

Reassessing the Role of Literacy in Technology Education

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It was December 22, 1938; a hot and humid morning. Marjorie Courtenay-Latimer, curator at the East London Museum, gazed at the beautiful, mauvy blue fish lying among the catch on the deck of Captain Goosen's fishing boat. Five feet long, with four limb-like fins and covered with hard scales; she had never seen anything like it. She knew it was valuable and was determined to preserve it until it could be identified. She took it first to the mortuary, but was refused entry – "What would people say?" said the man in charge. She tried the town's cold storage facility, but again the manager refused to have anything to do with her "stinking fish". These being the only refrigerated facilities in town large enough to hold the fish, Marjorie went to Mr Center, a taxidermist friend, and together they wrapped the coelacanth, for that is what it was, in newspapers soaked in the small amount of formalin she managed to find, and a bed sheet. Marjorie wrote to Dr J. L. B. Smith, then an amateur ichthyologist, but failed to hear from him. After five days, the fish had deteriorated to such an extent that in order to save anything at all, Marjorie had Mr Center remove the strange white flesh from the hard skin and later, dispose of the rotten insides when they had still not had any word from Dr Smith. It was thirteen days before Marjorie heard from him, urging her to preserve the viscera, but it was too late. Dr Smith devoted his life to the coelacanth, a "fossil fish" thought to have been extinct for 70 million years, but it was 14 years before another was found and a full scientific study begun.¹

This local story demonstrates the inter-relationship between science, technology and society that is central to my theme. Clearly, Marjorie Courtenay-Latimer had to save the fish for scientific study because she recognised its rarity, even suspecting (correctly) that it was a ganoid fish, thought to be extinct for 10s of millions of years, yet she was beaten by societal conventions that would not allow the fish to be refrigerated with bodies at the mortuary or food at the freezer. There was no ice, and insufficient formalin for preservation, so the technological means for preserving the fish were not available. Although no-one would have teased out the relationship at the time, nor probably since, this story illustrates the seamless interaction between science, technology and society in real life. This seamlessness is in stark contrast to the way these things are dealt with in most school curricula, and for that matter, most tertiary curricula as well. For example, in places as far apart as England (Mayoh & Knutton, 1997) and Namibia (Kasanda, !Gaoseb, Kandjeo-Marenga, Kapenda, & Lubben, 2001), researchers observed science lessons and noted that out-of-school experiences were mentioned, on average, only once or twice a lesson, and that teachers rarely built on experiences volunteered by students.

In this presentation I will look at the way science, technology and society are tackled in schools and argue the importance of trying harder to make links between them. My title is an expression of my growing belief about how little of what happens in school seems to prepare our students to be technologically and scientifically literate in ways that are valued by the community. My purpose is not to review technology education, other people have done that better than I can (see, for example, Donnelly [1992], Lewis [1991], and Medway [1989]), nor to review current happenings in what is still, essentially, a new curriculum area. Rather, I will

¹ This account is based on Weinberg, S. (1999). *A fish caught in time: The search for the coelacanth*. London: Fourth Estate.

explore briefly the relationship between science and technology and, drawing on two recent reports as a framework, look at how science and technology might be juxtaposed more effectively in the normal course of schooling in order to promote technological literacy.

SCIENTIFIC AND TECHNOLOGICAL LITERACY

In terms of the individual person, the general goal of scientific and technological literacy is the same as any other literacy, in reading, writing or using numbers, for example. It is "to provide people with the tools to participate intelligently and thoughtfully in the world around them" (Pearson & Young, 2002, p. 3).

From a different perspective, it is worth pointing out that both scientific literacy and technological literacy are slogans and not prescriptions for action (Jenkins, 1997). Thus, Jenkins posits that they are "something of a rallying cry for key ideas, serving as a convenient means for generating political, educational, social or financial support without the convenience of explaining the meaning of the terms involved" (p. 29). Interestingly, Jenkins argues that it is just this "imprecision and ambiguity of slogans which allow them to play a significant role in bringing about change" (pp. 29-30).

