Insights into Preservice Primary Teachers' Thinking about Technology and Technology Education

Sarah J. Stein, Campbell J. McRobbie and Ian Ginns
Centre for Mathematics and Science Education
QUT - Kelvin Grove
Victoria Park Road
Kelvin Grove QLD 4059

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Abstract

Many novice primary school teachers have a low level of confidence in their ability to teach the key learning area of technology. This low level of confidence may be related to their naive perceptions of technology and technology education and lack of exposure to appropriate design and technology teaching and learning experiences in preservice primary teacher education programs. The effectiveness of technology education subjects in changing preservice teachers' perceptions of technology and technology education may be enhanced by the use of open-ended project work. This paper reports an investigation, using an interpretive research methodology, of changes in preservice primary teachers' thinking about technology and technology education, prior to, and as a result of their engagement in open-ended technology projects similar to ones that might be typically suggested by primary school children. Students enrolled in a one year postgraduate teacher education program were the participants in the study and the methods of data collection included the use of survey instruments, interviews, field notes and a Repertory Grid. This paper analyses the influence of open-ended technology projects on students' thinking about technology and technology education and discusses implications of the approach for the design of technology education subjects in preservice teacher education programs.

Introduction

Technology, as referred to in this paper, has been defined in the document A Statement on Technology for Australian Schools as involving "the purposeful application of knowledge, experience and resources to create products and processes that meet human needs"
The subsequent development of technology curricula by various states in Australia has been underpinned by the above document along with a curriculum profile for technology, also developed by the Curriculum Corporation (1994a, b). The statement provides a rationale for teaching technology and establishes principles for teaching and learning technology. In addition, it describes the content and processes embodied in four strands of learning that constitute this key learning area - design, make and appraise; materials; information; and systems. The curriculum profile consists of learning outcome statements for each of eight levels across four bands of schooling from Year 1 to Year 12. The profile provides guidance for state curriculum developers concerning the evidence that teachers should collect to determine if students are achieving particular outcomes.

In an examination of the dimensions of technology education, Custer (1995) argued that there is a critical need for all individuals to develop at least minimal levels of understanding of technology as it has a profound influence on all parts of human life in the world. The implications of this justification for technology education are that teachers themselves must have a knowledge and understanding of technology and possess knowledge of appropriate teaching and learning strategies that will enable students to achieve these minimum levels of understanding of technology. Ideally, the development of individuals' understandings of technology should commence with the provision of learning experiences in early childhood and primary schools settings. However, it is well established that many experienced and novice primary school teachers have a low level of confidence in their ability to teach technology (Australian Science Technology and Engineering Council, 1997). Consistent with this is the observation by the researchers in their school-based research, that there is very little deliberate teaching of technology in Queensland primary schools. Further, given the limited substantive technology content in preservice courses (Australian Science Technology and Engineering Council, 1997), the lack of confidence of recently graduated teachers in their ability to teach technology is not surprising. Clearly, there is a need for teacher educators to increase the effectiveness of technology education courses in preservice and inservice primary teacher education in order to meet the challenge of developing minimal levels of understanding of technology in all individuals.

**Theoretical framework**

Research studies have revealed that the past experiences of primary and secondary school teachers, both in and out of school, greatly influence their understandings of technology and technology education (Jones & Carr, 1992a). In particular, research conducted into primary teachers’ understandings of technology indicated that they possessed very limited or narrow views of technology (Jarvis & Rennie, 1996; Jones & Carr, 1992a; Jones, 1997; Symington, 1987) and these views influenced the ways in which they attempted to implement technology teaching programs. Primary teachers tended to conceptualise technology as having to do with computers, or very technical and advanced machinery, or gadgets that they could not possibly incorporate into their classroom without expertise (Jones & Carr 1992a, b; Symington, 1987). Many did not necessarily see that technology was probably already part of their teaching programs.

It has also been found that secondary teachers have difficulty coming to a shared perception of technology and technology education, being influenced strongly by discipline subcultures or beliefs about the discipline(s) they usually teach and about how they see those discipline(s) in relation to the rest of the school and students' education in general (Jones & Carr, 1992a, b). A lack of breadth exists in secondary teachers' understanding of technology that does not apply necessarily to teachers of technology studies or teachers of those subjects usually classified as technical or craft-oriented. These teachers have been shown to hold a broad notion of the meaning of technology (De La Rue & Gardner, 1996).
Teachers' understanding of the differences between science and technology may be a problem. Many teachers see technology as applications of scientific knowledge (Bentley & Watts, 1994; Rennie, 1987), or something that cannot exist without the presence of science. Teachers of craft and technical subjects in secondary school do not necessarily hold this idea, probably because their past experiences of teaching students practical and technical skills has not involved the teaching of the associated science (van den Bergh, 1986).

Another view is that technology is the all-embracing area and science is one of the sources from which technology draws its information (Bentley & Watts, 1994). A third view is that science and technology are integrated and although both are separate and distinct ways of knowing they are inextricably linked (Bentley & Watts, 1994). In the light of these different perceptions teachers hold about science and technology, it has been concluded that teachers need to become aware of the commonalities and differences between science and technology, and to be given opportunities to explore the relationships between the two subjects (Jarvis & Rennie, 1996; Jarvis & Rennie, 1998).

It may be concluded that many teachers, in particular primary school teachers, need assistance to clarify and reflect on their own perceptions of technology. However, the changing or broadening of teachers' views about disciplines is proving to be a difficult task the world over (Black & Atkin, 1996) and there is a limited research base on this issue in relation to technology (Jones & Compton, 1997). If a parallel is drawn with science where it has been shown that students' understanding of the nature of science can influence how they think and learn about science (Fleury & Bentley, 1991; Roth & Roychoudhury, 1994) and teachers' views of science can influence the way they teach science (McRobbie & Tobin, 1995; McRobbie, Roth & Lucas, 1997; Lederman, 1992), it would seem to be important for preservice teachers to develop perceptions of technology that are in accord with the aims of the national statement on technology (Curriculum Corporation, 1994a).

