INTERNATIONAL TECHNOLOGY EDUCATION SERIES

Technology Education for Teachers

P. John Williams (Ed.)

SensePublishers

Technology Education for Teachers

INTERNATIONAL TECHNOLOGY EDUCATION STUDIES

Scope
Technology Education has gone through a lot of changes in the past decades. It has developed from a craft oriented school subject to a learning area in which the meaning of technology as an important part of our contemporary culture is explored, both by the learning of theoretical concepts and through practical activities. This development has been accompanied by educational research. The output of research studies is published mostly as articles in scholarly Technology Education and Science Education journals. There is a need, however, for more than that. The field still lacks an international book series that is entirely dedicated to Technology Education. *The International Technology Education Studies* aim at providing the opportunity to publish more extensive texts than in journal articles, or to publish coherent collections of articles/chapters that focus on a certain theme. In this book series monographs and edited volumes will be published. The books will be peer reviewed in order to assure the quality of the texts.

Technology Education for Teachers

Edited by
P. John Williams
University of Waikato, Hamilton, New Zealand

SENSE PUBLISHERS
ROTTERDAM/BOSTON/TAIPEI

A C.I.P. record for this book is available from the Library of Congress.

ISBN: 978-94-6209-159-7 (paperback)
ISBN: 978-94-6209-160-3 (hardback)
ISBN: 978-94-6209-161-0 (e-book)

Published by: Sense Publishers,
P.O. Box 21858,
3001 AW Rotterdam,
The Netherlands
https://www.sensepublishers.com/

Printed on acid-free paper

TABLE OF CONTENTS

P. JOHN WILLIAMS

1. INTRODUCTION

Teachers are under no obligation to accept or develop a philosophy about what they do, but there is an obligation to think about what they do and why they do it; it is irresponsible not to. So teachers need to:

1. think through the issues and alternatives of the various approaches to what they do in the belief that intelligent thought can improve success,
2. consistently base their educational practice on the outcome of that thinking.

A clearly articulated philosophy is one way toward a heightened sensitivity to the challenges of professional responsibility, resulting in consistent, logical practice. This introductory chapter attempts to place technology education in a context – technology education must relate to technology, and is enacted in a school context of general education for all students.

GENERAL EDUCATION

An approach to general education is usually established by groups of educators (and sometimes politicians) who attempt to distil a consensus of beliefs which represent the social context and the social demands on education. Accordingly, there are three main functions of education:

- the transmission of a culture and a way of life,
- the improvement of the social environment,
- provision for the needs of individuals.

Most countries have statements which elaborate on their educational philosophy. For example the United States has the ten statements of the Imperative Educational Needs of Youth (Educational Policies Commission, 1944), India has its National Policy on Education (Government of India, 1986). Australia has the Common and Agreed National Goals for Schooling in Australia (AEC, 1989), which are typical of the general education goals of many countries. Australia's goals are:

1. To provide an excellent education for all young people, being one which develops their talents and capacities to full potential, and is relevant to the social cultural and economic needs of the nation.
2. To enable all students to achieve high standards of learning and to develop self confidence, optimism, high self esteem, respect for others, and achievement of personal excellence.

P. J. Williams (Ed.), Technology Education for Teachers, 1–14.

3. To promote equality of educational opportunities, and to provide for groups with special learning requirements.
4. To respond to the current and emerging economic and social needs of the nation, and to provide those skills which will allow students maximum flexibility and adaptability in their future employment and other aspects of life.
5. To provide a foundation for further education and training, in terms of knowledge and skills, respect for learning and positive attitudes for life long education.
6. To develop in students:
   - skills of English literacy, including skills in listening, speaking, reading and writing
   - skills of numeracy and other mathematical skills
   - skills of analysis and problem solving
   - skills of information processing and computing
   - an understanding of the role of science and technology in society, together with scientific and technological skills
   - a knowledge and appreciation of Australia's historic and geographic context
   - a knowledge of languages other than English
   - an appreciation and understanding of, and confidence to participate in, the creative arts
   - an understanding of and concern for balanced development of the global environment
   - a capacity to exercise judgement in matters of morality, ethics and social justice
7. To develop knowledge, skills, attitudes and values which will enable students to participate as active and informed citizens in our democratic Australian society within an international context
8. To provide students with an understanding of and respect for our cultural heritage including the particular cultural background of Aboriginal and ethnic groups, and for other cultures
9. To provide for the physical development and personal health and fitness of students, and for the creative use of leisure time
10. To provide an appropriate career education and knowledge of the world of work, including an understanding of the nature and place of work in our society.

