Deakin Research Online

This is the published version:

Jane, Beverley and Tytler, Russell 2003, Technology education, science and science education : exploring the relationship, *in Initiatives in Technology Education: Comparative Perspectives: Proceedings of the American-Australian Technology Education Forum*, Technical Foundation of America and the Griffith University Centre for Technology Education Research, [Gold Coast, Queensland], pp. 97-111.

Available from Deakin Research Online:

http://hdl.handle.net/10536/DRO/DU:30026399

Technology Education, Science, and Science Education:

Exploring the Relationship

Beverley Jane and Russell Tytler
Deakin University

Introduction

In this paper the nature of technology education in relation to science and science education is explored. Ways forward are indicated for both technology and science in the curriculum so that the two areas can be mutually supportive. In the 1990s, when curriculum writers were attempting to provide technology a unique place in the curriculum, they tended to downplay the relationship between technology and science. One reason for this tendency derives from a perception that science is an academic and elitist discipline and technology is well served by emphasizing the distance between the two. The other reason is perhaps political, that science, by virtue of its status in the community, and the status of its special type of knowledge, would be in a position, if allowed, to subsume the new subject. There are philosophical and historical precedents that justify such a concern. In tracing the historical relationships between science and technology, in professional practice, in philosophical positioning, and in school curriculum, we inevitably need to deal with the politics of school subjects.

The position taken in this paper is that science and technology are different, both in their epistemological foundations, and in the nature of the professional communities and the concerns of individual practitioners within the two areas. In clarifying these differences the essential nature of technology and of science are illuminated. The paper also explores ways in which the two areas can benefit from each other's existence in the curriculum, and ways of approaching teaching that both clarifies the special nature of each type of knowledge, and allows them to be mutually supportive. This may necessitate a reconstruction of the nature of school science.

Science in the curriculum: an historical perspective

In 19th century Australia, as in the UK, the curriculum of public schools was dominated by classics, seen as cultural pursuits to serve the ruling elite by virtue of their value for

the training of the intellect, and the acquisition of cultural graces. Science, by contrast, was available in popular writings and was not seen to conform to the ideals of the classical curriculum by virtue of its accessibility to the burgeoning middle classes, and its utilitarian nature. Its initial inclusion into the public school curriculum was opposed by those who argued that it did not represent the mind-training qualities of the classical curriculum, and was better seen as the province of men of practical minds, artisans. Only by emphasizing its academic rigor and structural qualities, and by being represented by a growing acceptance of the pursuit of such studies within universities, did science gain a foothold. For science, the price of admission into the public school system was that it recast itself as concerned with universal principles and mind-training qualities. The type of knowledge that was valued in science was thus changing "... an emphasis on science in its applications to practical affairs was slowly yielding to one in which science was pursued for its own sake" (Layton 1973, p. 22).

The nature of science in the curriculum has changed considerably over the last 50 years, largely due to the wider social forces that impact on schools and determine the shape of the curriculum. In the 1950s and early 1960s, science curricula included many technological details, about how things work, and contained a myriad of facts and applications. Technology was mostly presented in these curricula as applied science, included as examples to enhance students' interest in science and to illustrate science in action. Sometimes courses began with a technological context from which science principles were developed. In both cases technology was subservient to science. At the upper levels of schooling the curriculum was essentially seen as a preparation for a career in professional science. Very few students remained at school beyond the compulsory years, and many of these pursued a technical education from the beginning of secondary school, quite separate from the general education meant for those whose preferences lay in mental rather than manual work.

With the sputnik 'scare' in the USA (in the late 1950s), when Russia was suddenly seen as technologically advanced, and in the context of the cold war therefore a threat, there was a re-evaluation of the USA upper level science courses. Large curriculum projects, such as BSCS biology and PSSC physics were produced. Both of these courses, which found their way into Australia, had been structured by teams of professional science academics (the government had looked to the 'experts') who emphasized within them the structure and essential nature of the discipline, throwing out many of the detailed applications that had characterized previous courses. Science was thus driven further toward higher level abstractions as epitomizing the science way of knowing. For example, in the PSSC physics, the way scientists use models as ways of understanding the world was a core idea around which the content was structured, and many of the engineering applications which had grown up within previous courses disappeared. In primary schools, science had been mainly associated with studies of nature, and it was not until the 1960s that serious attempts were made to define appropriate subject matter in the area of physical science.