In view of the limited research base, a way of proceeding with the design of this study was to draw a parallel with existing science education research. Shapiro (1996), in a study of changing student teachers' thinking about science, reported major changes in many students' thinking (over 80%) towards more scientifically acceptable views, as a result of engagement in an independent investigation in science, an important outcome being the identification of recurrent change features in students' thinking about science, or change themes. Other studies (for example, Anderson & Walvoord, 1990, 1993; Swain, 1991; Tyler, 1992) confirm the usefulness of independent investigations as a way of exploring participants' thinking in the conduct of independent projects. The richness of data related to students' changes in thinking about science obtained by Shapiro (1996), and the evidence from other studies involving independent projects, provides a strong rationale for: firstly, investigating an independent technology project as a way to change participants' views about technology; and secondly, using the novel approach of a Repertory Grid, devised by Shapiro, to observe and analyse changes in students' views about the design process in technology. However, Shapiro did not observe or monitor the students conducting the independent investigations and therefore was unable to provide compelling triangulated evidence to support her interview and Repertory Grid data.

The aim of the study was to investigate changes in preservice primary teachers' perceptions of technology and technology education as a result of their engagement in a technology project. The specific objectives were:

1. to investigate preservice teachers' perceptions of technology that they bring to a preservice teacher education course.
2. to describe changes in preservice teachers' perceptions of technology and technology education as a result of engagement in an independent technology project.
3. to draw implications for preservice and inservice teacher education.

**Design and Methods**

An interpretive research methodology (Erickson, 1986) was utilised as this approach provided "the meanings and purposes attached by human actors to their activities" (Guba & Lincoln, 1989, p. 106) which was the focus of this study. The study employed the criteria of Guba and Lincoln (1989) for quality interpretive inquiry - trustworthiness, authenticity and the benefits of the hermeneutic process. Trustworthiness was enhanced by prolonged engagement over eight weeks, persistent observation, peer debriefing, and member checks with participants including returning transcripts of interviews for checking. Fair presentation and analysis of assertions including actively seeking negative examples and a range of interpretations enhanced authenticity. A hermeneutic cycle was employed in developing and testing assertions as the study progressed. Emerging assertions were discussed with students and colleagues and tested and refined in the light of further evidence. Triangulation involving the use of multiple data sources maximised the probability that emergent assertions were consistent with a variety of data. With extended classroom observations, the tendency for participants to exhibit contrived behaviours was minimised.

**Informants**

The informants were drawn from a cohort (about 130 students) enrolled in a one year postgraduate preservice primary teacher education course. A range of undergraduate backgrounds such as arts, performing and visual arts, psychology, business, architecture, and science were represented in the cohort. The gender distribution was approximately three female students to one male student.

**Preservice Course Design Features**

As part of their program the preservice teachers were required to study two compulsory, combined course units in mathematics, science and technology education, one course unit in each semester. The technology component of the second semester course unit provided the teaching and learning context for this study.

Half the overall contact time for the course unit was allocated to mathematics education and the remainder was divided approximately as follows - two-thirds technology education and one-third science education. Contact time with the cohort of preservice teachers in technology education consisted of a lecture (one hour for four weeks) and workshops (1.5 hours for eight weeks). The cohort was scheduled at different times in four approximately equal workshop groups.

**A Teaching and Learning Platform for Technology and the Independent Technology Project**

The majority of students had done little or no formal study in technology and the technology process in their schooling and undergraduate education. Therefore, the first three weeks of lectures and workshops in the technology program were designed to be a teaching and learning platform for technology and the independent technology project. Experiences were provided that enabled students to immerse themselves into the content and processes embodied in the four strands of learning in the technology key learning area - design, make and appraise; materials; information; and systems (Curriculum Corporation, 1994a). A sequence of guided experiences were provided which allowed students to: (a) design an artefact such as a swing, a cradle or a carry bag, and to test the properties of materials, for example, strength, that could be used to construct that artefact; (b) discuss and analyse critically, print and audiovisual information about tools, machines, systems, and a range of
technological artefacts; (c) construct an artefact, *A Breathing System*, based on a prescribed
design from Primary Investigations (Australian Academy of Science, 1994); and (d) engage
in more open-ended exercises involving strengthening an object made out of four paddle
pop sticks, and designing, constructing and testing a bridge made out of materials such as
straws or spaghetti. The students worked in threes in this initial phase of the technology
program.

In the next phase of the technology program, the students, continuing to work in the same
small groups, were asked to select and conduct an independent technology project that
might be typically suggested by an upper primary school child. The independent project was
conducted over a period of five weeks and involved students in designing, making and
appraising a product or artefact. No specific guidelines for the production of the artefact were
provided, however, sample projects sourced from technology curriculum materials such as
*Nuffield Technology* (1998) were available for perusal. The students were given guidance
as required in the selection of a suitable task, and the clarification of issues relating to the
technology process without compromising the independent nature of the project.

*Data Sources*

Prior to the commencement of the second semester of the course, all students in the cohort
completed a technology survey, which was comprised of three instruments to elicit and
describe children's perceptions of technology (Rennie & Jarvis, 1994). Parts of these
instruments were originally designed to measure 13 year old students’ attitudes and ideas
about technology - PATT (Pupils’ Attitudes Towards Technology) instrument (Raat & de
Vries, 1986) - but the version used in this study has since been developed to determine a
variety of aged children's ideas (Rennie & Jarvis, 1994) and has also been used to
determine teachers’ views about the nature of technology (Jarvis & Rennie, 1996). The
instruments consist of a writing/drawing activity which represents a response to the general
questions "When you read the word 'technology' what comes into your mind?" and "What
does technology involve?"; a picture quiz in which respondents mark the pictures of objects
that they believe have something to do with technology; and a questionnaire which requires
Likert type responses to ten question each in two categories - "What is technology?" and
"What do you think about technology?"

Semi-structured interviews were conducted with a preliminary sample of 30 students to
probe further their responses to the technology survey and to provide additional elaboration
of their views about technology and technology education. Also, the students were asked to
make predictions about the experiences they might have and methods that they would adopt
during the teaching and learning platform and the independent technology project. The thirty
students were representative of a range of views about technology evident in the
writing/drawing activity.

