In order to explore the usefulness of a pedagogic model for integrating mathematics learning in a technology practice setting it was decided to engage students in design projects in which they constructed working models of amusement park rides, since the school was located near the Dreamworld theme park, and the students were familiar with its theme park activities. To increase the scope and authenticity of the design projects the students were required to present their respective constructed artefact to a wider audience and include an explanation of its functioning.

Ann and the author used the new Mathematics syllabus (Queensland Schools Authority, 2004) to identify specific mathematics outcomes that could be associated with the design and production of a Dreamworld ride. In order to document the extent of outcomes linked to the working models projects the author designed a checklist of key mathematics outcomes. Throughout the technology practice based activity the teacher linked the design, production and evaluation of the rides to the outcomes, particularly those associated with space, measurement and proportion. This was done as pre-requisite teaching as well as at the point of need teaching.

**Technology Practice - Description of Ideation and Production Phases**

The students participated in an excursion to Dreamworld where they discussed the rides with an engineer, recorded notes, took video and digital photographs, as well as experienced the rides. Upon return from the Dreamworld investigation the students began a planning (ideation) activity. The students were placed into one of three design project groups according to Grade level as follows: The Giant Drop (Years 6 and 7); The Vortex (Years 5 and 6), and Vintage Cars (Years 3 and 4). The Years 1 and 2 students were attached to the three groups to act as apprentices for the older students. The students used their notes, sketches, video and digital records, the internet and books on mechanics and science to research how to construct the rides. The students drew plans including sketches and made lists of materials needed for their respective constructions. The students purchased materials they needed from hardware and electronics stores.

The Giant Drop team of two girls used information from the excursion and subsequent research to plan their model. Their focus early in the design process was on the materials they needed to make the tower. Various obstacles were encountered and overcome in the selection and fixing of materials to make the model. The final model used a hand winch made of Lego components and a pulley to lift the carriage. The carriage fell guided by two doweling rods and plastic tube runners. Increased friction at the bottom of the runners acted as a brake.

![Figure 1: Design project - the Giant Drop. N.B, Two doweling rods to guide passenger cage; A small manual winch behind the tower. The blue poster contains explanations of key concepts associated with the project. The students are presenting to classmates and invited parents](image-url)
The Vortex: A group consisting of three boys (Years 4 and 5) decided to construct a model of *The Vortex*. The students had listed the materials they thought they needed and drew some preliminary sketches. The main problem in this activity was to get a cylinder to rotate inside a larger cylinder. The final model used a lettuce washing colander driven by an electric motor.

![Figure 2: Design project – The Vortex. Partial construction of The Vortex showing components of the propulsion system – motor; belt; colander.](image)

The Vintage Cars: Two boys and a girl in Year 3 participated in this project. The children drew rough sketches and made a list of components. Several prototypes were produced and tested until the final car made of Lego pieces, a switch and an electric motor was constructed.


One way of charting the extent of student change in perceptions about the nature of mathematics was to ask the students to interview each other at the beginning and end of the projects. Exemplars of before and after responses are presented in Table 1.

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<th>Before</th>
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<td>Helen: Year 6; I think maths is to do with counting and measuring and using scales and that sort of thing and using decimal points and like A=1; B=2; and C=3.</td>
<td>I think maths is to do with cooking, space, measurement, multiplication, division, money, squares and cubes, pi=3.14, like being an accountant. Also like cooking, like you need half a cup of flour, and stuff. Also like being a builder, you have to have plans, you really have to do the planning, you have to do the measurements And large numbers. You have to learn and not give up on your goals.</td>
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<td>Susan: Year 7: I think maths is adding up, taking away, counting time tables, measurement such as pi and working with millimetres and centimetres.</td>
<td>I think maths is space, volume, measurements, pi, capacity, 3D shapes and fractions.</td>
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<td>Mal: Year 4: I think maths is about counting, measuring, adding up, division, take away and times tables and without that you can not do anything.</td>
<td>I think maths is measuring, shapes, multiplication, numbers, space and all different kinds of measuring. Like metres, centimetres, kilometres and all the different things.</td>
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<td>John: Year 4: Well, I think maths is counting up, taking away, division and measuring.</td>
<td>I think maths is about measuring, and adding up and division and all that stuff, and you need to work and write books and stuff. And shapes and sizes and other things.</td>
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In each instance, the respective student’s initial perceptions of the nature of mathematics were that it was primarily about number computations with only Helen and Susan including a measurement dimension. Following the intervention, all students stated that space and measurement were part of mathematics and these enhanced perceptions could be ascribed to the practical and applied technology practice environment. Further Hanna, Ben, Mal and John included broadening comments such as linking to practical outcomes including being an accountant or builder, planning, cooking, and "stuff you need for work," and "to write books." This seems strong evidence that their perception of mathematics had gone beyond number and as part of their description of the nature of mathematics they included utility and communication.

