CHAPTER 18

Technology and science education

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Introduction

The incorporation of technology into the school curriculum is part of a world-wide trend in education. The way in which technology is incorporated depends on which country the reform is initiated in. The *New Zealand Curriculum Framework* (Ministry of Education, 1993a) includes science and technology as distinct learning areas. This chapter considers the view of technology expressed in both *Science in the New Zealand Curriculum* (Ministry of Education, 1993b) and in *Technology in the New Zealand Curriculum* (Ministry of Education, 1995).

The chapter is divided into four sections. Firstly, the concept of technology in the science curriculum is identified and discussed; secondly, the use of some types of technological application to enhance the learning of science outcomes is considered; thirdly, the technology curriculum itself is discussed in order to highlight the concept of technology underpinning this statement so that comparisons can be made with the concept employed in the science curriculum, and finally the introduction of technology outcomes by science teachers in a science environment is explored.

Technology in the science curriculum

The term *technology* is employed throughout the science curriculum in a number of ways. In the introduction to the science curriculum, science and technology are used as if they are interchangeable terms (Bell, Jones and Carr, 1995). In many of the strands, technology is mentioned as a context for teaching or introducing scientific concepts. For example, in the 'Making Sense of the Physical world' strand, students are expected to investigate how everyday technology works in order to understand how physical phenomena are incorporated in these technologies. However, it is not made clear in these strands what aspects of technology should be focused on, nor is it stated how technology is, in fact, being conceptualised.

Upon further analysis of the strands, however, the concept of technology does become more apparent. Through examination of the 'Making Sense of the Nature of Science and its Relationship to Technology' strand, in particular

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achievement aims 2 and 3 and their corresponding achievement objectives, an interpretation of the underlying concept of technology can be formulated. It is our interpretation that the concept reflected in this strand is that of technology as applied science.

For example, the second achievement aim and the corresponding achievement objectives in the 'Making Sense of the Nature of Science and its Relationship to Technology' strand have a similar overarching theme centred around linking technological artefacts with scientific principles. In the lower levels, this is primarily for the purpose of clarifying and demonstrating the scientific principle. At higher levels of the curriculum, the focus shifts to that of more generally investigating the relationship between science and technology. Emphasis is now placed on acknowledging and understanding how technological advances have aided – or in fact enabled – the development, or major rethinking of scientific ideas – for example, the way in which recent laser technologies have impacted on theories of atomic collisions. The ways in which scientific principles have provided crucial knowledge for technological development and advance are also highlighted; for example, the development and uses of genetic fingerprinting. When there is a focus on learning how technological artefacts function, this is in terms of scientific principles only, ignoring the other knowledge bases crucial to the successful functioning of technological artefacts, systems and environments. Technological knowledges, including technological concepts and principles, are not acknowledged. Rather, the principles behind technological innovation are perceived to be those belonging to science.

There is some opportunity within this aim to see how technological developments impact on scientific knowledge, and vice versa. However, this opportunity is confined to those technologies fitting the applied science notions of technological developments. Similarly, there is an opportunity for the exploration of the effect of technological development on society, but it is specifically stated that the means of such an evaluation should be through the application of scientific knowledge.

Science, technology and society

Essentially, all the achievement objectives in the 'Making Sense of the Nature of Science and its Relationship to Technology' strand pick up on some of the themes coming from the Science, Technology and Society (STS) framework. Fensham (1987) identifies eleven dimensions or aspects of STS learning. These are: the relation between science and technology; technocratic/democratic decision making; scientists and socio-scientific decisions; science/technology and social problems; influence of society on science/technology; social responsibility of scientists; motivation of scientists; scientists and their personal traits; women in science and technology; social nature of scientific knowledge, and characteristics of scientific knowledge (scientific methods, models, classification schemes, tentativeness). The STS movement began as a result of a combination of factors, including the growing concern in the 1960s that science education had become divorced both from its social origins and from the social implications of scientific endeavour. Solomon (1988) states that

> 'STS has emerged as a discipline with as discernible history and development'. (p. 379)

The STS inclusion of a societal stance was often expressed as increasing the 'social relevance of science' (Fensham, 1987, p. 1). There was also a push for science education to become more technology-related. For example, Hurd (1991), expressed this movement as a result of the

> 'call for the reconceptualisation of science teaching to bring it into harmony with the ethos of modern science and technology'. (p. 258)

Previously in New Zealand, and in other countries, an STS focus has often been an 'add-on' in the teaching of science. The *Science in the National Curriculum* statement, (Ministry of Education, 1993b), shows a clear attempt to move away from this and rather integrate such a focus *into* the learning area of science. In so doing it would appear to be recognising that STS knowledge is 'knowledge of worth' (Fensham, 1987) within the learning area of science.