Science has always had an impact on society. In recent decades the rate of scientific knowledge production has increased dramatically. New scientific knowledge has been associated with technological advances that may improve the quality of life or threaten it.

Demands for science/technology to solve many of the world's problems have fuelled the development of technologies that can advance medical science, space science, organic chemistry, and engineering science. Advances in electronic media have vastly increased the capacity to bring news of scientific discoveries and problems to world attention. When technology fills the marketplace with inventions, gadgets, and sophisticated hardware, consumers face bewildering decisions about what to purchase and how to intelligently use these innovations. When scientific investigation foresees difficulties in the availability of future energy sources, pollution, or environmental degradation, the impact of these findings ripples through the very fabric of society affecting economics, politics, lifestyles, and the quality of living for all citizens. When there is a rapid growth of technology-dependent industry, there are increased demands for a technologically literate work force. When scientific research suggests new and daring possibilities in areas of nuclear energy, genetic engineering, pesticide development, and artificial life support, people must deal with moral and ethical value questions that have never previously been part of society's concerns. The quality of life and the welfare of people are closely linked to science, technology, and the politics of society. Future decisions demand that people in society recognize the interdependence between scientific and technological developments and the quality of society and environment.

During the 1970s it was increasingly argued that science teachers must assume an important role in fostering this understanding by developing student understanding of science and technology within the context of social progress and environmental quality. Science education is still grappling with the challenges associated with educating young people so that they can function effectively in a rapid-paced scientific and technological-driven society. But it took a crisis in classroom science teaching to gain the attention of the educational community. Large-scale studies in several countries including the UK, USA and Canada have highlighted similar program inadequacies ranging from narrowly-conceived and implemented goals to over-reliance on texts as curricula and overuse of the lecture as a teaching strategy. Yager and Penick (1984) found that science was very negatively viewed by the bulk of school students. Other studies also found that on the whole, students become increasingly disenchanted with science as they progress through the secondary school years. It is argued that the crisis in science education is the failure to respond to changes in society and an avoidance of an orientation toward public understanding of science and technology. There is wide agreement among science educators, if not among teachers, that science programs must present basic concepts and processes within the context of personal and social applications and issues (Bybee 1985; Hurd 1986).

The growth of the Science-Technology-Society movement

'Science-Technology-Society' (STS) is the descriptor that characterizes a major reform movement in science education that began in the 1970s and was increasingly active through the 1980s (Aikenhead 1985; Bybee 1985; McFadden 1991; Ziman 1980). Convinced of the inadequacy of current programs and teaching methods, reformers of

science education aimed to completely reconceptualize the entire discipline. STS proponents put forward a series of recommendations for reform in science education which ask teachers of science to encourage students to become both capable and motivated to actively participate in a science and technology oriented society (Hurd 1986). To accomplish this goal, teachers must rethink their beliefs concerning what is worth knowing about modern science and technology to enable students to respond appropriately to the demands of social change. The essential skills to be developed in science teaching are those necessary for accessing, processing, and using information in the contexts of thinking critically, making decisions, and forming ethical judgments.

One of the driving forces behind the STS movement was the increasing 'Science for All' argument that science education must cater for all citizens, rather than simply an elite of students intending to pursue careers in science related fields. One difficulty that has always beset the STS movement is its challenge to the nature of science as a body of knowledge, as a discipline that is structured around generalisable, abstract knowledge. STS thus runs hard up against the discourse established in the 19th century to legitimate science as a school subject. By their nature, the more radical STS formulations largely emphasize local, conditional aspects of science knowledge as it applies in context, rather than pushing for universal and mathematically formulated abstractions. The question of status thus becomes critical.

Apart from a conservative academic resistance to STS ideas, there have been criticisms (e.g. Hart & Robottom 1990) from a methodological perspective concerning the process by which STS courses have been implemented. From a technology perspective, criticisms of the mainstream of STS formulations include:

- Technology is treated as an object of study, often theoretically presented (Layton 1991, 1993) rather than as a set of knowledge and skills in its own right. STS courses traditionally have not been concerned with educating technologists.

