

# THE INTEGRATION OF TECHNOLOGY AND MATHEMATICS LEARNING

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Curriculum documents in Technology, Mathematics and Science are increasingly advocating an integrated and problem solving approach to the study of these subjects. Unfortunately, it has been found that when students engage in real problems that involve engineering and creative design, frequently the underpinning mathematics, science and technology principles and concepts remain implicit. In addition, on many occasions students commence the process of design and production without the necessary understandings of concepts, processes and skills and are neither able to convert design ideas into production realities nor to understand their products. This paper involves describes two design interventions in primary schools that attempt to address these concerns. Bernstein's theory of instructional and regulatory discourse (Bernstein, 1990) was used to plan and evaluate tasks and pedagogies in which creative and constructive activity would be explicitly linked to the learning of technology, mathematics and science concepts and processes. It was found that with careful and specific planning and provision of preparatory and "at the point of need" scaffolding, students were able to make specific links between design activity and underpinning technology and mathematics concepts and processes. The findings have implications for the planning and enactment of integrated design teaching tasks.

## Background

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 knowledge, scientific knowledge or technological capability. Those without a basic understanding in these key areas will, in the future, be either disempowered or misled in exercising their democratic rights and powers within a technologically dependent society (Australian Academy of Technological Science and Engineering, 2002). Despite this, research indicates that participation in more advanced mathematics, science and technology courses is an issue for concern with respect to national proprieties (e.g., Barrington, 2006; Batterham, 2000).

Anderson (1999) notes that mathematical literacy "goes beyond number and includes transferable skills such as ability to reason logically and to be organised and systematic ... to weigh up both quantitative and qualitative evidence ..." (p. 11). This view is supported by the National Council of Teachers of Mathematics (NCTM) (2004).

The National Advisory Committee on Creative and Cultural Education (NACCCE) (1998) reports that technological literacy carries with it the idea of action and purpose, with drafting or giving an idea a rough shape or outline being the first phase of the creative process. In curriculum documents such as the Queensland Technology syllabus (Queensland Studies Authority (QSA), 2003), drafting is frequently referred to as planning. Planning is a cognitive activity where the development of an appropriate solution strategy begins. It is also a process that students need to learn in order to develop problem-solving capabilities (Deek, Hiltz, Kimmel, & Rotter, 1999). It is a central activity embodied in curriculum documents in both subject domains of mathematics and technology, (and indeed science) used in most western educational systems. This overlap of goals suggests that there is merit in investigating the potential of integrating the learning of technology and mathematics.

Technology education has received formal recognition and additional educational status by technology's inclusion as a Key Learning Area (KLA) in Australia, (e.g., Curriculum Corporation 1994a, 1994b). This was because technology study was seen to have the potential to provide students with learning opportunities that lead to innovative technological practices, including those associated with mathematics and science (Australian Science Technology and Engineering Council (ASTEC), 1997). As a consequence, in recent years, there has been a distinct shift in technology education from the industrial arts (e.g., home economics and agriculture) emphasis on the development of domain skills to the development of more generic problem solving processes (e.g., Custer, 2003) along with awareness and conceptual understanding of the broader issues of technology in society (William, 2003). This is a transition advocated in official curriculum documents (e.g., Australian Education Council (AEC), 1989).

Innovation is a key component of technology syllabi and innovative designs are important outcomes of technology education because they offer an opportunity to develop student creativity. Creativity is generally thought to involve the interaction of thinking and intuition to generate a novel or new thought or solution (Davies, 1996). It develops incrementally, building on previous creative ideas and understandings. Creativity or innovation in design is usually characterised by success in solving ill-defined problems based on an understanding of the present world (Davies, 1996). Clearly, to make an innovative leap, that is, to go beyond current design solutions, requires being creative in design; in short, it requires thinking (de Bono, 2004).

There is evidence that the processes and conventions of technology practice can help learners to compartmentalize, organize and structure their thinking in ways that enable them to innovate (Norton, McRobbie, & Ginns, 2004). Thus, innovative design requires two conditions: first, an understanding of the current design solutions and their underpinning mathematical (and scientific) knowledge and technological outcomes capabilities; and, second, an understanding of the processes and conventions of design in technology practice. In various ways, educational bodies have reflected this synthesis in curriculum and policy documents (e.g., NCTM, 2004; National Science Foundation, 2005). The Queensland Technology syllabus (2003) contains four strands; (a) *information* with a focus on understanding the nature of information including finding, using and transforming it; (b) *materials* – understanding the nature, transformation and use of materials and (c) *systems* – understanding the nature of systems including techniques for assembling and controlling systems (d) – Technology Practice.