It is important to note at this point that, whilst technology as conceptualised within STS is *in practice* very much aligned to 'applied science', this is in conflict with early warnings where science was only one of a number of knowledge bases to be used in technology. For example:

> 'Technology, in the context of STS courses, will mean neither the intricacies of microelectronics and mechanisms, nor those 'big machines' that are the general public's equation to technology. Our students need to see technology as the application of knowledge, scientific and other, for social purposes. They will have to recognise some of the pressures for innovation (once called the 'technological imperative') and its cultural dependence. Technology may be either small scale or large, but it is always the process of producing social changes as well as the result of social needs.'
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> (Solomon, 1988, p. 381)

Research in this area would suggest that the mismatch between the concept of technology as stated above by Solomon, and that apparent in science education curricula and practice, is a direct result of the science subcultural effect that construes technology as 'applied science' (Jones and Carr, 1993; Jones, Mather and Carr, 1995; Paechter, 1991; Goodson, 1985). Of course, in terms of science education, technology as applied science is not a totally negative phenomenon, in fact, as discussed in the next section, employing such a concept of technology has been shown to enhance students' learning in science.

Use of technological contexts

There is a significant body of research both from within New Zealand and internationally, which supports the use of technological applications in science education. For example, research in science education which explored the use of technological applications for the teaching of science, suggested that such contexts do have a positive effect on students' learning of scientific principles and concepts (for example, Jones and Kirk, 1990; and Rodrigues, 1993). This is in keeping with international research findings on the importance of context in student learning (Hennessy, 1993; Brown, Collins and Duguid, 1989; Lave, 1991; Perkins and Salomon, 1989).

Care must be taken, however, to ensure that the technological context used is appropriate for the students and to the scientific content, and that it is presented as an integral part of the learning experience rather than as an 'add-on' for the sake of sparking interest. For example, Jones and Kirk (1990), qualify their statement regarding how a technological focus enhances the learning of science concepts for most students, by stating the need for the context to be linked to suitable teaching sequences and for the context to be integrated into the lesson sequence rather than being used for illustrative purposes.

Research was carried out by Jones (1988), into the effect of introducing technological applications on students' concepts of physics. Using such applications as earthquake monitoring systems and baby breathing monitors, students indicated that these technological applications helped them to remember scientific concepts involved. No change was recorded, however, if the applications were used as an add-on either at the beginning or end of a lesson. The students also commented that the use of such technological contexts also provided frameworks for the construction of further scientific concepts to those specifically targeted. Another important outcome from this research was the significant increase in the students' level of confidence, interest and enjoyment in science generally. This was a factor noted by both the students and their teachers.

Rodrigues's (1993) research included exploring the role and effect of context on female students' learning of oxidation and reduction. Using such technological applications as breathalysers, hair perming and colouring systems as contexts, Rodrigues found that not only did students become more interested in the scientific concepts of oxidations and reduction, but they also showed a large increase in the number and quality of classroom interactions both with each other and with the teacher. These interactions took many forms, including direct questioning and discussion centred on both the functions and use of the application and the scientific concepts involved (Rodrigues, 1993). The researchers' observations were that the students appeared to take 'control of their learning' (Rodrigues and Bell, 1995, p. 807) and teacher, student, and researcher statements all appeared to suggest that the students experienced an increased conceptual understanding of redox reactions.

It would appear that student learning in science can be greatly enhanced by using technological applications in order to increase their understanding of scientific concepts and principles, as well as increasing their enjoyment of science generally. An STS approach allows for an understanding to be developed of the impact of applied science technologies on society and an understanding of the relationship between society and science.