- The relationship between science and technology is often seen as unproblematic, with technology treated as the application of science and subservient to it.

- Value positions have not been taken as seriously as they should (Cross 1990).

During the latter half of the 1980s the emergence of technology as a key learning area, separate from science, forced science to reconsider its position. The comfortable notion that technology could be encompassed within science to represent its interface with the real world of artifacts, a product of the scientific method, was no longer tenable either philosophically, or in a curriculum sense. Therefore, work needed to be done to clarify the essential differences, or demarcation line, between science and technology, and in doing so to clarify the essential nature of both. This process has had political as well as philosophical overtones, in that interested parties, and champions within the academic community, inevitably exert their influence on the course of curriculum events.

Science and technology: epistemological issues

David Layton (1991) has been a staunch opponent of the view that technology is a derivative of science. He contends that technology has its own unique community of practice, different in important ways to science, and that the essence of technology lies in the notion of praxis. In science there are limited opportunities for students to engage practically in the design and construction of technological inventions in 'real-world' situations. The notion that our understandings of phenomena are inherently context bound is a fundamental aspect of the theoretical position of the situated cognition school (see, for example, Resnick et al. 1991). Rogoff and Lave (1984) argue that context is an integral aspect of cognitive events, and that one cannot hope to divorce thinking from the social and other contextual elements of a problem-solving situation. Rahm (2002) highlights that studies of the everyday practice of scientists have helped change the view of school science to one that now emphasizes the 'doing' of science and its embeddedness in people's daily lives. Science principles, which have a high level of abstraction, cannot be used directly for the practical action required in technological tasks. Layton (1988) argues for a redefinition of technology that is independent of science, an argument that lent support to the growing impetus during the 1980s in the UK to formulate technology as an area of study in its own right.

Technology as Applied Science (TAS view)

The media, public and politicians regularly use the phrase 'science and technology' and always in that same order. This practice stems from the common perception of Technology as Applied Science (TAS) and fails to acknowledge the complexity of the relationship between science and technology. Proponents of a TAS view believe that technologists rely on scientific knowledge in order to create their artifacts. The TAS perception holds that science is the generator of ideas which technology then utilizes to produce artifacts. Examples from history that illustrate such a belief include the electrical and nuclear power industries that have science foundations.

Technology influences the development of ideas and perceptions of the world (materialist view)

Another perception holds that technology actually influences ideas and mediates perceptions of the world, and in this role is not subservient to science but rather a foundation for scientific thought. Numerous historical examples show that technology is not necessarily subservient to science. The light microscope is one technological development that led to scientific discoveries. Improved techniques and the invention of better instruments have enabled scientists to refine scientific descriptions and explanations. Examples of technological inventions made by craftsmen prior to the

scientific theory can be found in Gardner (1994). More fundamentally, Ihde (1983, p. 29) sees technology as a way of revealing the world: "It is a certain way of experiencing, relating to and organizing the way humans relate to the natural world". For example, in the mid-fourteenth century, the invention of clock technology (the clock's movements represented the heavenly bodies) changed the way western society perceived space and time. In cultures without clocks time was perceived differently. Furthermore, in the Renaissance period, technological developments such as systems of warfare and mechanical power in agriculture formed the foundation of modern science.

A symbiotic science-technology relationship (interactionist view)

Proponents of an interactionist view regard the science-technology relationship as a two-way interaction. Jobling and Jane (1996) use the term 'symbiotic' to describe the position where science and technology interact in a mutually beneficial way. Science often provides a purpose for technology, whilst products designed and made by technologists can enable scientists to carry out their investigations. In the past scientists and technologists worked together to produce the steam engine, Bell's telephone, pneumatic pistons and energy-efficient machines (Fensham & Gardner 1994). These are only some examples of new discoveries in science that have influenced the developments of products and vice versa.

Science and technology are independent (demarcationist view)

Not all writers accept the view of science and technology as being related. Historically, most philosophers of technology recognized the craft phase of technology and believed that technology was a unique way of thinking and an autonomous realm of knowledge (Lewis & Gagel 1992). Scriven puts the case for developing technology curricula independently from science by arguing that technology has its own knowledge, skills and equipment.