With this background in mind the Queensland Government instigated a project in conjunction with Griffith University and Queensland University of Technology that had the following broad aims:

1. to teach technology and mathematics concepts through integrated projects;
2. to evaluate a teaching model planned in consultation with the teachers for teaching technology and mathematics through integrated units of work in primary schools;
3. to analyse the findings for implications for the planning and enactment of integrated design teaching tasks.

### **Approach and Methodology**

The methodology was essentially a case study. The involvement of the researchers as active participants with the teachers in this process gave the approach a participatory collaborative action research element (Kemmis & McTaggard, 2000). The participants in this study were the principals, teachers and their classes in four small, rural schools in southern Queensland, namely, Meadows (Years 1-3), Bellbird (Years 3-4), Tree Tops (Years 5-7), and Plough Shears (Years 1-7) (all names are pseudonyms). Each school had an enrolment of less than 60 students. Thus, in some cases, teaching principals were involved. In this paper, only abbreviated results of the projects at Meadows and Bellbird (where the projects were titled Package and Bug Catcher respectively) are reported. Data were collected over the life of the study, a semester's work and included: (a) observations - audio and video tapes and field notes of classroom interactions and teachers' and students' activity in each of the units; (b) interviews – audiotapes and field notes of semi-structured interviews with the administrators and teachers and a sample of students in each school; and (c) artefacts - collection of material associated with the units (e.g., teacher planning drafts and student work).

The first phase participatory collaborative action research involved the participating staff in each of the four schools attended a two-day professional development and planning seminar. Staff from Education Queensland, Griffith University and QUT assisted. Much of the first day was spend describing the intent of the Technology Syllabus (Queensland Schools Authority, 2003), in particular, the process of technology practice and the three strands of information, materials and systems. Technology practice was presented as consisting of interacting processes of *investigating* (what is the problem, what are the considerations), *ideation* (possible solutions, planning), *production*, and *evaluation*. In the main, the professional development was top down and "just in case". The teachers at Meadows and Bellbird schools chose to modify existing units to meet the needs of the integrated technology/mathematics learning projects.

The analysis was guided by Bernstein's theory of instructional and regulatory discourse (Bernstein, 1990). According to this theory, instructional discourse refers to the rules negotiated and developed during the intervention for selecting and organising instructional content. Instructional content essentially refers to what is intended to be taught, while regulatory discourse refers to the models of the teacher, learner and pedagogic relations, which underpin the selection and organisation of content within learning activities.

## Results

The results describe the projects, their respective aims and how these were achieved, and provide students' and teachers' reflections on the project.

### *Meadows School Project - Package (Years 1-3)*

The Years 1-3 teacher at Meadows school adapted a unit titled *Package* for her technology and mathematics integrated project. This unit originally had a study of society focus.

The technology aspect was to have students investigate, plan (ideation), produce and evaluate a package to transport a fragile artefact from various parts of the world. The package was tested according to criteria of whether it could protect the artefact during: (a) a fall of 1 metre (package was dropped from this height and artefact remained intact); (b) immersion in water (artefact did not get wet when package was placed in a bucket of water for 3 minutes); and (c) compression (artefact was not harmed when a large brick was placed upon the package).

In designing their packages students investigated existing forms of packaging (an employee from Australia Post discussed packages with the students) as well as researching on the Internet and from books, thus meeting outcomes associated with the information strand of the Technology syllabus. In constructing their packages, students drew diagrams of packages, constructed three dimensional packages from two dimensional nets, used measuring tools, and compared sizes and weights of objects with and without packaging. In the wider project, the students also worked with maps and globes, investigated time and time zones, used coordinates, did money exchanges and cost calculations (using all four operations), and used numeration processes (e.g., regrouping).

The Meadows teacher reported that "the maths that came out of this unit was incredible ..." She argued that a large number of concepts associated with space, measurement and number were linked to the project. She contended that, in constructing and testing their packages, the students tested material properties and transformed the materials in various ways meeting many outcomes associated with the Materials Strand of the Technology Syllabus (QSA, 2003).

Classroom observations, student interviews and teacher statements indicated that the students were highly engaged in mathematics learning and enjoyed the integrated unit and learning in that way. As the Meadows teacher stated:

These students were full of beans (sic), the project really helped them to focus and apply maths. They saw the purpose of doing maths much more, and they had a lot of fun. It allowed students of all ability levels to participate. It was real to life, so the maths just flowed. The kids really enjoy it. It has more meaning to them. The students were also engaged in technology learning.