The relationship between science and technology

As Jenkins (1994) and Layton (1991) note, science and technology can in some cases be inextricably linked. For example, the laws of physics can limit technological innovation, and scientific activity can be constrained by factors such as commercial advantage. However, even in these instances, the *purposes* of science and technology are different. For the scientist, the purpose is developing a greater understanding of the natural or made world. The purpose of the technologist is to intervene in that world and to change it in some way. This means that technological solutions will often be specifically situated, whereas scientific solutions are usually thought to be more generalisable.

Layton (1991) and Gardner (1995) note that scientific information needs to be reworked and translated into different forms for use in technological practice. Technology has a knowledge base in its own right and is not subservient to other forms of knowledge. Technological practice also relies on accessing multiple knowledge bases. Jenkins (1994) and Gardner (1995) provide numerous examples to indicate that technology can not be understood merely as applied science. For example, engineering concepts often need to be developed or utilised in the realisation of a technological solution. These concepts are often a long way removed from an understanding of the physics theory. Engineers use concepts such as leakage inductance, effective sensible heat ratio, solar heat gain, ergonomics, functionality, and disability glare, in order to design features and enable the use and viability of different materials. Jenkins notes that the role of scientific knowledge in technological development is frequently over-stated or misunderstood. Even in electronics, the role of science has been overstated (Jenkins, 1994, p. 12), for example, no new scientific knowledge was necessary for the development of the diode valve and although science contributed initially to radio it made little contribution to the technology from then on. The use of Maxwell's equations did not provide a successful route for the development of an induction motor.

Much technology was in place before there was a scientific understanding of the particular principles involved. For example, iron extraction was taking place before an understanding of redox reactions. Gardner (1995) notes that in some cases innovations have worked even when the inventor has a faulty scientific theory to account for them. For example, hot-air balloons based on a concept of rising smoke; or heat-treating food to 'get the air out'. Scientific knowledge is therefore not always needed for technological innovation. Gardner makes the point that the case of the steam engine shows that technology can develop from science, make progress without science and also contribute to science. From an historical perspective therefore, Gardner (1995) clearly shows that technology cannot be understood merely as applied science.

Technology education in the New Zealand curriculum

The next section of this chapter considers the structure of the technology curriculum, and provides a brief summary of the major components of technology education in New Zealand in order to illustrate the concept of technology employed in this curriculum statement. It is important that both teachers and students develop an understanding of the technology curriculum and the nature of technological practice if technological outcomes are to be achieved in the classroom.

As outlined in the technology curriculum statement, technology education contributes to the intellectual and practical development of students, both as individuals and informed members of a technological society. The general aims of technology education in *Technology in the New Zealand Curriculum* (Ministry of Education, 1995) are to develop:

- technological knowledge and understanding
- technological capability
- an understanding and awareness of the interrelationship between technology and society.

These are interrelated and overlap. For example, technological capability involves using knowledge and understanding and also takes into account issues related to technology and society. The three general aims provide a framework for developing expected learning outcomes, and provide a crucial basis for the formulation of a balanced school and classroom curriculum in technological education. Technology is conceptualised in technology education as more than artefacts; it also includes processes, systems and environments. Therefore in technology education students will design, make, modify, maintain, evaluate and improve devices, processes, systems and environments. The aims of technology education, in terms of creativeness and inventiveness, can only be realised if the learning environments actively encourage this. Technology is a multi-disciplinary activity and this should be reflected in students' experience of technology education.

Technological areas

The practice of technology covers a diverse range of activities within a diverse range of contexts. Technology education must reflect this diverse practice and not limit itself to designing and making artefacts with a limited range of materials. The development of technology education in New Zealand should reflect the technological activities within New Zealand.

Each technological area, and community of technological practice, has its own technological knowledge and ways of undertaking technological activity. It is important that students experience a range of technological areas and contexts to develop an overall understanding of technology and technological practice. Theories of learning also point to the fact that the more students can work in a number of contexts and areas, the more likely they are to develop effective knowledge about technology and transfer this knowledge to other contexts and areas (Perkins and Salomon, 1989). In the New Zealand technology curriculum, technological areas include: materials technology; information and communication technology; electronics and control technology; biotechnology; structures and mechanisms, and food technology.