> Science is defined as the process and publicly accessible product of our attempts to describe, explain and predict natural phenomena. Technology is the systematic process, and the product, of designing, developing and maintaining and producing artifacts. (Scriven 1985 cited in Rennie 1987, p. 122)

Such a definition shows that science and technology are independent, and have different goals, methods and outcomes (Gardner 1994). Other proponents of this view include Cross and Price (1992, p. 27) who perceive both science and technology to be human endeavors but each has its own purpose. "Science is the process of explanation, answering the question 'why' in its various meanings and Technology is the process of knowledge, answering the question 'how' to make or do something". Scientists are driven to seek knowledge and understanding, whereas technologists search for practical

solutions to personal or social problems.

How does engineering compare to science and to technology? Goldman (1990) argues that engineers view engineering as a way of knowing separate from science. Engineers generate their own knowledge by selecting appropriate scientific knowledge and transforming it. Design has a central place in engineering problem solving, but this is not the case in science. Gunstone (1994) examined technology education and science education by discussing engineering as a case study of relationships. He argued that engineering is a unique way of knowing, different from science and not equivalent to technology.

Solutions to engineering problems involve contextually bound issues as Goldman (1990) explains.

> The objects of engineering reasoning are far more complex than the objects of scientific reasoning; the former, unlike the latter, never lose their particularity and are <u>explicitly</u> inseparable from the intentional, contingent, willful, and value-laden contexts of their formulation. (Goldman 1990, p. 129)

Solomon (1993, p. 9) contrasts science and technology in the following way.

Science is concerned with	Technology is concerned with
Identifying questions.	Identifying needs.
Explaining and predicting.	Producing successful products.
Discovering.	Inventing.
Theorizing about causes.	Theorizing about processes.
Analyzing.	Designing.
Making distinctions between concepts and isolating phenomena by controlling variables in experiments.	Bringing many different factors to bear on complex design problems.
Searching for causes.	Searching for solutions.
Research for its own sake.	Research for practical purposes.
Pursuit of accuracy.	Pursuit of only as much accuracy as is necessary for success.
Reaching correct solutions based on accurate data.	Reaching good decisions based on available data.

Technology in the curriculum

The creation of a new subject inevitably raises a number of issues. These include the need for interested groups with some stake in the curriculum, around which practice can be built and support provided for teaching and curriculum development. The other issue, which involves the status of the subject and its legitimacy within a system that requires a coherent assessment program, is the development of an agreement about the fundamental purpose and nature of the subject (Layton 1994). In the search for fundamentals, technology is laying claim to greater academic weight than would be accorded to that collection of skills which was the central feature of the craft subjects that were in many respects the forerunners of technology. Another argument for

focusing on generalisable knowledge that has been a feature of arguments for a technology curriculum, has related to the need for citizens to have knowledge and skills that will provide them with the flexibility to contribute in a society that is increasingly marked by rapid technological change. Particular skills outlive their usefulness very quickly in such an environment. Even outside a workplace situation, the prospect of developing in students a transferable technological capability is an attractive prospect.

With the emergence of technology as a new curriculum area on the international scene, the particular form the subject has taken has varied considerably from country to country, depending on particular histories and other circumstances that have led up to its introduction. In the context of the Western European situation, de Vries (1994) developed a taxonomy of approaches to technology curricula that identified eight different possible approaches to technology education. These approaches are the craft-oriented approach, industrial production-oriented approach, high-tech approach, applied science approach, general technological concepts approach, design approach, key competencies approach, and the Science/Technology/Society (STS) approach. Each approach fosters a particular view of technology.

Approach to Technology Education	Concept of Technology students will acquire
Craft-oriented approach.	technology is a way of making things.
Industrial production-orientation approach	technology is product oriented.
High-tech approach	technology is very product-oriented.
Applied science approach	technology is a cognitive activity that depends on science.
General technological concepts approach	technology is a cognitive, analytical activity.
Design approach	technology involves creativity, designing skills and making skills.
Key competencies approach	technology has innovation as a key issue.
Science/Technology/Society (STS)	technology is broad, includes human/social and scientific aspects, and downplays role of design.