As the Meadows teacher stated:

The kids really enjoy it. As they get more used to it, they are getting better at seeking information on the web, of thinking and reasoning. They made the packages and also a model nose cone of a jet to travel around the world in. The main materials were paper, cardboard, plastic wrap, foam and they used rolls and rolls sticky tape, and glue. They had to use scissors, a tape measure and be able to work out angles.

The project also encouraged the Meadows teacher to reflect on her own practices. She stated the following with respect to her models of instructional discourse:

The model of integration was to do basic work in the morning, cover the essential mathematics concepts and processes. In later sessions these ideas were applied. In the afternoon the focus was more on the technology processes involved with producing the packages. This reflection also involved self criticism as the teacher's reflections with regard to creativity development show: I have to learn to let go. I have changed, before I would have been more formal. You still have to set up the basics especially in mathematics, but I have learnt to think about letting go and letting the students take more control of the design and to put forward their own ideas.

As well, the teacher was able to think about the project as a whole as her reflections on the interaction of instructional discourse upon regulatory discourse show:

Well, this time we used an existing project. But, in hindsight I think it would have been better if we had started a project from fresh. The maths really came through, but the technology aspect was a bit weaker. Partly, it was because I did not link the materials aspect in as well as I could, and I could

have made more of the information gathering. I think it was a matter of planning, as I became more familiar with the technology syllabus I got better at connecting outcomes to the activities. Next time I will design a project to meet the needs of both syllabuses.

#### *Bellbird School Project – Bug Catcher (Years 3 and 4)*

*Bug Catcher* was chosen as the technology and mathematics project by the Bellbird teacher because of the strong student interest in bugs and insects and because it could support and extend understandings about Life and Living Processes, a curriculum unit in which students were already involved. Therefore, like the *Package* project, the technology and mathematics project for Bellbird School evolved from an existing unit.

In the school's original Life and Living Processes unit, the children worked in groups to collect and analyse data and search for information in order to find the variety of living things in a local garden. Once this was completed, the students were to focus on butterflies and find the needs of a butterfly in the various stages of its life cycle, discover the variety of butterflies that are common to their area, and grow plants from seedlings, seeds and cuttings to attract butterflies. The original assessment tasks for the project were to: (a) design a board game that shows the life of an insect or garden dweller; (b) develop a 2-D or 3-D plan of a garden designed to attract butterflies and cater for the needs of the butterfly throughout its life cycle; (c) create a butterfly that will live in the designed garden environment; and (d) write a report explaining how the butterfly has adapted to live and survive in this garden environment, labelling the adaptations the butterfly has developed to ensure its survival.

To incorporate a technology and mathematics unit, the Life and Living Processes project was modified to include the design, construction and use of a bug catcher that could be used to safely catch bugs and insects. The collected bugs and insects were used for observation purposes and as data for determining the variety of bugs and insects in the vicinity of the catcher. The catcher was evaluated in terms of its success in catching bugs.

The mathematics focus of the bug catcher's production was intensive; covering as it did: (a) number; (b) space (scale and perspective; classifying and analysing 2-D and 3-D shapes; drawing 3-D shapes from different angles (drawing their desks to scale and in perspective); (c) data summary methods (tallying, picture graphs); proportion (the basis of scale); and (d) chance (how to infer populations from specific examples). The teacher encouraged the students to apply these mathematics ideas in the unit (e.g., when the unit required students to collect and process data). The teacher also encouraged the students to transform the data using computing software such as Excel. In this way, chance and data concepts of the mathematics syllabus were matched to outcomes from the Information strand of the Technology Syllabus.

In the construction of the bug catcher, the teacher allowed the students independence in investigating and constructing their respective artefact, thus making this unit the one in which there appeared to be the most student-originated ideation. Students examined and evaluated existing designs and adapted them to suit their own specifications. As one student (S1) commented:

I just thought it would be interesting to catch insects, but at home I want to catch lizards. I am going to catch all insects, then measure them, draw them and write a report on it. Then I will let them go. Say I catch a butterfly; mum has an encyclopaedia so I can find out about it. I will write the species on the picture I draw, I can find out about the bugs in the garden, it will be fun. I am going to try every season, but expect to get more in summer and spring. I can do a bar graph on them. It is going to be useful to me. I will learn some more stuff. If I catch a rare caterpillar, people might come to me to find out more about it.