Following a process developed by Shapiro (1996), a Repertory Grid reflecting the views of
the interviewed group about the technology design process was developed. The interview
and survey responses were coded and categorised into a set of dipolar constructs (ten)
consisting of terms and phrases commonly used by students about technology and the
conduct of technology investigations (Table 1), and a set of elements (nine) of the
technology process consisting of typical situations or experiences in the conduct of an
investigation (Table 2). The Repertory Grid developed consisted of a seven point rating
scale situated between pole positions on the individual constructs, one set for each element.
A sample Repertory grid chart is shown in Table 3.
Table 1

*Repertory Grid - Constructs*

<table>
<thead>
<tr>
<th>Label</th>
<th>Descriptor - One pole</th>
<th>Descriptor - Opposite pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Creating my own ideas</td>
<td>Just following directions</td>
</tr>
<tr>
<td>b.</td>
<td>Challenging, problematic, troublesome</td>
<td>Easy, simple</td>
</tr>
<tr>
<td>c.</td>
<td>Have some idea beforehand about the result</td>
<td>Have no idea what will result</td>
</tr>
<tr>
<td>d</td>
<td>Using the imagination or spontaneous ideas</td>
<td>Recipe-like prescriptive work</td>
</tr>
<tr>
<td>e.</td>
<td>A frustrating experience</td>
<td>A satisfying experience</td>
</tr>
<tr>
<td>f.</td>
<td>Doing real technology</td>
<td>Doing things unrelated to technology</td>
</tr>
<tr>
<td>g.</td>
<td>Theoretical considerations</td>
<td>Practical considerations</td>
</tr>
<tr>
<td>h.</td>
<td>Using a specific method to solve the problem</td>
<td>Not using any particular method</td>
</tr>
<tr>
<td>i.</td>
<td>Process oriented</td>
<td>Product oriented</td>
</tr>
<tr>
<td>j.</td>
<td>Group based/collaborative discussion</td>
<td>Individually based</td>
</tr>
</tbody>
</table>

Table 2

*Repertory Grid - Elements*

<table>
<thead>
<tr>
<th>Label</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Selection of a problem for investigation by the participant</td>
</tr>
<tr>
<td>2.</td>
<td>Identifying and exploring factors which may affect the outcome of the project</td>
</tr>
<tr>
<td>3.</td>
<td>Decisions about materials and equipment may be needed</td>
</tr>
<tr>
<td>4.</td>
<td>Drawing of plans may be involved</td>
</tr>
<tr>
<td>5.</td>
<td>Building models and testing them may be required</td>
</tr>
<tr>
<td>6.</td>
<td>Modification of original plans may be required</td>
</tr>
</tbody>
</table>
7. Modification of original models may be required
8. Appraisal of the process and product may be required
9. Solving of problems may be needed

Table 3

**Sample Repertory Grid Chart**

The following statement is a brief description of a typical experience you, as a participant, might have while conducting a design and technology project.

**ELEMENT #1: Selection of a problem for investigation by the participant.**

Rate this experience on the scale of 1 to 7 below for the following constructs, or terms and phrases, you might use when describing the steps in conducting a design and technology project. CIRCLE YOUR RESPONSE.

<table>
<thead>
<tr>
<th>CONSTRUCT</th>
<th>SCALE</th>
<th>CONSTRUCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Creating my own ideas</td>
<td>1 2 3 4 5 6 7</td>
<td>a. Just following directions</td>
</tr>
<tr>
<td>b. Challenging, problematic, troublesome</td>
<td>1 2 3 4 5 6 7</td>
<td>b. Easy, simple</td>
</tr>
<tr>
<td>c. Have some idea beforehand about the result</td>
<td>1 2 3 4 5 6 7</td>
<td>c. Have no idea what will result</td>
</tr>
<tr>
<td>d. Using the imagination or spontaneous ideas</td>
<td>1 2 3 4 5 6 7</td>
<td>d. Recipe-like prescriptive work</td>
</tr>
<tr>
<td>e. A frustrating experience</td>
<td>1 2 3 4 5 6 7</td>
<td>e. A satisfying experience</td>
</tr>
<tr>
<td>f. Doing real technology</td>
<td>1 2 3 4 5 6 7</td>
<td>f. Doing things unrelated to technology</td>
</tr>
<tr>
<td>g. Theoretical considerations</td>
<td>1 2 3 4 5 6 7</td>
<td>g. Practical considerations</td>
</tr>
<tr>
<td>h. Using a specific method to solve the problem</td>
<td>1 2 3 4 5 6 7</td>
<td>h. Not using any particular method</td>
</tr>
<tr>
<td>i. Process oriented</td>
<td>1 2 3 4 5 6 7</td>
<td>i. Product oriented</td>
</tr>
<tr>
<td>j. Group based/collaborative discussion</td>
<td>1 2 3 4 5 6 7</td>
<td>j. Individually based</td>
</tr>
</tbody>
</table>
The Repertory Grid was administered to the preliminary sample of thirty students who rated their perceptions for each element for each construct in turn; that is, if the first element was *Selection of a problem for investigation by the participant*, students rated each of the constructs as they pertained to this element and then the same constructs on the next element, *Identifying and exploring factors which may affect the outcome of the project*.

Twelve focus students were purposefully selected (Guba & Lincoln, 1989) from the preliminary sample of thirty for in-depth study during the guided experiences and the independent technology project. The focus students represented a range of views of technology and technology education as evidenced in their technology survey, interview, and Repertory Grid responses. The focus students worked in threes, one group of three in each scheduled workshop.

The actions of the focus groups as they worked through the guided experiences and conducted the independent project were videotaped and radio microphones used to capture the discourse within and between the groups. Stimulated recall, using video replay, at the completion of the independent project provided further descriptions of what students were thinking at various stages as they worked on the project. The research team who observed each of the focus groups made field notes.

The research team developed tentative assertions on the effect of the experience on the students’ perceptions and actions, for ongoing testing as the study proceeded. During the conduct of the independent project all students completed a journal of their reflections on their progress, the technology process they were experiencing, critical incidents, and project notes.

After completing the technology project the sample of 30 students again completed the Repertory Grid. The grids were analysed to identify changes in perceptions on each construct for each element. The individual grids of the focus group students showing pre- and post-perceptions were the stimulus of further interviews for those students. Particular attention was given to pre-post responses that differed by two or more units on the seven point scales of the constructs within particular elements of the Repertory Grid, and critical incidents recorded in the student journals or noted in field notes, so as to provide further description of the perceived reasons for the changes noted and relating those changes to particular experiences in their project work. Replay of videotape segments was utilised as required to stimulate recall of events discussed in the interviews. The tentative assertions proposed previously were reviewed, and case studies representative of important changes in the initial perspectives held by the participants were developed.