For some time now, particularly since Australia has closely followed developments in the UK, the emphasis on design has been an essential part of Australian technology curricula. With an autonomous education system in each state, there was bound to be differences in the way technology curricula were framed. The development of an Australian Technology Statement and Profile provided an overarching commonality (to a certain extent) for the introduction of a Technology Key Learning Area. However, particularly in the upper secondary school level, the relationship of the technology subjects with certification courses and vocational education has been quite varied across the states (Gardner, Penna & Brass 1996).

Science and technology in the curriculum

The issue of the relationship between science and technology in the curriculum is linked to the historical and 'real world' relationship, but has its own dimensions. How science and technology relate to each other in the curriculum has a lot to do with the politics of

school subjects and the realities of school organization, and not just the relationship between science and technology as ways of thinking and acting. Science may have argued its place in the school curriculum on the basis of technological advances that do not necessarily owe their existence to science, and has adopted a very formal view of knowledge in response to pressures from academics. However, science and technology are closely linked in many contexts, and the curriculum should reflect this situation. Curricula should also reflect the complexity of the relationship between technology and science. Science curricula need to retain technological thinking and purposes within the Key Learning Area if they are to truly represent the nature of science as it is practiced, just as technology curricula need to acknowledge the importance of science knowledge and processes. How the two curriculum areas relate will be different for primary and secondary schools. In secondary schools the subjects are necessarily demarcated to a larger extent. The organization of curriculum in primary schools provides the flexibility to explore the different ways in which science and technology can interact.

The challenge for Science Education

Roth (1998) defines the field of science education as being concerned with understanding the learning and teaching of science. Technology has posed a serious challenge for science educators that led to considerable activity in the literature, and in schools, during the 1990s. Until recently, science occupied a position of comfortable dominance in which it was assumed that science knowledge was the engine that drove both the industrial and technological revolution by providing the core intellectual content that was then applied by technologists as artisans. This view had implications for the status of science within the curriculum, and the reputation and funding of scientists and their research. The opposing view is that in most respects technology is prior to science in generating innovations, and indeed in an important sense is ontologically prior in defining the cultural and intellectual framework that underpins the science program. Layton (1993) uses the metaphor of 'science as cathedral, or quarry, or company store' to draw attention to the competing notions of science as a self-contained and impressive edifice, compared to a resource ('a charwoman serving technological progress'; Smolimowski 1996, p. 373) for the use of technology studies. A reasonable perspective would have it that science education must serve both functions, but the questions What is the main priority? How is the curriculum to be structured to do this effectively? are important questions that will occupy the minds of science educators over the next decade. Some time ago Fensham (1990) highlighted the difficulties that science as a curriculum area faces with technology established as a separate curriculum area. The difficulties he identified are still with us.

In many respects science is seen as being in competition with technology. With the subject still in its infancy, some technology educators tend to distance themselves from science as they struggle to carve out a unique place for the subject within the curriculum. While this is understandable, and probably necessary, too severe a de-linking of the two areas does a grave injustice to the way they relate historically and philosophically, and to

possibilities for fruitful interaction within the curriculum. Many science educators have been important advocates of the new technology subject, and have played key roles in defining the area in the UK, in New Zealand, in Australia and elsewhere. In primary schools there are many opportunities for a fruitful linking of the two areas, and in secondary schools there are an increasing number of interesting models being developed that explore the relationship within the curriculum. With the growth of the science and technology studies movement it has become evident that there is potential for interdisciplinary work between the two domains science and technology studies and science education. Roth (1989, p. 5) identifies: "At this time, there appears to exist only few in either science education or science and technology studies interested to straddle the boundaries in their work" and he hopes that more collaborations will occur between members of the both sides.

Earlier in this paper we foreshadowed the necessity for a reconstruction of the nature of school science. One reason for such a change is the shift away from the traditional view of science that regards the universe as a machine ruled by linear cause and effect, to a systems view that emphasizes integration, context and relationships (Capra 1996; Jane 2001; Hogan 2002). Consistent with this view, science in schools could be taught in a contextual way integrating with technology. How might technology educators respond to such close links with science? Jones (1997) highlights the influence subject sub-cultures have on students' expectations of classroom practice. His New Zealand studies show that when technological problems are solved in science classrooms the students played by the 'rules' of the science classroom and focused on the collecting of information to present to the class. The wider social issues were often not explored by students because they did not perceive these to be relevant to their science understandings.