Jenkins makes three other points that are relevant here. First, scientific and technological literacy have had various interpretations over time, reflecting different rationales and they are context dependent. It is important to emphasise to this multicultural audience that different people at different times and in different places have need for different kinds of scientific and technological literacy. Second, scientific and technological literacy are commonly coupled together, as I am doing now, despite the clear distinctions that can be made between science and technology as fields of endeavour. Jenkins himself has written on this, and see also Gardner's work (Gardner, 1994b, 1995). One of the reasons for this is that science and technology are invariably conflated in the mind of the community and the media, possibly the greatest source of information to the general community, both conflates and confuses them. This leads to Jenkins' third point: Schools and other formal educational institutions do not have exclusive responsibility for promoting scientific and technological literacy. There is an enormous range of other avenues for learning about science and technology and, for the majority of the population who have left formal education, these avenues – including the media, but also museums and similar institutions, respected community members or elders, and religions – have (sometimes conflicting) roles to play.

Not surprisingly, in view of the above, scientific and technological literacy have a variety of meanings. It is beyond the scope of this paper to review those meanings or the rationales behind them, but it must be noted that for each term there is little more than a broad consensus for its meaning. Different stakeholders in different contexts have different perspectives and these may change over time. For example, Gagel's (1997) extensive text analysis in his attempt to derive the epistemology of technological literacy merely elucidated the complexities of its definition. Significantly, he concluded that "as long as humans continue to practice technology, what it takes to be considered to be technologically literate will change" (p. 27). Sometime earlier, Ost (1985) had underlined the centrality of change in his thinking about technological literacy in the context of science and mathematics education. He emphasised that knowledge and databases will constantly change, so the skills to access information using ICT have to be coupled with an appreciation of the tentative nature of any solution to a current problem.

Undeterred by the difficulties of definition and having acknowledged the unlikelihood of consensus, I will be bold enough to offer definitions for both scientific literacy and technological literacy in order to provide a context for the subsequent discussion. I will deal first with scientific literacy because this concept was established earlier than technological literacy. In each case I have tried to operationalise (albeit at a rather abstract level) what the scientifically or technologically literate person might be like in a way that gives direction to the school curriculum.

SCIENTIFIC LITERACY

Scientifically literate people are interested in and understand the world around them; engage in the discourses of and about science; are sceptical and questioning of claims made by others about scientific matters; are able to identify questions, investigate and draw evidence-based conclusions; and make informed decisions about the environment and their own health and well-being.

This definition is based on one developed in a report commissioned by the Australian Government entitled *The Status and Quality of Teaching and Learning of Science in Australian Schools* (Goodrum, Hackling, & Rennie, 2001). This report was based on the premise that the purpose of science education was to develop scientific literacy; however, the report concluded that the current nature of schooling, especially at the secondary level, was unlikely to achieve that goal because of curriculum emphasis on content coverage and failure to present science as interesting and relevant to students. One of the report's recommendations was the need to "promote the importance of science education in schools, particularly its fundamental importance in developing scientific literacy" (Goodrum et al., 2001, p. 170). This recommendation has resulted in a series of school-community projects aimed at increasing science awareness and I will return to these later.

TECHNOLOGICAL LITERACY

Because it suits my purpose, I have chosen to offer a definition, or a statement, about technological literacy that has a similar structure to that for scientific literacy. It doesn't have the extensive review given in developing the Goodrum et al. (2001) definition, but in suggesting it, I have drawn heavily from the literature, especially Pearson and Young (2002), Black and Harrison (1985, although they do not mention literacy, their analysis remains seminal), Jenkins (1994), Gardner, Penna and Brass (1990), Rennie (1988) and the curricula from a number of countries, including South Africa (Potgieter, 1999).

Technologically literate people understand the designed world, its artefacts, systems and the infrastructure to maintain them; have practical skills in using artefacts and fixing simple technical problems; are able to identify practical problems, design and test solutions; recognise risks and weigh costs and benefits associated with new technologies; can evaluate, select and safely use products appropriate to their needs; and contribute to decision-making about the development and use of technology in environmental and social contexts.