The final assertions and the case studies developed were reviewed for their implications for the influence of student technology projects on changing students’ perceptions of technology.

**Findings**

There are a number of key ideas evident in the definitions of technology provided by the *Statement on Technology for Australian Schools* (Curriculum Corporation, 1994a), Johnson (1989), and Jones and Carr (1993). The key ideas can be summarised as follows.

- Technology is a purposeful activity;
- Technology is a process which involves doing, making and implementing;
- Technology is used to solve problems, meet needs and extend capabilities;
- Technology is enhanced by discoveries in science;
- Technology is subject to the laws of nature and may often precede science;
• Technology leads to the development of products, systems and environments;
• Technology is conducted within contexts and constraints, or is situated;
• Technology draws upon resources, experience and knowledge;
• Technology is conceived by inventors and planners;
• Technology is promoted by entrepreneurs;
• Technology is used and implemented by society;
• Technology has effects on society;
• Technology is influenced by value judgements.

It can be assumed that the more key ideas included in any answer to a general question "What does technology mean to me?" may be indicative of a more comprehensive and deeper understanding of the word technology.

When responding to the questions associated with the writing/drawing activity in the technology survey, many students in the cohort included ideas, which could be associated with the concept of change due to technology (54%), products (68%), and the social implications of technology (78%). A smaller number of students included references to the human element in technology (34%) and the design process inherent in technology (31%). The range of ideas about technology is evident in a selection of students' responses below.

Technology is man's utilisation of created objects to aid him in his existence. It also means knowledge of matter to be able to create objects for himself. It is the vehicle through which man has advanced and survived, and is the vehicle of his own destruction. Technology is associated with an age and with human institutions. (Ivor)

Technology to me means moving forward, innovation, and invention. It also means advancement and things associated with recent advancement. When you say the word technology I would associate it with science and computers, with research and science labs, and computer factories and research. I would also associate the word technology with social changes it has caused, for example, televisions and media in the last 50 years. I probably form my ideas of technology on the last 100 years and changes in those 100 years in the way we live and how technology has changed this. (Maree)

Technology to me is the means by which advancements are made in all areas of life. It is the future of our world's survival. (Lynn)

Technology involves processes to develop, refine, design, and manufacture a range of goods and services. It is involved in nearly every facet of our lives. (Joseph)

Technology is the ideas and development behind any particular object or process. Technology is often limited to advances in computers and appliances but, in fact, relates to advances made in all fields of human life. (Lachlan)

Technology means computer, television, video, and spaceships (Mary)

Technology for me means, to some extent, something with more complexity; something which may make life easier; something technical and maybe mechanical; or something which may be difficult to understand. The new, the innovative. Technology is the pathway for the future. (Angela)
Students' responses to the two remaining parts of the technology survey, the picture quiz and the questionnaire, were in accord with what might be expected of mature age students enrolled in a postgraduate program. For example, 98% marked the picture of the telephone as having something to do with technology; 96% agreed that making models and testing them is part of technology; 92% agreed that they wanted to learn more about technology; and 50% could not make up their minds whether technology has brought more good things than bad things.

The open-ended writing/drawing activity provided some insights into preservice teachers' thinking about technology prior to the commencement of work on an independent technology project. However, these insights were limited when compared with the key ideas described previously, for example, less than a third of the students referred to design and design processes as being an integral part of technology. No information concerning students' thinking about technology education was be obtained using these instruments.

Hence, there was a need to use data collection methods that were conducive to in-depth analysis to determine students' views of technology and technology education, and changes in those views, as a result of engagement in an independent technology project. The following section of this paper reports the analysis of data collected, using interviews, the Repertory Grid, workshop observations, and students' reflective journals, for three focus group students working together on the independent technology project.

**In-depth Study of a Focus Group**

a) **Prior Knowledge about Technology**

The findings from the first interview with each member of one of the focus groups, Mary, Angela and Ivor, supported the conclusions from the technology survey that students' thinking about technology covered a number of ideas but was not comprehensive. The following responses were provided to the general question "What does the word technology mean to you?"

To me it means a lot of things. I sort of think about computers. The other day I was watching something on TV and it was to do with this probe that they used on this gentleman's brain to kill Parkinson's disease, so to me it means a lot of things. It's not just one thing in specific. (Mary)

Technology. You're talking about the future. You're talking about things that we think of as new and complex; machinery; discovery. There's a lot of words that we associate with it. (Angela)

Just off the top of my head, to me, it means advancement, change, progress. I think of usefulness. (Ivor)

All three were able to elaborate further when responding to additional questions along the same theme. Angela and Ivor, in particular associated technology with problem solving and satisfying human needs. For example,

To satisfy particular problems that we have; to make our life easier...to be more efficient in the way that we do things. (Angela)

Ivor, however, expanded upon this and suggested that technologies came about as a natural development of discovery or what was already there.
Technology is a purposeful thing, but I think sometimes it's just discovering. It's just left behind as a consequence. It's there in all its forms, I mean and each generation builds on it and reaps from it, you know. I mean we have today discoveries that we have. Tomorrow's children or whatever will be benefiting from that. ... But now technology has advanced and like aeroplanes are more high tech and streamlined and that, so they use alloys and totally different things, but it's still based on an old concept which is like birds flying, you know, the whole thing. ... I mean, maybe back in the early 1800s they would have, the raw materials would have been that they used would have been in accordance still with their thinking and the technology at the time which would have been like wood and like linen, canvas or something like that. (Ivor)

Mary, on the other hand, indicated that technological advancement was initiated by ideas and that the outcome of technological activity was products.

It [technology] probably starts off with an idea and then by working with it, they work with other people and you know people talk about how they can improve upon things. ... Technology to me ... always produces something, so now whether that can be more defined information on something or whether it produces a building or a vaccine or whatever, I don't know. (Mary)

Mary, also was not able to explain further about the resources that are utilised in such activity and go into the production of technological artefacts, whereas Angela spoke about the knowledge required by technologists regarding the materials they used and the need for a vision of the end-product. Angela used the example of making a boat to illustrate her point.