Goals like these constitute a philosophy of general education upon which school systems and subject specialists base more specific educational development. Specific subjects within a curriculum then become the mechanism to achieve these goals.

TECHNOLOGY

The relationship between technology education and technology is fraught, particularly in those countries where technology education has developed from a trade or craft focus. Where technology education is being developed as a new subject, for example in China where there is no history of a related subject in schools, it can be organized on the basis of technological principles. However, those countries in which Technology has morphed from other subjects which had a different focus, invariably retain aspects of the traditional subjects. Consequently, a subject called Technology, may only reflect technology to a limited extent.

Technology has a history as long as the history of mankind, which has been documented and discussed elsewhere (Singer, Holmyard, & Hall, 1958). The technology method was used by early humans in the effort to firstly survive and secondly to impact on the environment in which they existed. When a problem was perceived, a solution or a number of solutions would be developed with the best of these being implemented. As the experience of the practitioners developed, knowledge grew and better solutions were developed and new applications of these skills and knowledge were found. The early method was simply trial and error with the knowledge and skills gained from this being passed down to the next generation.

However the history of Technology as a subject worthy of thought and study is much more recent. The history of the philosophy of technology is generally dated from the work of Ernst Kapp, in Germany in 1877. Except for Kapp's work, and an essay on the origins of technology by Espinas in France in 1897, Technology as an area of study has been limited to the twentieth century.

Although technology has played a significant role from the very beginning of human history, in no major writings of the classical philosophers does there exist a systematic treatment of technology (Feibleman, 1982). At times the products of technology have been referred to, but no discussion of the significance and meaning of humans engaging in technological activity. This is surprising given the well established relationship between advances in technology and advances in civilization (de Camp, 1963), and the fact that the one consistent theme throughout human history has been the advance of technology.

It may be relevant to examine the values and attitudes attributed to one of the origins of the discipline of technology, namely manual labour, or work with hands. The most obvious manifestation of this to us as teachers is the attitudes towards technology subjects by school administrators, parents, other students and aspects of society. Studies about technical things that are pursued in a workshop are still regarded by many as second class and for the slower students. Why is there such an attitude?

This attitude is not a modern phenomena, and the historical precedents go back at least as far as the Greeks. In Homer, Hephaistos, the god of the goldsmiths, blacksmiths, masons, and carpenters, was deformed and was the object of the other gods mirth as he hobbled about. He was a divine smith, but the only divinity misshapen and subjected to the other god's mirth. This was in spite of the wonder of his almost magical creations - a throne that could move under its own power, a self propelled tripod, impenetrable armour. Plato and Aristotle share this same mistrust of the marriage of creativity and manual labour, they held the view that those who work with their hands are not truly free men (Chaplin, 1987).

A new respect for technological achievement developed throughout the industrial revolution. Technology developed to be different from what it once was, and since then it has gradually emerged as a system of values and action capable of encompassing every part of human existence. It has become a type of professionalism, a method of organizing society and a way of thinking (Kitwood, 1980). Technology has developed rapidly and ubiquitously to the extent that it is now considered in most countries to be worthy of a place in the core curriculum of schools.