LINKS BETWEEN SCIENTIFIC AND TECHNOLOGICAL LITERACIES

Trends in Technology Education

The concept of technological literacy found its way into the US science curriculum via the publication of *Science for All Americans* (American Association for the Advancement of Science [AAAS], 1989). In an issue of the *Journal of Research in Science Teaching* entitled "The Interdependence of Science and Technology", Cajas (2001) explains how three sets of standards, *Benchmarks for Scientific Literacy* (AAAS, 1993), *National Science Education Standards* (National Research Council, 1996) and *Standards for Technological Literacy* (International Technology Education Association [ITEA], 2000), "have spelled out a common set of ideas and skills that form the core of literacy in technology ... a common ground for science and technology and make a case for rethinking the role of technology in general education" (p. 719). The articles in the special issue refer to learning science through technology, and all but one refer to design technology. The inclusion of technological literacy as part of scientific literacy is also explicit in the framework Bybee (an architect of the NSES) provides for multidimensional scientific literacy (1987, pp. 84-85) which "presents scientific and technological literacy as a continuum on which an individual develops greater and more sophisticated understanding of science and technology" (p. 84).

Besides its existence in the US curriculum as a context for science, technology has long been present in vocational education, and from the 1980s there were increasingly louder calls in the US that technology education as design technology should have its own place in the K-12 curriculum (Lewis, 1991, Raizen, Sellwood, Todd, & Vickers, 1995). This was in line with the development of technology with a focus on design, not science, in the United Kingdom, Europe and other places in the Western world where technology had become, or was becoming, a subject in its own right. The recent report from the National Academy of Engineering and the National Research Council, *Technically Speaking* (Pearson & Young, 2002), grew from the view that "the concept of technological literacy is poorly understood and significantly under-valued" (p. vii). While recognising the "science and technology are tightly coupled" (p. 13), the report draws more attention to technology's links with engineering and defines technological literacy in terms of "an understanding of the nature and history of technology, a basic hands-on capability related to technology, and an ability to think critically about technological development" (pp. 11-12). In this definition, technological literacy can stand beside scientific literacy rather than under its umbrella.

The last two decades of curriculum change in England and Wales have seen the development of technology as a separate component of the National Curriculum as Design and Technology. It has struggled somewhat, as a new subject built on practice rather than theory (Kimball, Stables, & Green, 1996), but by the mid 1990s was pronounced successful (Kimball et al., 1996). In what seems to me to be a contrast to the developments in the US, a recent report from the UK prepared for the Engineering Council and the Engineering Employers' Federation (Barlex & Pitt, 2000) has called for closer links between science and design and technology in the secondary school curriculum. The authors noted that while these subjects are separate in the schools, they are seen to be intimately connected in the mind of the public. While recognising their unique and distinguishing features, Barlex and Pitt (2000) urge closer ties between science and technology in terms of the development of pupils' metacognitive skills and for science to reinforce decisions in technology, and for technology to reinforce learning in science.

Relationships between Science and Technology

The links between science and technology have been thoroughly explored (see for example, Gardner, 1994a, 1994b, 1995), and Barlex and Pitt (2000) draw attention to Gardner's (1994a) summary which presents four kinds of relationships between science and technology in school curricula.

First, there is the **technology as applied science** (or TAS) view, that is, science is historically and ontologically prior to technology. For example, physicists were studying the phenomenon of light amplification by the stimulated emission of radiation (laser) long before it was used in any practical applications. Lasers are now fundamental to the use of fibre optics, CDs, laser cutters, and so on, even stitching detached retinas back into place in the eye. While there are many examples where the science clearly preceded the technology, it is very easy to think of examples where it did not. In fact the TAS view is easily discredited (see Gardner, 1995); but one only has to open any standard school physics text to find that this view is alive and well. It is described by Bybee (2000) as "archaic and mostly erroneous" (p. 23) but its pervasiveness reinforces the higher status attributed to science compared to technology.

Second, there is the **materialist** view that places technology historically and ontologically prior to science. My favourite example here is the fashioning of stone tools, where the tool-maker exploited properties of the stone without any knowledge of the crystalline structure which determines them. It is easy to offer both examples and counter-examples to the materialist view, but there can be little argument that today, technology is shaping our ways of thinking to a much greater extent than science.