The challenge for Technology Education

One difficulty facing technology education is the varied perceptions of the nature of technology. Many pre-service teachers continue to associate technology with recent high tech products such as computers, microwave ovens, lasers (Fleer & Jane 1999). Recent research studies by science educators recognize the need to teach the nature of science in schools (Jane 2002; Schwartz & Lederman 2002). Is there a similar push by technology educators to teach about the nature of technology? The USA *Standards for Technological Literacy: Content for the Study of Technology* devotes a whole chapter to The Nature of Technology (Dugger 2000). We argue that the nature of science should be included in all primary teacher education programs, together with opportunities for students to engage in authentic technological tasks that help to develop an understanding of technological concepts. Links with science can be fruitful, and indeed are essential, in certain areas such as materials testing and machines. However the differences between science and technology should be made explicit. If technology educators choose not to work with the science education profession they will fail to capitalize on the benefits that can be gained by linking science and technology in mutually supportive ways. For primary school teachers confronted with an overcrowded curriculum (with an emphasis on numeracy

and literacy programs), planning units of work that link science with technology can be productive. When teachers set technological tasks and make the links with other curriculum areas this practice can foster connected learning. Authentic tasks, often devised by students as they recognize a need or a problem to be solved, can encourage students to view technology as a real life enterprise. Anne Marie Hill (1997, p. 137) argues for reconstructionism (attending to the action that realizes the invention) "with its holistic approach, allows for connections between the humanities, the sciences and technology". She also reminds us that it is important to include values and environmental concerns when students design and create products.

Bencze (2001) argues very strongly against the status quo for science and technology, and calls for 'technoscience' education, a combined technology and science program that would treat technology and science as equals. Such a framework (developed by science teachers engaged in collaborative action research) is inclusive, explicit, authentic, contextual, personal, problem-focused and involves apprenticeship. However, there are two possible limitations associated with this program. Firstly, the differences between science and technology may be blurred. Secondly as the status of science is generally perceived to be higher than technology, technology may be consumed under the science banner. The question becomes should the technology education profession be lobbying for technology education to become a science subject on par with biology, chemistry, earth science, and physics? We contend that the notion of technology coming under the science education umbrella would be a backward step and is an idea that should be resisted. Such an amalgamation could result in a loss for technology education, because it may be difficult to argue a place for woodwork and food technology in a science program. In this paper we have argued for technology as a subject in its own right because technology has a different way of thinking, involves a different process and philosophy. If technology education became amalgamated with science education this would result in less flexibility, and that runs against the trends happening in the Australian State of Victoria. The Victorian Certificate of Applied Learning (VCAL) is providing flexible and challenging options for students in years 11 and 12. Technology should be taking the initiative to feed into these programs and it cannot do so if it is under the umbrella of science.

Ways forward for technology education and science education

Can science education and technology education co-exist in a school's curriculum? In this section we put forward several different approaches to implementing technology education and science education in the classroom. Firstly, John Williams (1997) examined a collaborative problem-based learning (PBL) approach to teaching technology in teacher education. He concluded that PBL was appropriate to achieve the goals for technology education and should be one of several methodologies made available in technology education. This approach may or may not include science.

Secondly, reform efforts in science education have led to a project-based science

(PBS) approach being implemented in classrooms. PBS involves extensive use of student-directed scientific inquiry supported by technology and collaboration. The performance of students in classrooms using PBS has been monitored and the findings show that these students outscored the national sample (Schneider, Krajcik, Marx & Soloway 2002). The study recommends that educators should endeavor to use PBS to implement reform in school science. In PBS the questions students investigate relate to their community or their own lives. PBS involves design activities that help students understand important science concepts. Students investigate a real-life question or problem that drives activities and organizes concepts and principles. Students use cognitive skills to develop a series of artifacts in response to the question/problem through collaboration with students, teachers and community members. Although students design and produce artifacts, the investigation focus aligns this approach strongly with science and not technology.