The first process probably is understanding the sorts of things that float [and that it is] because of the physical make up of them they are going to float. ... You could make a boat just out of a piece of wood that, you know, doesn't need to be a shape. ... You've just got your little plank of wood and your little sails sticking up out of it and that's all it is - it's a plank of wood and it's going to float and that's because it's wood, not necessarily because it's shaped in a particular way or whatever. ... [You also need to have an] understanding about sealants and things like that - the sorts of things that [are] going to stop water from coming in which is going to be important to that. (Angela)

Ivor, too, identified the need to have knowledge about materials if working on a task such as building a model boat.

I would look around for materials with which to build a boat, you know, materials for instance that would be, say, impervious to water and it would have good, like, buoyancy. (Ivor)

All three students in the focus group were able to identify the situatedness of technology. Mary, for example, recognised the influence the acceptance of ideas by the public can have on technological advancements.

It can be governed I suppose by public demand if there's something that is not working so well out in the world. I mean people would tend to get together and collaborate and get their ideas together and work on something to maybe help. (Mary)
Angela pointed out how availability of finance and perhaps cultural need and situation would all influence the nature and extent of technological activity.

I mean they've got to start out with that sort of idea and have some sort of direction and get funding for their project ... In a capitalist society, of course, people sort of tend to have this drive to make money and things that are economically sort of viable ... Also, I mean, there's cultural ideas from what they think is important. If they don't think it's important to, you know, develop computer technologies because people in their country aren't going to be able to afford to buy them, then they maybe are not going to invest in them.  
(Angela)

Ivor, on the other hand, placed a great deal of importance upon societal implications of technology and questioned the motivation behind modern day technology.

I think primary motivation for a lot of technology is purely and simply money and benefits. ... Some people are getting, have inspiration to create new technology, but it drains, it's like it drains its recipients of all creativity. I mean they'd look no further, they just sit there and gobble it up. ... Well, I think nowadays you've got no choice ... it's forced upon you ... it can be a benefit and yet sometimes it's not. It's a totally destructive thing. (Ivor)

He expressed concern about the power that technology can have over people. He illustrated what he meant with an example, which drew on his past experiences in Indonesia.

It throws everything out. ... the children in the villages are pulled away to the cities because they see images of new technology and different things, you know, western concepts coming through. They're pulled away from looking after the land and carrying on the traditions. ... I guess it has become a status thing. A poor man, he can produce a bigger crop, you can produce a better crop. It's not all bad, though, because for instance, I think it might have been the Germans in this particular place developed irrigation systems which went quite well for irrigating the paddy fields. But then again there's other things, like people pour money in and offer incentives to families for instance, who won't convert to Islam and they pour money in and they can buy bigger and better land, they can get all this fertiliser and all the stuff. It just snowballs and I mean it's just basically they use it to buy people, you know, money and technologies. (Ivor)

Upon consideration of what could be ahead of them as students participating in a course on technology, linked with technology education in primary classrooms, the three students had a number of ideas to express. These ideas were predictions based upon their limited experience of technology education. Angela drew on her experiences of making boats with her father when she was a child to suggest that the processes involved in a technology project would include:

Well I guess you'd ... draw a picture of it. I mean that's how you actually approach making a boat. You need to have certain measurements and things that are going to be involved in that to some extent. ... If they had a flat piece of wood, they would have to decide on measurements - how big they'd want it. ... You'd probably need to look at trial and error with it. ... Like with a class at school, maybe give them a whole lot of different sizes of things to experiment with and see what the differences between them [are] - or try and sort of give it some sort of method. (Angela)
Ivor was able to express more elaborate ideas. For him, engagement in a technology education project would have to be practical and relevant to everyday life. Involvement would mean undertaking tasks such as drawing on prior knowledge about the artefact to be created and about suitable materials to match the extent of its ultimate functionality. The task would be a co-operative one and a collaborative one and value would be placed upon sharing and considering others' ideas. At the same time the product outcome would also be important because it would be a culmination and concretisation of the goal.

I'd want to go from that [blue print] stage to having a working model. I wouldn't be happy with anything less. ... I mean that's the goal. The working towards it, it's exciting, it's discovery and when you've reached that goal and you've actually created the thing, that exciting too. You've got something concrete that you can know from your efforts. (Ivor)

Ivor suggested that appraisal would also be important as a means to assist learning when goals were not achieved.

I mean, the boat may not work, but it would be enough that people had endeavoured to create a boat. Now if it didn't work, then they would need to be told why. ... The people in the group could learn from that and next time they could actually improve on the design. (Ivor)

Mary, however, was unable to explain what she thought would be involved in a technology education project to a great extent. She suggested that technology education would involve computers in some way but could suggest little more concerning the content of such sessions. She was able to say more about teaching strategies that would have to be involved. She, like Ivor, suggested that group interaction would have to occur and that guided, hands-on activities would be prominent.

So I imagine there would be a lot of, you know, hands-on work. You'd be actually physically doing something as well as probably writing down from the board or given notes on particular technology. ... Well they have got to have an activity to do and have, you know, a format to follow, maybe some steps to go through and use the equipment and then record their results. (Mary)

b) The Independent Project

The first of the independent project workshops engaged all students in making initial decisions about their projects. After a short discussion the focus group of Ivor, Mary and Angela decided to make a boat. They spoke extensively about its proposed structure, size, and shape and about how it was to be powered. Finally, agreement was upon making a hollow hulled boat shaped from balsa wood, powered by a "jet" engine: a pump from a car windscreen wiper motor brought in by Ivor. As shown through evidence collected from video recordings and field notes during the workshops, discussion was extensive throughout as particular problems arose or as decisions had to be made. For example, Ivor's pump stimulated at least 45 minutes discussion about its workings, how it was going to be incorporated into the structure of the boat and what structural changes would have to be made in order to house it. During these discussions, diagrams were drawn continuously, mostly by Angela, with members of the group, principally Angela and Ivor, using them as support, illustration and focus of their developing ideas. Although Mary contributed less verbally to these discussions than Angela and Ivor did, she did identify the worth and role of the drawings during these interactions.
For me, I was learning by listening and looking at the drawings that Angela had drawn (while drawing these sketches she was also giving and explanation to her idea). I believe this process is an important step in the brainstorming stage and is very helpful to people who don't know very much about the topic. (Mary - Journal Reflection 11.8.98)

Thus, Angela tended to take on a leadership role, facilitating as well as contributing to the development of ideas and to the progress towards the group's construction of its boat. There were plenty of complex negotiations held between Ivor and Angela, as well as active, hands on sharing of ideas. Mary, on the other hand, tended to take a more passive role as listener, making occasional important interjections.