Third, the **demarcationist** view holds that science and technology are different, in terms of their goals, methods and in the social groups who carry them out. I find this view rather contrived, but nevertheless, certainly in England and Australia, and other countries too, this is the curriculum in practice in most secondary schools. Barlex and Pitt (2002) draw attention to this enforced separation in the National Curriculum Orders.

Fourth, the **interactionist** view posits that science and technology engage in mutually beneficial, two-way interaction, and that scientists and technologists learn from each other. An example here concerns gramophone records. The first recordings were found to sound best when recorded and played at between 70 and 90 rpm. This speed was a compromise between maximising the amount of information that could be recorded on the record and the quality of the sound that could be reproduced. When electric recording techniques were introduced in the mid 1920s, the speed of turntables was linked to the 60Hz AC electricity used in the US; 60 Hz is 3600 cycles per minute. Using simple gear ratios, the speeds of 78 (actually 78.26) rpm, and the later speeds of $33\frac{1}{3}$, and 45 rpm could all be derived from the 60Hz AC. This dynamic interplay between science and technology as data storage improves has brought us to laser-read DVD recordings. The interactionist relationship might be seen to be the most profitable for learning in both science and technology, yet it is the one least likely to be found in secondary classrooms.

Clearly, each of these four views of the relationship between science and technology has some currency, but in the context of a balanced curriculum, and from a position that refuses to privilege the academic over the practical, the fourth, interactionist view is my preference.

Barlex and Pitt (2000) used these four positions to interview educators in science and design and technology about both subject areas. They found that science educators had coherent views about the aims of science education in schools, and design and technology educators had coherent views about the aims of design and technology, but these people had a variety of views and considerable uncertainty and misunderstanding about the aims of the other subject. I have no doubt that I would find the same if I were to interview educators in Western Australia. (In fact, I did examine science teachers' ideas about technology some years ago [Rennie, 1987] and found that most of them regarded technology as applied science.) Barlex and Pitt concluded that "if there is to be a useful relationship between science and design and technology in secondary schools a first necessary step will be to find ways by which the two communities can begin to understand one another" (p. 25). But there was some agreement between these experts. Both groups saw the relationship between science and technology in academia and industry as variable but dynamic, and in schools as demarcationist, and most were in favour of moving towards the interactionist position.

But how might this be done? Barlex and Pitt (2000) are under no illusion as to the difficulties involved but they argue for a closer relationship for four reasons (pp. 32-41). First, students need to be reflective about their own practice in both science and design and technology. This reflection is built into design and technology through appraising what one has designed or made, but often in science there is little concrete to be reflective about (especially with cookbook experiments). Design and technology can help by providing a means for active reflection. Second, both science and design and technology require students to model mental ideas – a challenge to most students that demands frequent opportunities to practice, such as in designing artefacts or explaining phenomena. A consistent approach across both subjects would enable students to progress in their metacognitive and mental modelling skills. Third, students can use the knowledge acquired in science to justify the decisions they make in design and technology. Fourth, the use of technological contexts to develop understanding for concepts provides relevance for science content. In both subjects, the use of common language and analogies, and taking opportunities to link the concepts and contexts at an appropriate level of detail could build a relationship between science and technology that is mutually reinforcing.

I am happy to concur with Barlex and Pitt (2000) in their argument, but I believe there is an even stronger reason for better links between science and technology, and that is, it is more reflective of life outside of school. Barlex and Pitt paid little attention to the social, ethical and value aspects of science and technology in their analysis, although neither science and technology nor science education and technology education can be considered value-free (Layton, 1988). Students spend a great deal more time out of school than in it, and only some of school time deals explicitly with science and technology. It makes little sense to me to teach in ways that discourage links with how the human world really works.

But back to Barlex and Pitt (2000), who identified three models for an interactionist relationship between science and design and technology – coordination, collaboration, and integration. By integration, Barlex and Pitt mean combining the two subjects into one and they consider this not only inappropriate, but "illogical and highly dangerous to the education of pupils" (p. 43). The two subjects are different but necessary, and design and technology in particular, they argue, must not be impoverished by subsumption. This leaves the coordination model, where the timing of topics allows common development of concepts and understanding, and the collaboration model, an extension of coordination so that some activities make explicit links between the subjects to reinforce learning in both.