Thirdly, for several years a community project approach (CPA) has been successfully implemented in Primary Technology Education, a core unit in a primary teacher education course in Victoria. This approach encourages students to identify needs or problems that are relevant to people in their local community. In CPA the students write their own design briefs and use their design drawings as a basis for communication with their clients. Students engage in interviews, investigations, and the testing and purchasing of materials. On a need-to-know basis they learn to use tools and equipment safely. There is on going dialogue with the client as the product is being devised and produced. An important feature of the CPA is the student and client evaluation of the product in terms of its durability, appearance and effectiveness. Students incorporate a range of Information Communication Technologies (ICTs) when they present their product to their peers. Many students tell their 'CPA stories' by preparing PowerPoint presentations on CDs which incorporate digital photographs and music, while others show videos of themselves interviewing clients and making the products. Many students use recycled materials to minimize the cost, but also for ecological reasons. Although students were not required to illuminate the science concepts underpinning their products, their science understandings were often revealed in their narratives (Jane 2002).

These three approaches (PBL, PBS and CPA) are different ways to incorporate technology in the curriculum that are not isolated one-off technological tasks which are often set in science classes. By embedding the design task within a framework of helping people in their community to make a better world, brings in the important value component that is frequently missing from technology curricula. When technology education is recognized as a real-life enterprise the technological process can be the organizing process that integrates other subject areas such as science.

Conclusion

As a technology educator and science educator we are interested in examining the boundaries between science education and technology education from both sides. In this paper we began by exploring the historical relationship between technology and science,

and then investigated ways of linking the two areas fruitfully in the school curriculum. We argued against placing technology education under the umbrella of science on the grounds that the two areas are unique ways of knowing and have different processes and content. We strongly contend that technology education and science education can be implemented in the curricula in mutually supportive ways.

References

Aikenhead, G. 1985. 'Collective decision making in the social context of science'. *Science Education* vol. 69, no. 4, 453-475.

Bencze, J. L. 2001. Technoscience education: Empowering citizens against the tyranny of school science. *International Journal of Technology and Design Education*, vol.11, no. 3, 273-298.

Bybee, R. 1985. The restoration of confidence in science and technology education. *School Science and Mathematics* vol. 85, no. 2, 95-108.

Capra, F. 1996. *The web of life: A new scientific understanding of living systems*. New York: Anchor.

Cross, R. 1990. Science, technology and society: Social responsibility versus technological imperatives, *The Australian Science Teachers Journal,* vol. 36 no. 3, 33-38.

Cross, R. & Price, R. 1992. *Teaching science for social responsibility*. Sydney: St Louis Press.

de Vries, M. 1994. Technology education in Western Europe. In D. Layton (Ed.), *Innovations in science and technology education, vol. V*. (pp. 31-44). France: UNESCO.

Dugger, W. 2000. Standards for Technological Literacy: Content for the Study of Technology at the Elementary School, *Technology and Children*. pp. 6-9.

Fensham, P. 1990. What will science education do about technology? *Australian Science Teachers' Journal*, vol. 36, no. 3, 8-21.

Fensham, P. J., & Gardner, P. L. 1994. Technology education and science education: A new relationship? In D. Layton (Ed.), *Innovations in science and technology education*, vol. 5 (pp. 159-170). Paris: UNESCO.

Fleer, M. & Jane, B. 1999. *Technology for children developing your own approach*. Sydney: Prentice Hall.

Gardner, P. 1994. Representations of the relationship between science and technology in the curriculum. *Studies in Science Education*, vol. 24, 1-28.

Gardner, P. Penna, C. & Brass, K. 1996. In P. Fensham (Ed.), Science and technology in the post compulsory years. In P. Fensham (Ed.), *Science and technology education in the post-compulsory years* (pp. 140-192). Melbourne: ACER.

Goldman, S. L. 1990. Philosophy, engineering, and western culture. In P. T. Durbin (Ed.), *Broad and narrow interpretations of philosophy of technology*. Dordrecht, Netherlands: Kluwer.

Gunstone, R. 1994. Technology education and science education: Engineering as a case study of relationships. *Research in Science Education,* vol. 24, 129-136.

Hart, E. & Robottom, I. 1990. The Science-Technology-Society Movement in Science Education: A Critique of the Reform Process. *Journal of Research in Science Teaching* vol. 27, no. 6, 575-588.