Problems mostly related to the properties of the materials and the way the materials worked together arose throughout the construction period. These emergent problems (McCormick, Murphy, Hennessy & Davidson, 1996) occurred as the materials were manipulated and construction was attempted. The group found that they were not able to predict the problems until they faced them. For example, initially, gluing was the only means considered for joining the wooden parts of the boat. When the practicalities of gluing had to be faced, it was decided that because of the fragility of the wood which had to be bent, nailing and then stapling were also considered, both in conjunction with glue, as to means of providing a firmer join, thus providing structural strength. The group also had to deal with the difficulties of bending the balsa wood to form the curved sides of the hull, the practicalities of which were not considered at all during the sketching/discussing phase of the project. Angela, who took the structure home to bend the sides and attach them, solved the problem in ways that were a product of the discussion held with Ivor and Mary during the tutorial and also of the materials and tools that were available to her at home. She wet the wood, glued it with wood glue she had at home, secured it with packaging tape because it was available and began drying the wood using her hair drier. This continual problem solving, and indeed the variety of types or levels of problems similar to those that arose during this group's design task have already been recognised elsewhere (Roth, 1995b; McCormick, et al., 1996). The solutions to such problems are a product of the complex interplay amongst a variety of variables, including materials and tools at hand, interactions with colleagues, as well as purposes or intentions of the tasks and subtasks (Roth, 1998). Some elements of this complexity were noted by the focus group members, for example, Mary noted that problems do not end once planning has finished.

There was still a lot of problem solving happening in this phase [making phase] as well. This was to do with the construction and the best way to mould the balsa wood into its new shape and how to fix both pieces together. (Mary - Journal Reflection 31.8.98)

c) The Group's Reflections on the Experience and the Changes They Made

At the end of the project all members of the group were able to speak differently in some way and to varying extents about technology and technological processes. These differences were apparent in their presentation to the whole class, during which they made a formal appraisement of their boat and through other data sources collected as part of this study.

Angela's responses for all elements of the Repertory Grid at the start of the project tended to be at either of the extremities of the scale (i.e, 1 or 7) or in the middle (i.e., 4). Angela assigned most elements similar construct ratings and these did not change in her second Repertory Grid response. This indicated her very clear ideas about the design process, which were supported by her comments during the interviews and attributable, in part at
least, to her antecedent knowledge gained through experiences such as building model boats with her father. While beginning the project with personal experience of construction of models in her childhood and some explicit awareness of design processes, Angela was able to talk about them to a greater degree and provide insights into how those experiences influenced the activity during the project.

But I think the experiences from my childhood...made me sort of more aware of what was going to be going on in that sort of situation. So it was sort of drawing on past experiences. ... And I think those types of experiences mean that I could build a life-size boat and I would know what I was doing more so than some people would. And I think for kids that that sort of an experience really does, you know. (Angela)

She was also able to express her predictions about technology in primary classrooms more extensively and with more certainty. For example, upon reflection of the varying artefacts produced by other preservice teachers during the project, Angela's comments showed that she was thinking about the applicability and worth of approaches to design activities presented in primary classroom situations.

Well I think what they [other preservice teachers] were trying to do was design something that the kids could build. And I think that that's okay, except that you've already given them the idea and taken away from the whole design process. ... And that's okay if you don't want a lot of openings to be there, I guess. ... I thought they did it as if they were designing it themselves, but I still didn't think that they left the room for it to be designed in other ways, in the way that we did with ours, where we basically, we looked at other options that the kids could have, so that they wouldn't just have to use our option of using the balsa wood. (Angela)

Like Angela, Ivor's past experiences and observations seemed to have provided him with a basis from which to operate during this course. His initial Repertory Grid responses revealed very similar patterns for elements 3, 4, 5, 6, and 7 (see Table 2) with near extreme responses - 2 on the scale of 1 to 7 - for the constructs (c), (d), and (h) (see Table 1). At the end of the project Ivor stated that he did not wish to make any changes to his Repertory Grid response (Field Notes 27.10.98). This indicted that these views of the design process may have been linked with his knowledge of materials, the use of materials in construction, and the need to use drawings as part of the constructions. Like Angela, Ivor already held certain ideas about technological processes, and the experience of the independent technology project confirmed those ideas. Early in the project, he demonstrated that he possessed knowledge about materials, making many comments about their properties, use, and selection. For example, upon reflection of early workshop sessions before the group began its boat-building project, Ivor made the following points in his journal.

Some materials, by virtue of their inherent composition are naturally strong. However, as I perceive it, the strength of materials is not always determined by what the material is made of, but rather by its design, construction, and form. (Ivor - Journal Reflection 21.7.98)

Later, during discussions with his group about the selection of materials for the boat, he had many ideas to contribute, of which the following was typical.

It would be harder, I think. You'd have more flexibility with balsa. With hardwood you'd be confined to one solid block and you'd have to cut it out. (Workshop Video 11.8.98).
Throughout the workshops, he was also very open to people working together and he expressed a positive attitude towards the worth of collaboration within the group and amongst groups, as well as towards the importance of individual effort in producing a quality end-product. The following quotation illustrates the value he placed upon ideas gained from other students.

During discussion about the boat a colleague suggested that the jet motor might need to be primed with water in order for it to begin pumping a stream of water from the rear of the boat. This idea had not occurred to us when we had originally tested the motor, in and out of the water. Acting upon this simple observation, we placed the motor under a stream of tap water, forced out all of the air bubbles, then turned on the electric current. The pump worked perfectly and we learned a valuable lesson. (Ivor - Journal Reflection)

Ivor’s past observations of life in Indonesia may have been an influence upon his ability to describe the steps and processes involved in such activity at the beginning of the project. However, by the end of the project, it seemed that Ivor’s knowledge had been confirmed, and more than that, he was able to analyse elements contributing to design processes more explicitly. Also, he was able to recognise how technology could become a reality in primary classrooms. One way he demonstrated this was through design of lesson plans, which aimed to support children’s exploration of materials and systems (Journal Reflection).