DEVELOPING SCIENTIFIC AND TECHNOLOGICAL LITERACY IN SCHOOLS

In the remainder of this presentation I will give two examples of technology education which I believe promoted technological literacy and also scientific literacy. Both involve Year 9 students, but where one exemplifies collaboration between science and technology (and in this case, mathematics) teachers, the other example involves one teacher's science project that, perhaps accidentally, became a very powerful technology project. But before I present those stories, I want to re-emphasise the essential differences between science and technology and what it means to be scientifically and technologically literate.

Science and technology differ in terms of their purpose – “the scientist's aim of generating new knowledge and theoretical understanding and the technologist's aim of producing and improving artefacts, systems and procedures to meet human needs and desires” (Gardner, 1994a, p. 4). They also have different criteria for success, better theories (simpler, greater explanatory power, etc.) in science and better products (more durable, reliable, efficient, etc.) in technology (Gardner, 1994b). Further, one might argue that the successful scientist publishes and the successful technologist patents (Layton, 1988).

Despite these differences in the nature of the disciplines and the purposes of their practitioners, however, there are undeniable parallels that facilitate the relationship between scientific literacy and technological literacy. To demonstrate this, the definitions I presented earlier have been rearranged into Figure 1 using the three dimensions articulated by Pearson and Young (2002): knowledge, capability, and ways of thinking and acting. I feel justified in thinking about capability in science as well as technology because it has been done well before me (see Black & Harrison, 1985; Fensham, 1990).

Figure 1:
Parallels between scientific and technological literacy.

Dimension	Scientifically Literate Persons	Technologically Literate Persons
Knowledge	Are interested in and understand the world around them	Understand the designed world, artefacts, systems, infrastructure
Capability	Engage in discourses of and about science	Have practical hands-on skills and fix simple technical problems
	Are able to identify questions, investigate and draw evidence-based conclusions	Identify practical problems, design and test solutions and evaluate results
Ways of thinking and acting	Are sceptical and questioning of claims made by others	Recognise risks, weighs costs and benefits
	Make informed decisions about the environment and their own health and well-being	Evaluate, select and safely use products appropriate to their needs Contribute to decision-making about the development and use of technology

THE SOLAR-POWERED BOAT PROJECT

Academically talented Year 9 students at a high school in Perth, Western Australia were given the task of constructing a solar-powered boat as the focus of a three-month course in technology, science and mathematics. Three subject teachers each taught the appropriate background concepts and skills in a synchronised way in what they described as an integrated curriculum, but in Barlex and Pitt's (2000) terms it was collaborative, as the subjects remained separate but coordinated. My colleagues and I have described the details of the project elsewhere (Venville, Wallace, Rennie & Malone, 2000) so I won't give further background here. Recently, we have been reviewing the data to explore how students selected and used knowledge from different sources in making key decisions during the construction of their boat (Rennie, Venville, Wallace, & Malone, 2002), and I will use one of those decisions to look at the development of technological literacy and scientific literacy.

Essentially, each boat comprised a hull on which was mounted solar cells and a small electric motor to propel the boat. Most students used a winch to wind up fishing line attached to the destination that also served to steer the boat. My story focuses on the decisions students made about constructing the electric circuit because it most clearly shows the relationship between the science and technology. In lessons from the science teacher students learned about series and parallel circuits, Ohm's Law, and the relationships $V=RI$, $P=VI$, $P=W/t$ and $W=Fs$. They built and tested their circuits using a multi-meter on both sunny and cloudy days. The teacher reminded students that when unloaded, the motor would spin at 10,000 rpm, but more like 2,000-3,000 rpm when loaded, and that with a low current the motor would not work. Also, the motor operated at between 1.5 V and 3 V and the maximum current they could use was 2,000 mA.