Contexts

The technological areas provide opportunities for the achievement objectives in *Technology in the New Zealand Curriculum* (Ministry of Education, 1995) to be met. All technological areas can be accessed through a variety of contexts, such as personal, recreational, business, community, home, and industry. Each broad context will provide many specific contexts for exploration, for example, within the home context there will be contexts involving safety (design of burglar alarms; safer electric stoves) economy (design of fuel-saving systems) and comfort (ergonomically designed furniture) which are of direct relevance to the students. Technology education emphasises a holistic approach: the individual achievement aims are not discrete entities to be taught separately. It should be recognised that whilst a specific *learning activity* in technological education may not address all of the aims, within a specific *unit of work* it is expected that objectives from each of the three general aims of technology education will be addressed.

Components of technology education

The individual achievement aims and objectives arise from the general aims of technology education. Rather than list the achievement aims and objectives, we will consider the components of technology education from which the achievement aims and objectives have arisen.

Technological knowledge and understanding

It is crucial that the technology education curriculum does not become a purely process-orientated one, where knowledge is not deemed to be important. It is impossible to undertake a technological activity without some technological knowledge and the utilisation of other knowledge bases. It is crucial that the use of other knowledge bases is valued and this is an essential part of a technological activity. Each technological area will have different knowledge bases that are important. It is important that students have an understanding of a range of technologies and how they operate and function. Technological activity does not occur in isolation from people and their needs and values. Different ideas contribute to technology and students need opportunities to investigate how these ideas influence technology, including the direction of technological developments. Students need to develop an understanding of the principles underlying technological developments such as aesthetics, efficiency, ergonomics, feedback, reliability and optimisation. The understanding of systems is essential in developing knowledge in technology. Students should investigate technological systems and analyse the principles, structure, organisation, and control of systems. These knowledges and principles will be dependent on the technological area and context the students are working in.

Technological capability

Technological activity arises out of the identification of some human need or opportunity. Within the identification of needs and opportunities students will need to use a variety of techniques to determine such things as consumer preferences. Most technological developments occur through modifications and adaptations. Students should investigate existing technology in order to propose modifications, innovations, and adaptations to meet needs and opportunities. In a technological activity, it is crucial that students develop implementation and production strategies to realise technological solutions. Part of this process will involve students in developing possible ideas. This, in turn, will lead to the finding of a number of solutions and strategies in order to realise these ideas. To achieve this, students will need to manage time, resources, and people. Outcomes suggested and/or produced should be related back to the previously identified needs or opportunities, but need not be constrained by them. Students should communicate their designs, plans and strategies and present their technological outcomes in appropriate forms. Part of this process is the devising of strategies for the communication and promotion of ideas and outcomes, such as advertising, marketing, pricing, and packaging. Throughout the technological activity, students should continually reflect upon and evaluate the decisions they are making. Research has indicated (Jones, Mather and Carr, 1995) that this is essential if students are to realise their technological outcomes. Students should not only appraise their own outcomes but also those from the past, the present and other cultures.

Technology and society

The understanding of the complex relationship between technology and society is essential to any technological activity. Too often we have considered only the impact of technology on society rather than the 'different views' people have about technology and the ways these are influenced by their beliefs, values and ethics. Past technological developments have been shaped by people making decisions based on their own and others' opinions and interests. It is essential that students be given the skills and opportunities to investigate the basis of these past influences and explore the impact they have had, and continue to have, on technological innovation and development. Such a level of critical awareness of the way in which the lived world is constructed is crucial to developing in students a sense of empowerment. People cannot initiate change if they do not understand the frameworks upon which any change is dependent. In many ways, understanding the relationship between technology and society is about not only learning the 'rules of the game', but also being in a position to critique these rules.

Technological areas, contexts and achievement aims are to combine into an approach to technology education which is appropriate for meeting learning outcomes across all levels of schooling. The individual achievement aims should not be seen as linear, progressive steps. They act as a guide to the opportunities that should be provided for students. They are targets to be achieved over a period of time, and through more than one technological activity. As students carry out a task, they will be refining their approach through reflecting and evaluating; developing a complete understanding of it through gaining technological knowledge and understanding; understanding the interrelationship between technology and society, and, at the same time, developing a more appropriate strategy in their planning, developing and producing. Undertaking technological activities involves a dynamic interplay between knowledge and skills, and the contexts within which the activity is situated.