There have been some spikes of public interest in Technology education which should help to reinforce its place in the core curriculum, though it has not been referred to as Technology education. For example the books by Crawford (Shop Class as Soulcraft, 2009) and Anderson (Makers, the New Industrial Revolution, 2012) decry the demise of practical technical activities in schools, and advocate their reinstatement as a way of contextualising important cognitive skills, and avoiding the misguided separation of thinking and doing. As Anderson states:

> But now, thirty years after 'Industrial Arts' left the curriculum and large chunks of our manufacturing sectors have shifted overseas, there's finally a reason to get your hands dirty again. As desktop fabrication tools go mainstream, it's time to return 'making things' to the high school curriculum, not as the shop class of old, but in the form of teaching *design* (p 55).

The assumption of this book is that a philosophy of technology education is an essential starting point for any educational activity in technology. This philosophy is informed in a number of ways, and one of the ways is through an understanding of the nature of technology. Beliefs about technology will determine the content of subjects called technology, and will also determine how they are to be taught. The following discussion about technology covers some of the issues related to technology such as values, determinism, and technology as an area of study.

Technology and Values

Whatever problems technology brings with it, the trouble does not stem from the technology itself, but from the conflicts it creates and the uses to which it is put. There is nothing intrinsically good or bad about technology. It is the way we employ it and the uses to which we put it that create the problems. Given this, the real problems with which we ought to be concerned are the decision making processes we use to apply technology and how we resolve problems with different sets of values (Pacey, 1984, p122). There may be two strategies that represent the extremes of this value reconciliation.

The first is to make one set of values dominant. Conflicts are then resolved by subordination to this master set of values. The argument is that if we are to get on about the business of dealing with technology in a way that increases human potential and decreases misery, disaster, and human suffering, we need to agree on a basic set of values to avoid the debilitating battles that value conflict seems to encourage. This leads to a tough minded fundamentalist attitude, with few compromises.

Another less humanistic but similarly absolute criteria could be that of technological advance, where technological issues would be examined in the light of technological advances and which options would be most effectual. In this scenario, however, there would be no way of measuring competing demands such as the advantages of establishing space programs against more retraining programs for the unemployed.

Another approach is an attitude of tolerance toward ambiguity and a search for compromise. A range of values may then co-exist. Choices will not be seen and black or white, but shades of grey. A range of values would exist in our thinking and education about modern technology. A tolerance of this range of values, and a determination to make creative use of the tensions between human need values and technological advancement values would represent the path to conflict resolution.

Regardless of one's attitude toward technology, no one disagrees that conflict is essentially associated with technology and values. In fact conflict is often used to displace informed technical argument in public debate related to technical issues. For example, when steam locomotives were first introduced in England, it was argued by the opponents of this new technology that the noise from the engines would scare the cows so that they would not give milk. A similar more contemporary example is the effect large wind turbines have on the animals around them. The goal seems to be in such cases to couch the argument in emotional terms that all can understand as a way of swaying public opinion, and as a technique for relieving the anxiety of a technically ignorant public. People may not know if steam engines or wind turbines are good or bad, but all can get behind the idea of milk for children. We see that kind of generated conflict continually, for example with gun laws, and carbon and pollution controls.

Conflict is held to be essential by many. Ellul (1965) sees sources of conflict originating from the quantitative focus of technology and the qualitative aspect of human existence. At the same time technology permits great human achievements, it threatens the annihilation of humanity.

Walden (1981) sees conflict between the perpetuation of the myth of the self made man in the face of an economy of plenty powered by technology. Most people continue to believe that a decent moral life, honesty, and hard work would provide rewards, but in a technological society, this may not be the case.

Butts (1980) holds that a common source of conflict of those technological issues relating to values is between those that provide pressure to conform, and those which tend to alienation, both from nature and from each other.

'Technological fixes' (Weinberg, 1966) are capable of finding shortcuts to many social problems. Because technological problems are intrinsically easier to fix than social ones, we tend to transform social problems into technological problems. For example, faced with the problem of a water shortage, the alternatives are either social engineering - altering lifestyles and ways people use water, or a technological fix such as the provision of more fresh water through more and larger dams or the desalination of sea water. Technology defines the limits within which society can function. By developing new technologies, we can change the limits on society and thereby remove the conditions creating the problem.