Figure 2 shows the ways the three pairs of students who were the focus of our case studies used the science concepts at their disposal, together with other sources of knowledge, including the teacher, other students in the class and outsiders. From the science concept $P=VI$ the students could see that to get maximum power output they needed high voltage (favoured by a series circuit) and high current (favoured by a parallel circuit), so there was a trade-off to begin with in designing the circuit. There was resistance within the circuit that would vary according to its construction, and this could not be predicted easily. Further, the resistance of the motor varied according to load, and the load (the force needed to pull the boat through the water) was dependent in large part on the nature of the hull and unable to be calculated. In short, a great deal of trial and error testing had to be done to get a circuit that worked. Figure 2 shows that all of the students began with a circuit based on science "thinking" but none was effective. Kevin and Jin-Ming persisted, trying to understand the science concepts and asked the teacher for explanation and advice, but Sharon and Cynthia and Reece and Sam compared notes with other students and copied them. All ended up with a series circuit that performed well.

How did this task contribute to the development of students' scientific and technological literacy? Although students appeared to understand the science concepts on paper, they found them hard to apply. Our interviews suggested their understanding of abstract concepts like current and voltage was not good, and students told us that, in terms of constructing their circuit, "Ohm's Law didn't help." In fact, what students found was that science "laws" and formulae could be used successfully in algorithms to get a "right" answer, but in practice they didn't work nearly as well because other variables came into play. Even if students had been able to understand and articulate these other variables, the science was simply too complex

time. It is easy to see how the technological aspects of circuit building contributed to technological literacy. Obviously, students' hands-on skills were practised, and their understanding of the solar-powered boat as a system was enhanced. They also learned something about costs and benefits in terms of the trade-offs as each decision was made.

In the entire technological task, Venville et al. (2000) discuss how the project "bridged" the usually compartmentalised knowledge of science, mathematics and technology by providing an environment in which application of that knowledge gave it meaning, context and relevance, and we concluded that the whole learning experience was greater than the sum of its parts. Of course, this is a simulation, not a real boat, but the problems students encountered in using the resources of knowledge, materials and time efficiently and effectively, with differential success, is a real-life, literacy-enhancing experience that science simply could not offer without the opportunity for technological application.

MONITORING AIR QUALITY IN A MILL TOWN

Earlier I mentioned a recommendation from the Goodrum et al. (2001) report about the need to raise community awareness of science. In response to this recommendation, the Federal Government contracted the Australian Science Teachers Association to undertake a pilot project to develop and test a model whereby schools could work with their community on a science awareness-raising project. Seven local projects eventuated, one in each of the six Australian states and the Australian Capital Territory. Most were based around environmental conservation, but one in Western Australia was about an intractable waste disposal facility and another in Tasmania was about air quality in a mill town. As I write, the report of this research is being completed, but I have permission to talk about this latter project.

The mill town of 5,000-6,000 people is situated on a river and the mill itself is central to the town. A recurring environmental problem is poor air quality with smoke haze, especially in winter, and it was this community issue that led a local science teacher to propose that his Year 9 academic extension class work on this problem with the community. The aims were to raise community awareness and understanding of the problem and to erect permanently some air monitoring equipment on the roof of the police station as a tangible outcome of the project. In addition, a website would be set up so that current meteorological information would be available online.

Initially, a major contributor to poor air quality was suspected to be the (foreign-owned) mill. However, students found that it was not a simple matter to blame a company which was the town's major employer of their parents, as well as the sponsor for the local football team. The company even donated the expensive air-monitoring equipment to the project! Fortunately, when students visited the mill, they were able to conclude that not only was it operated in a responsible manner to keep the river clean, but it was trivial contributor to the smoke haze in the air. In fact, it rapidly became clear that the major culprit was the large number of domestic wood-fired stoves and heaters, many of which were poorly maintained. Students surveyed the community via the local newspaper about their knowledge and use of wood burners and published their results there. A town meeting was arranged, and a petition organised for the local member of parliament requesting that the government implement a buy-back scheme to reduce the reliance on wood burners. Members of the community donated paint and a wall on the main street for a large mural about the project that the students designed and painted as a very visible public sign. Interest in the project was so high that at one time, students had to be rostered to respond to telephone calls to the school. Not

all went according to plan, however. The launch of the monitoring website during National Science Week had to be postponed due to bureaucratic difficulties in coordinating the Education Department and the Weather Bureau to email data for publishing on the website, and there were software problems which took a lot of sorting out. Nevertheless, our evaluations showed very high levels of community awareness about this project and positive changes in people's ideas about science and about science education (a major aim of the national project).