Technology outcomes in a science environment

This section of the chapter explores the effects on learning in technology, of introducing technology education outcomes in a science environment. The Learning in Technology Education (LITE) research project has identified a number of factors as being important to the success or otherwise of the learning of technological outcomes in a science classroom (Jones, Mather and Carr, 1995). Of particular relevance to this paper are factors such as teacher and student perceptions of technology and technology education, how they effect practice, the effect of subject subcultures on both these conceptualisations, and in particular the effect of science classroom practices.

Teachers' and students' concepts of technology

The findings from the LITE project indicated that teachers' concepts of technology education were influenced by their experience both in and out of school. For example, some teachers who had been involved in careers outside education often had a more positive attitude to technologies and their usefulness; however, they tended to hold primarily 'high tech' concepts of technology. These were often teachers who had worked in or were familiar with the manufacturing, engineering sector. Other outside influences included past science education teacher development programmes where 'technology' had been used as a context, resulting in the teachers' developing perceptions that science and technology are very closely related (Jones and Carr, 1993).

Teachers also commented on the students' concepts of technology and expressed concern that these were often still quite far removed from their own and from those portrayed in the curriculum statement. They considered this to have a significant affect on the student's activity during a technology unit. These comments are supported by the research into students' concepts of technology and technology education. Mather (1995) found that the majority of students' concepts of technology were related to 'recent phenomena' and 'artefacts'. Mather and Jones (1995) indicate that in many instances, students' concepts of technology had a greater impact on students' technological practice than the teaching strategies employed.

Teachers' concepts and practices have shown strong links with the initiation and the socialisation of teachers into subject subcultural settings (Ball and Goodson, 1985; Goodson, 1985). These subcultures, according to Paechter (1991), represent reasonably consistent views about the nature of their subject, the role of the teacher, the way technology should be taught and expectations of the students' learning. Paechter (1991) also points out that the teachers' beliefs about what was important for students to learn in their existing subject areas, such as craft, design and technology, home economics and art, were transferred to technology education.

These teacher subcultures were supported by the findings of the LITE project. The secondary school teachers' subject backgrounds were shown to have a strong influence on their concepts of technology education. For example, all the science teachers who were interviewed saw technology education in terms of applications of science. In fact, many clearly stated that technology was a vehicle for teaching science. This is hardly surprising, given the support of the science curriculum for such a perspective, as discussed in the first section of this chapter. Science teachers were not alone in the subject relatedness of their perceptions of technology. For example, social studies teachers focused on the effect technology has on society, English teachers discussed technology as an information technology tool, and technical teachers' view of technology was primarily focused on specific skills, and the designing and making of artefacts.

The strategies developed by the science teachers in their classrooms when implementing technological activities were often clearly positioned within the science subculture already present in the school. The science subculture therefore had a direct influence on the way teachers structured the lessons and developed classroom strategies. Teachers developed strategies to allow for learning outcomes that were often more closely related to science than to technology. This was particularly noticeable when some teachers entered areas of uncertainty in their planned activities. In assessment also, teachers often reverted to assessing outcomes linked to science that they were more comfortable with, rather than assessing technological outcomes. For example, they might emphasise research and/or technical skills in isolation rather than holistic technological outcomes. Although some of the science teachers might have been widening their concepts of technology, when identifying what learning was important, they often emphasised the learning of scientific concepts or skills, rather than technological concepts and practices. Some science teachers put some emphasis on STS approaches, for example discussing the impact on society; however, this did not lead to technological solutions but rather to a widening of science content.