In the face of overwhelming technology and consequent conflict, some find consolation in the fact that some values cannot be displaced by technology, and some needs it cannot supply. For example, Paul Goodman (1968), Jacob Bronowski (1964) and Emmanuel Mesthene (1970) agree that while technology is threatening it cannot replace values related to habits, culture and religion. A technological way of thinking:

- remains under the control of values such as the desire for comfort, health, excitement, profit, power, etc. It is for us to balance and direct these values, or to divorce ourselves from the results.
- provides no reconciliation for the problems of moral evil and human suffering. These problems are in evidence everywhere in the world, including technologically advanced societies. While technology often does something to alleviate these problems, it can neither eliminate them nor supply an adequate philosophical answer to their existence.

A teachers attitude toward technological conflict, and their understanding of the relationship between technology, society and the individual, will influence the way they teach technology.

Technological Determinism

Several schools of thought have developed regarding the capacity of people to control the influences of technology. Some maintain that technology is predetermined to develop in a particular way because of certain conditions and events, without the possibility of human intervention (Pannabecker, 1991).

Jacques Ellul (1965) made the analogy between technology and a Frankenstinian monster which man has created that has grown beyond his control. Muller adopted this notion and titled his treatise on the subject "The Children of Frankenstein" (1971). Many writers and philosophers believe that because technology has come to have such a close relationship with the way people live, it dominates human life so much that it determines human values, character and destiny. Lewis Mumford (1934) is another who believes that technology, with its exponential rate of growth, has developed beyond the control of humans and thereby actually dominates and forces people to accept new ways of living and new meanings of the environment.

To those who think that technology has determinative powers over the way people live, technology is not simply the tools that help people do things in new ways. Technology is rather a way of thinking, a new 'world view', a new organization of meanings and assumptions about the world. Some thinkers such as Pierre Tielhard de Chardin, a Jesuit priest and Aurobindo Ghose, the Indian philosopher, agree that technology does dominate human life, but contend that is not necessarily bad. They see a technological way of thinking as a further step in the evolution of man, and part of the divine plan for humanity. The technological society promises to save humanity from limitations, disorganization and irrationality. The values of the individual are not the end of evolution. Technological thinking is a higher mode of thought.

The crucial question seems to be whether individuals are free to do what they want or whether technology forces them to do what it demands. Mesthene (1970) holds that a condition of freedom does remain for people within a technological society, but it sometimes appears that technology is in control because of the complicated relationship technology has with human life. The technological utopians believe technology reduces chaos, brings order, and generally can centralize human effort for the benefit of the public welfare; they are people with social consciences who are driven by their zeal to reform the world, to devise a utopia through technology. Technology is to be safe, aesthetically pleasing and productive of all the finer aspects of civilized life. For example, at the time of the industrial revolution, the mills were to be "lofty airy halls, walled with beautiful designs...the machinery running noiselessly, and every incident of the work that might be offensive to any sense reduced by ingenious devices to the minimum" (Bellamy, 1897).

What a teacher thinks about technology will influence how they teach and what they teach. If a deterministic approach is favoured, then, for example, consideration of the effects of technology on social systems may be not be taught in any significant way because of the considered inevitability of technological development. If a teacher has a more humanistic attitude toward technology, then they will be more likely to foster with their students a critique of technology within a sociological context.

STUDY OF TECHNOLOGY

The present need to defend Technology Education may not have been as obvious as it now is had it not been for Sir William Curtis, an illiterate Member of the English Parliament in the eighteenth century. The story is that he presented the essentials of education as what we commonly consider to be the Three R's: reading writing and arithmetic, but this was actually a misunderstanding of his original concept (Archer, 1986). The origins of the three R's were a lot more relevant and dynamic. The original triumvirate consisted of:

- reading and writing (literacy)
- arithmetic and reckoning (precision and judgment)
- wrighting and wroughting (how things work, making things)

Had wrighting and wroughting become established as one of the Three R's, the nature of our defence of the discipline of technology today would probably be quite different.