Classroom observations indicate that students' perceptions of the usefulness of mathematics changed over the life of the study. There were two main sources of data to support this assertion, first a pre-post response to the question "Why is maths useful?" The second source of data was a survey administered at the end of the intervention. The students were asked to state if their perceptions of the usefulness of
mathematics had changed during the time they were engaged in the project. The before and after intervention results are reported in Table 2.

| Helen: Year 6: I think maths is useful because when I grow up, I will probably know lots of things... | I think maths is useful because you need it to build a house, to do cooking, to draw plans and deal in money. |
| Susan: Year 7: I think maths is useful because you need it in your every day life because you can tell the time; you can get a job | I think maths is useful in your every day life to get a good job such as a chef, a hairdresser, or a mathematician and if you work in the supermarket, you are dealing with money. |
| Ben: Year 3: I think maths is useful because I like it and... | Cooking because you have to measure stuff, also speed, kilometres, adding up and money. |
| Mal: Year 4: I think maths is useful because you can use it in lots of other ways for doing lots of stuff. | You can use maths for making rides, for measuring, so you know how big, the length, the height, and the weight, and cooking, numbers, shapes, centimetres and metres. |

While all the students considered that mathematics was useful prior to the study, subsequent to the integrated teaching intervention they stated more connections between mathematics and practical use and gave specific examples that were linked to the project. Students' perceptions of the usefulness of mathematics could be linked to technology practice (e.g., construction and planning) in several cases (Table 2).

All students reported that their beliefs about the usefulness of mathematics had broadened. For example, two of five students reported an improved belief that knowing mathematics would help them earn a living; and four of the five students reported a stronger belief that knowing mathematics helped them to understand and explain how things worked.

Students were also asked to use a Likert scale to indicate how their perceptions of the usefulness of technology practice had changed during the project (The Vintage Car group did not respond). All but one student reported a more positive perception of the application and usefulness of technology practice, in particular, because it helped them to understand the world. Students further responded to questions asking them to assess if the integration of technology practice and mathematics helped develop their understanding of mathematics. All students responded that when mathematics, design and construction were studied together the mathematics "made more sense," in that it was more understandable and improved their understanding of the mathematics. Eighty percent responded that integrated study did not make understanding the mathematics easier – it remained the same. That is, although they believed their understanding improved as a result of the integrated study of mathematics and technology, mathematics study was still classified as "hard." The perception that the integrated study of mathematics and technology were mutually supportive found expression in written comments when the students were asked to state "something positive, something negative and something interesting" about their design project. For example:

Helen (Year 6): It was fun to do the presentation, I learnt a lot and now I can understand more about maths. We had fun finding the equipment and also building the rides and me (sic) and Susan worked well in group. I know how the rides worked, about gravity, and how the magnets slowed the ride down and how pulleys can be used to pull the ride up.

Susan (Year 7): It was good to go to Dreamworld, to the shops and learning how things worked and then we got to go on the rides. The most interesting thing was learning how the rides work. I liked learning maths that way. I've learnt that if two or more people work together to get the job done it is done much easier. And also, maths isn't all just adding up and subtracting, there is more to it.

Ben (Year 3): I liked going to Dreamworld and make the rides, I did not know how to before, but I do now. I liked when our parents came in. It was interesting how the car would not go around the track and then we made it (the car) smaller so it would.

The important aspects that emerged from these data include the challenge in figuring out how things worked, the perceived authenticity of tasks, and the importance of sharing information.
Conclusions

An important outcome of the research was that positive changes were observed in students’ perceptions of the nature and usefulness of mathematics study in the context of integrated learning of mathematics and science in a Technology Practice environment. Their thinking about the value of the subject domains are considered central to the educational process (e.g., Daniels, 2001; Singh, 2001) and important determinants of participation and success in learning and subsequent participation in further study (e.g., Wigfield & Eccles, 2000). Curriculum bodies also hold similar views (e.g., AAMT, 1997; NCTM, 2005). Analysis of interviews, discussions and responses on survey forms indicated that the students developed a more comprehensive view of the nature of mathematics and their perceptions had changed from one dominated by number computations to include aspects of other concepts such as measurement with more practical and applied dimensions. The positive changes in the perceived usefulness of mathematics were also evidenced in the interview and survey data. Student responses indicated that they were better able to articulate why mathematics was useful subsequent to the intervention.

Most students described how mathematics helped them understand how things worked, that is, through learning how things worked students learnt mathematics and how to apply the mathematics. All students reported that although the integration of technology practice (design, construction, evaluation) and mathematics helped them to better understand mathematics, it did not make the process easier, just better. Students’ perceptions that they can understand mathematical concepts are important for their long term participation (Liljedahl, 2005). Further, most students developed a greater appreciation of the usefulness of technology practice again, in part, because it helped them to understand how things worked. The relevance of these findings is likely to find the support of other researchers who link student thinking about a subject to later secondary and tertiary participation (e.g., Khoo & Ainley, 2005; Townend, 2001; Watt, 2005). The findings indicate that technology practice can form a suitable environment for the contextual teaching of mathematics and influence important student perceptions of mathematics. This is an important finding for Queensland schools in particular, since the education authorities are attempting to encourage schools to implement the new Technology Syllabus (QSA, 2003). The findings provide an added evidence for the establishment of a technology practice environment to foster student motivation and make mathematics concepts more meaningful and understandable for students.

References