Hill, A. M. 1997. Reconstructionism in technology education. *International Journal of Technology and Design Education*, vol.7, nos. 1-2, 121-139.

Hogan, K. 2002. Small groups'ecological reasoning while making an environmental management decision. *Journal of Research in Science Teaching*, vol. 39, no 4, 341-368.

Hurd, P. 1986. Perspectives for the reform of science education. *Phi Delta Kappan* vol. 67, no. 5, 353-358.

Ihde, D. 1983. *Existential technics*. Albany, USA: New York Press.

Jane, B. 2001. Accessing spirituality and sustainability: Letting go of a western science world view. In Gunn & Begg (Eds.), *Mind, Body and Society emerging understandings of knowing and learning* (pp. 21-28). Melbourne: The University of Melbourne.

Jane, B. 2002. The evolution/creation science controversy: educate rather than debate. *Proceedings of the 10th IOSTE Symposium* pp. 48-53. Brazil, July.

Jane, B. (2002). *Narratives in technology*. Paper presented at the 2nd Biennial International Conference on Technology Education Research, Queensland, December.

Jobling, W. M. & Jane, B. L., 1996. Exploring science-technology relationships from the classroom perspective. *Australian Science Teachers' Journal*, vol. 42, no. 2, 37-39.

Jones, A. 1997. Recent research in student learning of technological concepts and processes. *International Journal of Technology and Design Education*, vol.7, nos. 1-2, 83-96.

Layton, D. 1973. Science for the people. London: Allen & Unwin.

Layton, D. 1988. Revaluing the T in STS. *International Journal of Science Education,* vol. 10, no. 4, 367-378.

Layton, D. 1991. Science education and praxis: the relationship of school science to practical action. *Studies in Science Education,* vol. 19, 43-79.

Layton, D. 1993. Science as a resource for technological capability. In D. Layton, *Technology's challenge to science education* (pp. 41-55). Buckingham: Open University Press.

Layton, D. 1994. A school subject in the making? The search for fundamentals. In D. Layton (Ed.), *Innovations in science and technology education,* vol. V. (pp. 11-28). France: UNESCO.

Lewis, T., & Gagel, C. 1992. Technological literacy: a critical analysis. *Journal of Curriculum Studies,* vol. 24, no. 2, 117-138.

McFadden, C. 1991. Towards an STS school curriculum. *Science Education* vol. 75, no. 4, 457-469.

Rahme, J. 2002. Emergent leaning opportunities in an inner-city youth gardening program. *Journal of Research in Science Teaching* vol. 39, no.2, 164-184.

Rennie, L. J. 1987. Teachers' and pupils' perceptions of technology and the implications for curriculum. *Research in Science and Technology Education*, vol. 5, no. 2, 121-133.

Resnick, L., Levine, J. and Teasley, S. (Eds.), 1991. *Perspectives on Socially Shared Cognition,* Washington: American Psychological Association.

Rogoff, B. and Lave, J. (Eds.), 1984. *Everyday cognition: its development in social context,* Harvard University Press, Cambridge, MA.

Roth, W-M. 1998. Science and technology studies and science education: A natural mismatch? *Research in Science Education*, vol. 28, no.1, 1-7.

Schneider, R., Krajcik, J., Marx, R. & Soloway, E. 2002. Performance of students in project-based science classrooms on a national measure of science achievement. *Journal of Research in Science Teaching*, vol. 39, no. 5, 410-422.

Schwartz, R. S. & Lederman, N. G. 2002. "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching*, vol. 39, no. 3. 205-236.

Smolimowski, H. 1966. The structure of thinking in technology. *Technology and Culture*, vol. 7, 371-383.

Solomon, M. 1993. *LIFT OFF to Science and Technology*, Carlton: Curriculum Corporation.

Williams, J. 1997. Problem-based learning: An appropriate methodology for technology education. *Research in Science & Technological Education*, vol.15, no. 1, 91-104.

Yager, R. & Penick, J. 1984. What students say about science teaching and science teachers. *Science Education* vol. 68, no. 2, 143-152.

Ziman, J. 1980. *Teaching and learning about science and society*. Cambridge: Cambridge University Press.