Many writers on the subject of technology consider that it should be treated as a discipline. One of the reasons for this is an attempt to achieve a level of academic credibility for this area which will enhance the foothold technology is developing in academia, but another reason is to try and provide the boundaries within which technology can be contained. Technology can be defined in so many different and equally justifiable ways that are at times so broad as to be meaningless. If the framework of a discipline can be used in the context of technology, then it adds clarity to the boundaries and provides structure that may prevent the dissipation of technology to the extent that no two people agree on its nature.

The academic credibility of Technology has been enhanced by the Society for the History of Technology, which was founded in 1958 and is now a well established and accepted area of academic enquiry. It has university departments, professional associations and scholarly journals.

However some have argued that disciplines with an external non-academic focus cannot be regarded as scholarly or scientific. The argument is that they do not allow for reflection, contemplation, detachment, and those other cerebral qualities that produce true learning.

This rejection of ‘the unnatural divide between the thinker and the craftsman’ (Sir Lyon Playfair, 1861; Crawford, 2009) is in fact a powerful argument for the academic validity of technology. The unique consideration of both theory and practice in technology leads to a more thorough understanding of reality. Academic learning, disciplined reflection, and practical experience then inform each other. This ‘reflective practitioner’ (Scott, 1987) has both a broader and deeper understanding than either the practical expert or the academic analyst.

This could be interpreted as one reason why it has taken a long time to establish technology as an area of study, or conversely, why technology, as a discrete entity, is not generally considered worthy of study. Instead of defending an academic orthodoxy and protecting its own ‘sacred’ knowledge, technology encourages lateral thinking in solving practical problems, not abstract artificial ones. Technology strives to go outside of itself while many traditional disciplines are much more introspective. Technology rejects ‘the salami-sliced divisions of intellect and labour and the clear demarcation between theory and practice on which some more academic disciplines rely’ (Scott, 1987).

At times this argument is pursued gingerly. The emphasis on Technology Education’s intellectual and educational benefits is distrusted by some technologists who suspect an attempt to academize their work. They fear that, in this disguise, wooly thinking, or ‘the hollow faddish ideas and snake oil approaches of shallow amateurs’ (Hogan, 1991) may drive out good practice.

A balance must be maintained between theory and practice, and between method and product. If the balance is not maintained, and errs on the side of being totally activity based, then prejudice against technology will be maintained. If the intellectual aspects are not balanced, then suspicion will be fostered. The strength of the study of technology lies in the maintenance of that balance.

On the other hand, Technology is indisputably interdisciplinary. Most scholars agree that this is a strength of technology that distinguishes it from other established disciplines. 'Technology has long since burst the narrow banks of engineering (or applied science) and spread out across the wide plains of natural social and human sciences' (Scott, 1987). The proponents of technology as a discipline are left with the anomaly of an interdisciplinary discipline. The interdisciplinarity of technology is vital for it to achieve its full potential and to maintain its broad knowledge base. Some would argue that the interdisciplinarity of technology disqualifies it as a discipline. Because it involves the selective application of knowledge to specific problem situations, the crucial body of knowledge cannot be defined for all situations.

However, the fragmentation of technology into academically convenient packages should be resisted. For example, when universities design degrees in technology to train teachers, there is a danger that the discipline will dissipate all over campus (This is not to imply that it should be taught by educators or pedagogues in order to keep it together). To those who reject technology as a discipline, its interdisciplinarity is one of the rationales used. The point is made that it cannot be a discipline because it is composed of a selective composition from other disciplines. While it does use formal knowledge, the application of that knowledge is interdisciplinary.

A further argument against technology as an area of study is that it is essentially defined in a context, not in the abstract. If the context is removed, and an attempt is made to define technology in the abstract, then all meaning is lost. Technology is essentially activity based, and not possible to define generally in the absence of a specific activity.