Science subcultures also had a major influence on students' expectations of classroom practice, with regard to both themselves and their teacher (Jones, Mather and Carr, 1995). For example, throughout the technological activity which was situated in a science classroom and timetabled slot, the students played by the 'rules' of the science classroom. Their perceptions of the activities they were to be involved in were significantly affected by prior concepts of 'project' work in science. The focus throughout the unit was therefore primarily in terms of collecting information to present to the class. They also tended not to treat the activity as authentic, but rather in terms of motions to go through. They often did not continue with explorations of wider social issues as they did not see this as relevant to their notions of science. Jones and Carr (1993) and Jones, Mather and Carr (1995) indicated that the majority of students in the science classroom limited themselves to using science resources even though they had been encouraged by the teacher to use outside resources. The solutions that the students sought were often in terms of traditional solutions utilised in their prior experiences of the science classroom. When questioned, these students often clearly stated that they could have done more towards solving their problems, but that they had consciously limited themselves to what they considered to be appropriate within the science classroom. An example was making a simplistic model of a circuit rather than considering the factors involved in developing an actual circuit to solve a particular problem. Consumer benefits, costing and use of other material were often ignored when they were actually vital to developing an appropriate solution. Students often stated that they learned scientific concepts when undertaking the technological activity, and appeared to view this as the legitimate learning outcome for the activity.

There are numerous examples, from the research by Jones, Mather and Carr (1995), of students having difficulty translating knowledge taught in alternative subject areas to technological problems, including the translation of science concepts into technological solutions within a science classroom. Formal science knowledge needs to be reconstructed, integrated and contextualised for practical action (Layton, 1991). In applying abstract knowledge therefore, there needs to be an intermediate translation step. The transfer of knowledge in a useable form, from one context to another, is a difficult process and one that will be need to be taught to students. In fact, we found very little evidence that transferral of science concepts to full technological solutions had taken place. McCormick, Murphy and Hennessy (1994) also note that the students' inability to transfer was an obstacle in the technological activity. Transfer assumes that students have been taught for the understanding of when, and how, to use that knowledge.

Research shows that if technology is perceived simply to be applied science, then classroom practice tends to ignore economic, social, personal and environmental influences, needs and constraints (Gardner, 1995; Jones and Carr, 1993; Jones, Mather and Carr, 1995; Mather, 1995). This will therefore limit students' learning of technological concepts and practices. Because of the limiting effect of alternative subject subcultures, one must be very clear about the technological outcomes one is working towards and not allow them to be overridden by outcomes from other areas. There must also be an understanding of the subject subcultural effects on both teachers and students if technological outcomes are to be achieved. We are not suggesting that technological outcomes and science outcomes cannot be met alongside each other in practice. However, it is our observation to date that the difference in the power of the science subculture over the still emerging technology subculture, especially in a designated science classroom, indicates the need for extreme caution when attempting to do this.

▸ Conclusion

The introduction of STS and technological applications does appear to enhance the learning of science concepts, as well as to increase students' interest and motivation within their science classrooms. However, if science teachers choose to teach for technological outcomes in their science classrooms, then it is important that both teachers and students develop an understanding of technology, technology education and technological practice. In this way, teachers and students will develop an understanding that technology and science are two areas that can interact but are also distinct in nature.

Technology is a discipline in its own right (Mitcham, 1994) and is not a subset of other learning areas. For example, technological knowledge is not reducible to science, mathematics, or social studies learning areas. Science must not be seen as a gatekeeper for students undertaking further work in technology as this will limit students' learning in both fields. The development from, and use of, the technology curriculum will, one hopes, broaden understandings of technology and allow opportunities for enhancing the teaching and learning of **both** science and technology. School curricula and classroom practice can then be developed in such a way as to support the intention of the *New Zealand Curriculum Framework* (Ministry of Education, 1993a), *Science in the New Zealand Curriculum* (Ministry of Education, 1993b), and *Technology in the New Zealand Curriculum* (Ministry of Education, 1995).

REFERENCES

Ball, S.J. and Goodson, I.F. (1985) Understanding Teachers: Concepts and Contexts. In Ball, S.J. and Goodson, I.F. (eds). *Teachers' Lives and Careers.* Lewes: Falmer Press.

Bell, B., Jones, A.T., and Carr, M. (1995) The Development of the Recent National New Zealand Science Curriculum. *Studies in Science Education*, 26, pp. 73–105.

Brown, J.S., Collins, A. and Duguid, P. (1989) Situated cognition and the culture of learning. *Educational Researcher*, 18 (1), pp. 32–42.