Clearly, although the Tasmanian project was carried out under the umbrella of science, it was strongly technological. Class lessons dealt with some science issues (combustion, smoke haze settling in valleys, etc.) but the relevance of this science content was given by the context of the project. Risks, benefits, trade-offs, social interactions between various community members and groups, and communication and understanding of the science and technology issues in the dynamic social context that was central to the project have provided significant opportunities to develop scientific literacy in the context of the broader umbrella of technological literacy.

DISCUSSION

This brings me back to the main point of my presentation "Reassessing the role of literacy in technology education". I think this reassessment applies in three areas.

Science Education Contributing to Technological Literacy

I have given considerable space to the links between scientific and technological literacy and I think we should be much more explicit about making science education contribute to literacy in technology. Some time ago, Peter Fensham wrote an article for the Australian Science Teachers Journal entitled "What will science education do about technology?" (Fensham, 1990). Prescient as always, Peter noted that technology had begun to be associated with science education, and for the most part, scientists and science educators weren't ready (and probably not very keen) to be involved. As I recall, Peter presented much of this paper at an address to CONASTA, the annual conference of the Australian Science Teachers Association. He told how his engineer son was learning about steam tables, which were based on a tiny section of the 3-line phase diagram for water that Peter taught in chemistry. Peter wrote that the steam tables were "specific knowledge about steam about which I had only such broad general knowledge that [it] was not useful" (p. 20).

This relates to a point I tried to make about the solar-powered boat project. Often school (and even university) science is simply not useful, either because it is too general and abstract (as in the steam tables example), or because science laws and formulae are too idealistic because they refer to a perfect world and fail to explain the complex interaction of variables that occurs in real situations (like the solar-cell circuit). Students, even those who wish to pursue a scientific career, are best served by a science education through the compulsory years which links science with the activities they will be involved in outside of school. Such a science education must involve technology. By this, I mean much more than the fleeting use of technological artefacts to illustrate science concepts. Rather, I refer to the capabilities and ways of thinking and acting in my descriptions of technologically and scientifically literate people, as shown in Figure 1. If science is taken out of the text book and put into the context of the students' world, it is easy to involve not only both science and technology but the associated social interplay as well, and this really gets to the heart of technology education.

Recognising and Naming Technological Literacy

In describing the air quality project, I labelled it a powerful opportunity to develop technological literacy. I wondered whether the students realised just how much technology was involved. Reference back to Figure 1 in the context of the activities undertaken, confirms that the project could contribute to all dimensions of technological literacy, as well as scientific literacy. The whole project was undertaken in terms of raising community awareness of science, not technology, and I suspect there were many missed opportunities to draw attention to the interactive relationship between them. The technology in the project had much to do with the complex social, political and environmental issues relating to wood burners. The students were designing, making and appraising plans relating to communicating with the community as a whole and finding practical solutions to the air quality problem. All of these things contribute to education in technology, but students are unlikely to recognise or distinguish these components of technological literacy unless attention is drawn to them and they are named.

Technological Literacy Is More Than Computer Literacy

You may have noticed that I have not mentioned computers so far. I have mentioned that science and technology are conflated in the public mind, but if you ask someone to name an example of technology, you are almost certain to elicit "computers" or some other hi-tech communication device. Certainly, some level of computer literacy is a needed skill these days, but it alone does not equate with technological literacy, it is merely one aspect of capability. Paramount now is familiarity with applications in order to operate them safely, not to understand how they work. This, too, is part of technological capability. But technological literacy is more than using hi-tech appliances. It includes things like pencils and pesticides, balls and battleships, aspirin and asparagus. It includes the human stories of each and the costs and benefits of the processes that brought them into existence and govern their use. They deserve more attention in schools.