As in the Meadows School project, the students sourced information from various media (Internet, local hardware/agricultural retail outlets, resident entomologist). In addition, the construction and use of the bug catcher added mathematics outcomes associated with number, space, measurement and chance and data and ensured all the actions of the technology practice (investigation, ideation, production and evaluation) were present. Students were able to link the design activity to mathematics outcomes as evident in the following student's (S2) assertion:

There is lots of maths. I have to be exact with my measurements and cut out my plan exactly. And I have to graph the results.

The students could also describe aspects of the materials such as those that would withstand the weather and those that were hard to cut and join. Uniformly students were excited about their project, as indicated in the comments of S1:

I have had fun making things and have learnt to plan and make things. I have learnt different sorts of measurement and plastic bottles and how you can use them in all different ways. It has been fun to learn about bugs. I cannot wait until we try out our bug catchers. I want to be amazed at what I catch, and I will have fun making the bug catcher.

It was apparent that students had developed a broader understanding of the nature of mathematics, in particular, with respect to the roles of problem solving and thinking. For example, a third student (S3) commented:

Maths is useful, if you did not have it you could not build a room, if the measurements were out the walls on the bottom might not be the same as at the top. Maths teaches your brain and it helps you think more. You need maths in life, to know how tall you are and how much medicine to take. I used to think maths was always sums. Now it can be quite fun even though you might not realise you are doing maths.

Similar to the Meadows School project, the Bellbird teacher reported that the design activities gave purpose to mathematics. Her model of instructional discourse was to teach critical skills and concepts in the morning and have students use these in an applied sense later in the day in the context of the technology practice activity. The teacher reported that although the students used and fixed materials and tested them for various properties this was done informally and in future design projects more effort would be needed to make outcomes associated with the Materials Strand of the Technology Syllabus explicit.

### **Discussion and Conclusions**

There was strong evidence that students at both schools engaged in technology-based activity. They located, transformed and evaluated data as part of the technology practice actions of investigating, ideation, production and evaluation. In terms of information; data sources were divergent and included the Internet, books, local experts, parents and the teacher. In transforming information and describing artefacts students were simultaneously carrying out mathematical activity associated with space, measurement, number, and chance and data strands of the Mathematics syllabus (QSA, 2004).

Both teachers noted the significant extent of the mathematics syllabus that could be linked to the technology activity. They also suggested that, in this first project, although the students engaged in the transformation of materials through the projects, the specific linking of activity to cognitive outcomes associated with the Materials Strand of the technology syllabus was generally implicit.

Evidence from the teachers and student interviews indicated that, over the life of the study, the students developed a broader appreciation of the nature and utility of mathematical activity, in particular from one dominated by number and computation to something that was fun, used to solve problems and to be used in life. In this regard, the project provided a model for meeting the expectations of educational bodies about emerging mathematical literacy (e.g., NCTM, 2004; National Science Foundation, 2005; QSA, 2004).

A critical aspect of technology study is to assist students to foster innovation and creativity in design (ASTECC, 1997; Davies, 1996). There was considerable evidence that students developed a better understanding of current designs. For example, they were able to evaluate the suitability of various materials and describe the design and production processes in the package and the bug catcher development. However, there was little evidence that the students had gone beyond designs that had been made available to them. Perhaps it could be said that the students were better prepared to go beyond existing designs, that is, to be creative and innovative, but the data did not indicate this. However, the students appeared to have gone beyond their prior personal capacities to be creative and innovative.

With respect to instructional discourse, the teachers in this study gave priority to mathematics concepts. They reported two factors that contributed to this: (a) using an adaptation of existing projects; and (b) lack of knowledge of the new Technology Syllabus. Clearly, the teachers needed greater support in planning to make technology instructional content explicit.

In regard to regulatory discourse, teachers focused on mathematics at two points in the projects reported in this study. First, teachers identified prerequisite mathematics and prepared students to apply mathematical concepts by teaching them prior to engaging in technological activity. Second, teachers helped students make links between project activity and mathematical concepts during technology activity. Less frequently, teachers used activity to generate mathematical understanding.

While the descriptors above provide a useful starting point to guide teachers' instructional and regulatory discourse, clearly there is a need for further iterations in this educational design process. The first iteration is the conduct of research which develops instructional discourse models that will guide teachers in linking technology outcomes to technology practice based integrated studies. The second iteration is to investigate technology practices that can be used to help students generate mathematical understandings as distinct from describing or simply using technology practice as an opportunity to apply mathematical understandings. The third iteration is to develop models of instructional and regulatory discourse that will guide teachers in fostering creativity and innovation.

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