Fensham. P. (1987) *Relating Science Education to Technology.* Paper prepared for the UNESCO Regional Workshop, Hamilton, New Zealand, December 1–10.

Gardner, P. (1995) The Relationship between Technology and Science: Some Historical and Philosophical Reflections. Part 2. *International Journal Technology and Design Education*, 5 (1), pp. 1–33.

Goodson, I.F. (1985) Subjects for Study. In Goodson, I. F. (ed.). *Social Histories of the Secondary Curriculum.* Lewes: Falmer Press.

Hennessy, S. (1993) Situated cognition and Cognitive Apprenticeship: Implications for classroom learning. *Studies in Science Education*, 22, pp. 1–41.

Hurd, P. (1991) Closing the educational gaps between Science, Technology and Society. *Theory into Practice.* XXX (3), pp. 252–259.

Jenkins, E. (1994) *The relationship between science and technology in the New Zealand Curriculum.* Wellington: Education Forum.

Jones, A.T. (1988) Classroom perceptions of physics and the introduction of technological applications. Unpublished D.Phil. thesis. Hamilton, New Zealand: University of Waikato, New Zealand.

Jones, A.T. and Carr, M.D. (1993) *Towards Technology Education, Vol. 1.* Working Papers of the Learning in Technology Education Project, p. 148. Hamilton, New Zealand: Centre for Science and Mathematics Education Research, University of Waikato.

Jones, A.T. and Kirk, C. (1990) Introducing technological applications into the physics classroom. Help or hindrance to learning? *International Journal of Science Education*, 12 (5), pp. 481–490.

Jones, A. and Mather, V. (1996) Technology in Science Education: Implications for Teaching and Learning. Paper presented at the Australasian Science Education Association Conference, Canberra, July.

Jones, A.T., Mather V.J., and Carr, M.D. (1995) *Issues in the practice of technology education.* p. 125. Hamilton, New Zealand: Centre for Science, Mathematics and Technology Education Research, University of Waikato.

Lave, J. (1991) Situated Learning in Communities of Practice. In Resnick, L.B., Levine, J.M and Teasley, S.D (eds). *Shared cognition: Thinking as Social practice, Perspectives on socially shared cognition.* Washington: American Psychological Association.

Layton, D. (1991) Science Education and Praxis: The Relationship of School Science to Practical Action. *Studies in Science Education*, 19, pp. 43–49.

Mather, V. (1995) Students' concepts of technology and technology education: Implications for practice. Unpublished M.Ed. thesis. Hamilton, New Zealand: University of Waikato.

Mather, V. and Jones, A. (1995) Focusing on Technology Education: the effect of concepts on practice. *SET* Number 2, Item 9.

McCormick, R., Murphy, P. and Hennessy, S. (1994) Problem solving processes in technology education: a pilot study. *International Journal Technology and Design Education* 4 (1), pp. 5–34.

Ministry of Education. (1993a) *New Zealand Curriculum Framework.* Wellington: Learning Media.

Ministry of Education. (1993b) *Science in the New Zealand Curriculum.* Wellington: Learning Media.

Ministry of Education. (1995) *Technology in the New Zealand Curriculum.* Wellington: Learning Media.

Mitcham, C. (1994) *Thinking through technology: The path between engineering and philosophy.* Chicago: University of Chicago Press.

Paechter, C. (1991) *Subject subcultures and the negotiation of open work: conflict and co-operation in cross-curricular coursework.* Paper presented to St. Hilda's conference, Warwick University.

Perkins, D.N. and Salomon, G. (1989) Are Cognitive skills context bound? *Educational Researcher*, 18 (1), pp. 16–25.

Rodrigues, S. (1993) The Role and Effect of Context on Learning Form Six Oxidation and Reduction Concepts by Female Students. Unpublished D.Phil. thesis. Hamilton, New Zealand: University of Waikato.

Rodrigues, S. and Bell, B. (1995) Chemically Speaking: a description of student-teacher talk during chemistry lessons using and building on students' experiences. *International Journal of Science Education*, 17 (6), pp. 797–809.

Solomon, J. (1988) Science technology and society courses: tools for thinking about social issues. *International Journal of Science Education*, 10 (4), pp. 379–397.