Mary lacked confidence in her overall knowledge about technology, technology education and more specifically about the building of model boats at the beginning of the project. Mary’s initial Repertory Grid indicated "middling" allocations for each of the constructs within each of the elements (i.e., 3, 4, or 5). Changes in her second Repertory Grid responses were minimal, but pointed. For each element, construct (e) A frustrating/satisfying experience (see Table 3) was changed from 4 to either 5 or 6, that is, towards A satisfying experience. This response supports the personal satisfaction Mary expressed in her comments about her experience of the technology project overall.

While her contributions to group discussions were limited, she did make suggestions when she could and ask questions of the other two group members to clarify her understandings. She was confident and comfortable with the part she played and felt she was accepted as a worthwhile member of the group.

From my point of view I found the exchange between the two of them [Ivor and Angela] helped me understand the concept of what Ivor was planning [referring to his ideas about the water pump], even though I did not participate in the discussion very often. (Mary - Journal Reflection 11.8.98)

There was no animosity or anything like that that happened in the group. ... They’d say to me, ‘Oh [Mary], what do you think about that?’ And they were trying to draw me into the conversation as well, even though they were the more dominant people, they were still trying to include me, which was a really good thing to see. (Mary)

By the end of the project, Mary saw that her greatest development occurred in terms of her becoming much more clear about what could be involved in design and technology projects.

I believe I have a clearer understanding about technology from this process of working in a group. My understanding is that whether I'm teaching or learning about technology it's all about discovery and sharing of ideas with other group members or with other groups in the class. It's about getting students to
questions and identifying problems or solutions to problems that may arise. It calls on you to make predictions, classify materials, problem solve, work in small groups, hands on activities, design, make and appraise constantly through all areas of development. (Mary - Journal Reflection).

Her personal confidence about tackling such a project herself was increased and as a consequence she felt more able to implement one in her own future classroom. This was the result of her positive reaction towards the approach taken during the course.

I think the actual process of going through and reflecting upon your group work and what was happening with your technology and your artefact that you were making, has sort of been very beneficial. I really think that there's nothing better than sort of getting in there and having a go, but looking at it from both points of view as well, not just from the making of something, but also reflecting upon what was happening within the group, and looking at how we all attack different situations. (Mary)

These changes highlighted by Angela, Mary and Ivor were representative of those perceived by many of the students involved in this study. Overall, as well as an increase in their confidence as future teachers of technology education programmes, students expressed changes or developments in their perceptions of the meaning of technology as a phenomenon; about what is involved in design processes; and about teaching and learning technology within primary classroom settings.

**Assertions**

According to Jones, Mather, and Carr (1995), professional development in the area of technology should provide opportunities for teachers to reflect on their own and others' conceptions of technology, on pedagogical knowledge and upon technological practices. In this preservice teacher's course, opportunities for engagement in such areas were provided, even though the participants, unlike the ones for whom the recommendations of the Jones et al. (1995) study were made, had had little classroom experience to draw upon. The following assertions draw together some important features of the insights gained into the preservice teachers' experiences of their participation in the technology course.

1. **Repertory Grids may be useful for giving insights into preservice teachers' understandings about technological processes.**

   The Repertory Grids used prior to the preservice teachers' technology project and again at its conclusion generally supported the developments and changes they expressed in their understandings about technological processes. However, of the three preservice teachers who were part of the in-depth focus group described in this paper other evidence suggested that more change was experienced than the Repertory Grids actually indicated. Work will continue on further developments of the Repertory Grid as it has the potential for capturing the intricacies of participants' ideas and changes to them. Developments may include simplifying the grid itself or asking respondents to complete the Repertory Grid during an interview, so that ideas and indications of changes can be probed immediately.

2. **Preservice teacher education courses that engage students in authentic learning experiences in technology present the basis for learning more about technology and technology education through providing opportunities for personal meaning making and the development of confidence for future teaching.**
The majority of the students indicated a very favourable response to the authenticity of the projects in which they were involved. The projects were regarded as authentic because they were self-selected, emerging from problems that the students had identified themselves. The students were able to tackle the problems in ways they felt were most appropriate within the limitations of available resources and time. Authenticity continued into the appraisement part during which not only did individuals within groups scrutinise their own ideas, progress, constructions and so on, but others from across groups were given the opportunity to do so as well. All of the action took place within the framework of technology in primary classrooms, and so throughout, thoughts and comments, ideas and changes were made in relation to teaching and learning, as well as to the final product outcomes.

Through experiencing a design, make and appraise process for themselves, the preservice teachers were able to learn more about what technology was about and in particular more about the design process itself. Many of these students either confirmed or broadened their ideas about technology as a phenomenon and were given insights into how technology education could be operationalised in a classroom. As such, the outcomes of this project reflect recommendations and descriptions of authentic projects with school students, as described by McCormick et al. (1996) (in technology), and Roth (1995a) and Yager (1989) (in science).

In addition, confidence for future teaching was boosted. As beginning practitioners, while there may be still much to learn, it is hoped that the positive attitude generated by their being involved in this independent project will contribute to addressing the current situation of primary teachers’ lack of confidence in teaching technology (Australian Science Technology and Engineering Council, 1997).

3. *Open and ill-defined projects provide the basis for the development of communities of learners where technological discourse is used and developed.*

The open nature of the project became the enabling factor for the development of many of the other learnings perceived as important by the preservice teachers, for example, those related to collaborative interactions and the sharing and development of ideas within and across groups. Through these experiences the discourse of technology was supported. The discourse of a field of study is integral to it and a vital aspect of learning when becoming a participant within any community (Lave & Wenger, 1991). Likewise, the role language plays in the development of understandings within science/engineering learning communities in schools has also been identified as integral (McGinn & Roth, 1995; Roth, 1995b; Roth, 1996). During this study preservice teachers were given opportunities to engage in tasks that were technological in nature and purposeful and relevant both to them as learners and to technology itself. This provided an environment for authentic discourse development to occur. In turn, this aspect of the authenticity enhanced the students' thinking about the technology and the technological processes in which they were engaged. In other words, the openness of the task provided the learning environment for the use of the discourse to support the action and for the action to support the development of the discourse.