For some decades technological literacy has played a subordinate role to scientific literacy, just as technology education has played a subordinate role to science education, a situation continually reinforced by the prevailing TAS perspective in schools. However, I am beginning to think that, for most people in the community, technological literacy assumes much greater importance than scientific literacy. Bybee (2000) has stated that his "interest in technological literacy is fairly simple: it is in the interest of science, science education, and society to help students and all citizens develop a greater understanding and appreciation for some of the fundamental concepts and processes of technology and engineering" (p. 24). I agree, but I would argue that, on average, technological literacy is more immediately relevant to the ordinary person than scientific literacy in dealing with everyday issues.

Of course, I want people to be scientifically literate too, experiencing the joy and excitement of finding out and understanding things that interest them, just for the fun of it. But especially for urban people today, the focus is not on how things work, but on how to make them work. People can use computers and mobile phones without knowing the science that allows them to work. As technology becomes more visibly hi-tech, the science becomes less visible and it becomes more and more difficult to understand how appliances work. Gone are the days when the science concepts behind the workings of most appliances could easily be demonstrated (and for the most part those appliances could also be repaired, even by people who didn't know the relevant science). When science teachers use technological artefacts to

illustrate science concepts many are now so “lo-tech” and dated that there is a danger of them being unfamiliar to the students! But they are still part of our cultural heritage. And that takes me back to an earlier point: that what it takes to be technologically literate is context-dependent. Whereas Western science might conflict with people’s world views, leading to collateral (Jegede, 1994) and contiguous learning (Ogunniyi, 2002), people will have culturally and contextually appropriate technologies, and developing technological literacy for their particular circumstances is very relevant to them. Reassessing literacy in technology education means recognising these varied contexts and broader perspectives and, as Pearson and Young (2002, p. 3) point out, providing “people with the tools to participate intelligently and thoughtfully in the world around them.”

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Volume 1

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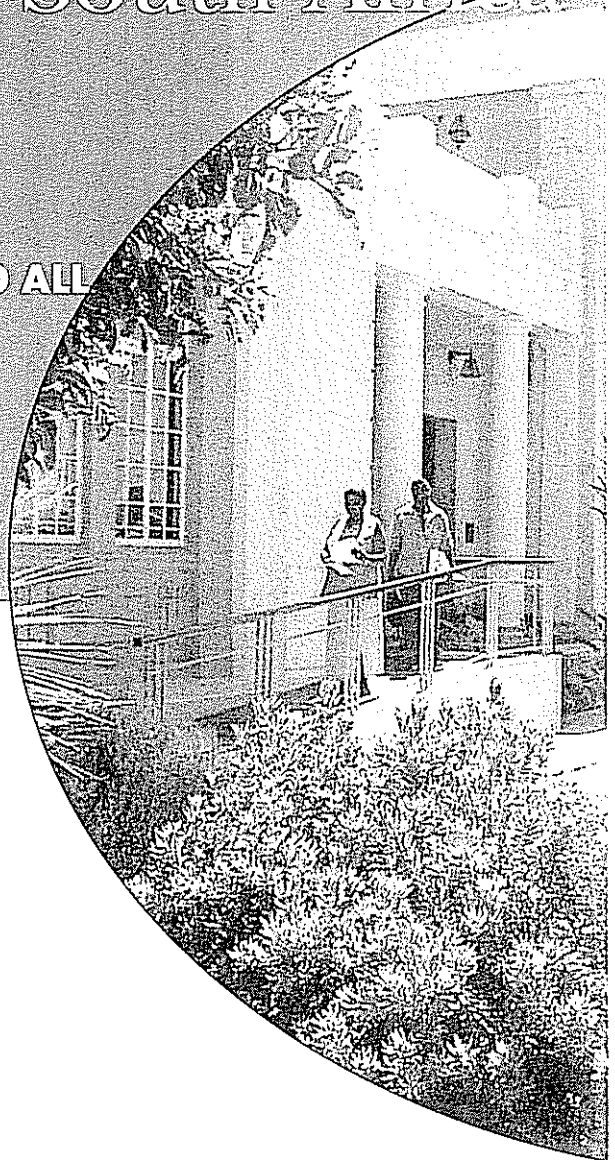
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Editors
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Published 2003 by the Key Centre for School Science and Mathematics, Curtin University of
Technology, Perth, Australia

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International Standard Book Number
ISBN

ISBN 1 74067 303 4