4. *Engendering open learning environments for preservice teachers to engage in technology tasks acknowledges abilities and knowledge they already possess and provides an environment for the sharing and development of that knowledge and those abilities.*
Many of the students acknowledged the previous technology experiences that they had had, (often not of the formal kind) in their former professional, study and everyday lives. Many of them possessed antecedent knowledge upon which they drew ideas for involvement in and reflection upon the projects selected during this course. They also noted that it was through engaging in their design, make and test projects that elements of technology and technological processes that they had experienced in some way previously became more explicit to them. This project focussed their attention upon the major steps they undertook in realising their ideas and plans; how those steps were not necessarily linear in nature, but interwoven, or recursive; features of materials and their importance to the designing and the making of products; the importance, value, and often the necessity of collaborative action to produce the best outcome. Students expressed their former implicit awareness of these features of technology, and that it was through the project that their awareness of what they had previously taken for granted was raised and made explicit.

5. The framing of the technology tasks presented to preservice teachers can provide direction and structure for learning by highlighting what is important about technology and raising awareness of issues related to the learning and teaching of technology in primary classroom situations.

Because the preservice teachers, generally, had little formal background knowledge about technology, the initial sessions during this course served to alert them to a variety of elements about the nature of materials, systems and information that they would not have necessarily regarded with any import previously. This introduction, together with access to teacher resources (Australian Academy of Science, 1994; The Nuffield Foundation, 1998) provided the basis upon which they formulated their plans and discussions during their group projects. The students were provided with some direction and structure upon which to base and develop their ideas about technology and the practicalities involved in making their artefacts.

Similarly, with the interests of the preservice teachers being upon teaching and learning in primary situations, the open tasks were framed around the need to think of a project that could be selected or undertaken by primary students. Throughout the course of the project, this framing of the task supported not only the students' interest in teaching and learning, but also represented and highlighted for them what their actions and decisions could mean in the light of learning and teaching within primary school settings. The formal appraisement episode that took place towards the end of the course served to reinforce the connections of the students' experiences with primary classrooms as the students questioned and reviewed each others' work with these ends in mind.

Thus a variety of issues found relevant by the students were raised and discussed. These issues related to such things as the availability of resources; the practicality of the tasks; the difficulty of concepts underpinning the workings of artefacts; the time involved for designing, making and appraising; the strategies to use to stimulate thinking and reflection on ideas and outcomes; and the educational value of technology. In this way, the relevance of the group projects was emphasised, not only in terms of the students' own learning about technology, but also in terms of what technology education in primary classroom settings could entail.

Implications

Incorporating open projects into preservice teacher technology courses provides the stimulus for heightening awareness of technology, technology processes, and technology education. Thus there is agreement with studies in the science area (Anderson & Walvoord
that engagement in independent investigations can provide insights into students' thinking and the development of their ideas. Some implications of this study are now made.

First, Repertory Grids may provide insights into students' thinking about design even if there are only small, or no changes. They have the potential to provide a fine-grain level of information that other data sources such as reflective journals may not necessarily give. This more detailed information may be of particular use to both learners - as a means to make explicit what they do know and also as a focus for reflection upon technological processes - and course designers - as a means to help plan for learners' needs and understandings.

Second, the type of learning experience can facilitate the development of a more comprehensive view of technology, particularly design. Learning experiences which engage preservice teachers first-hand in design projects broaden and deepen their understandings about technological processes. Open and ill-defined projects provide opportunities for authentic and personal experiences, enabling students to express more comprehensive views of the complexities of engaging in design - for example, the iterative nature of designing, making and appraising - and become conscious of the interdependence of technological processes, materials, information and systems. In addition, these types of projects highlight the role that language plays in the development of technological understandings and its importance for legitimate participation within technological contexts. As occurred for many students in this study, such experiences raised to conscious awareness that which they felt they had already experienced in the past, but which they had taken for granted.

A third implication relates to the development of knowledge about technology education in primary classroom settings. Strategies adopted during a technology course can increase the students' awareness of ways for teaching technology in the classroom. From the outset, learning experiences that provide opportunities both open and defined, help preservice teaching students to engage in personal learning about technology, as well as to reflect upon implications for primary teaching. Exposure to what might be called the "content" of technology education (viz., materials, information, systems) is important as many students express a limited understanding of what constitutes the key learning area, technology. Helping students gain insights into the ways that the selection and nature of materials, for example, impinge on the designing and making of technological artefacts early in the course, and then asking them to consider the place of materials in design projects and how to help children understand materials is a way of introducing them to this "content." Such activities provide a platform upon which the students can then draw ideas for later decision making within their own open and ill-defined projects. For their projects the students in this study were asked to design artefacts that could also have been designed by upper primary school students and during the formal appraisal sessions they had to focus upon the suitability of their projects for this level of children. Using these types of approaches in courses, preservice teachers can be encouraged to review and reflect continually upon their actions and ideas in terms of primary classroom appropriateness and applicability. As a consequence, awareness of classroom implications can be raised and opportunities created for explicit discussion of issues.

**Conclusion**

The study thus confirms the worth of open-ended projects in courses for preservice primary teachers. In this study, the personal involvement and the consequent meaning making that occurred within an independent project provided a richness of experience from which the preservice teachers were able to draw implications for their future primary classroom situations. The open-ended and ill-defined nature of the tasks in which they were involved...
stimulated their reflections upon themselves as learners, upon their learnings about technology and technology education. They were able to comment upon their experiences and link them with their thinking and their changes in their thinking about technology and technology education. This personal and practical involvement meant that the nature of technology and technological activity was also represented within and as part of the action and as well, issues related to technology education were either experienced or raised upon reflection on experiences. As Shapiro (1996) found with independent science investigations, in this study the preservice teachers themselves recognised the value of participating in their technology projects. Not only was their awareness of technology, its nature, and design processes raised, but also insights into their own learning experiences were gained.
References