The extent to which a teacher feels technology should be approached as a discipline will effect their attitude toward the subject they teach. For example the teachers who approach technology as a discipline will feel less comfortable with an integrated approach to technology where it is taught in all subjects of the curriculum, than its treatment as a separate subject.

FROM TECHNOLOGY TO TECHNOLOGY EDUCATION

The following are suggestions about the relationship between technology and Technology Education, and what these relationships mean for technology education (Frey, 1989). It is essential that the practical dimension of technology education be significant. Students must have the opportunity to do technology if they are to come to understand its principles and methods. While this component is essential it is not by itself adequate. There are many cognitive technology skills that students must acquire, and a well balanced technology education will provide for these skills.

There must be an integration between technological knowledge and technological activities, and that knowledge which is uniquely technological must be identified, compared with, for example, scientific knowledge. Activities need to be designed not only to be integrative, but to give students the opportunity to identify and use that knowledge which is technological through a design-like process.

The characteristics of a good designer and a good technologist do not always coincide.

Effective technologists tend to be unusually single-minded and completely committed to the task in hand, and do not naturally entertain the resolution of conflicting values that come with design. They favour a quick technological fix to problems and avoid the messy complications of more 'people oriented' solutions. This typifies the manner in which we have traditionally taught much technology, a linear unambiguous view of progress and problem solving, with little room for democracy and divergent values. Now design is being introduced into that context, and not without understandable difficulty.

In opposition to this single-minded approach is a more dialectic style of thinking in which views and definitions can be altered, allowing options to open and directions to change, rather than seeing progress only in linear terms. While the institutions of free speech encourage a variety of values to coexist, they depend on a common view about how value conflicts should be dealt with – a democratic value system as contrasted with a technocratic value system.

These two categories of thought are identifiable in design and technology. The consideration of a range possible alternatives to a problem may mean dissipating effort without getting results. While the designer needs to produce original ideas, the technologist works with a design and involves as few original ideas as possible.

Balance within Technology Education

Even a comprehensive review of the literature would not unearth a clear consensus of the organizational principles of technology for education purposes, or even more basically, an agreement on what constitutes technology.

The perceived role technology education is to play will partly determine the philosophy of technology education, and hence the content and methodologies that are employed. The options for technology education have generally been dichotomous and related to either the liberal arts or to vocational training.

There are a number of implications in this approach for both content and methodology. Important content is the concepts of technology, and these can be taught in the context of many different types of technology. The type of technology is not so important, and if it is to remain relevant, should change over time anyway. The social and human implications of the technology are important elements for technology education in a liberal arts context.

The methodology of technology education is particularly important in this liberal arts context because there are a number of identified methods of doing technology, and if students are to develop a heightened awareness of technology then they need to understand and use relevant methodologies. A methodological emphasis will also help ensure that the range of cognitive skills considered important in the acquisition of technological literacy are mastered.

Technology education as vocational training involves the preparation of students for a specific vocation. This is distinct from vocational education. Many subjects have an element of vocational education in that they educate students for entry into vocations. English, maths, science and technology all contribute toward the knowledge and experience necessary in order to enter the world of work.

In vocational training, the particular technological vocation dictates what content is relevant, and it is only relevant to those students wanting to enter that particular vocation. A range of competencies for entering workers are developed by the vocational experts, and when these have been mastered, the student is prepared to enter the vocation. The majority of the competencies are skill based, and the most efficient means of acquisition of these skills determines the appropriate methodologies for technology education as vocational training.

A curriculum model that accurately depicts the scope and nature of technology education should include:

- how technology functions in a persons everyday life
- how technology creates new technology
- how technology produces products and services
- how people use technology to meet their human needs and wants
- how people assess the impact of technology on themselves, environment and culture

PHILOSOPHY OF TECHNOLOGY EDUCATION

Traditional technology education has questioned the value of a philosophy through its approach to separating thinking and doing. This has implied a sense of inferiority to other subjects, related to technology educators and technology students. But a philosophy does not lack practicality. It offers one of the best possibilities for improving technology education, a reference point for examining concepts and activities in the technological world, a foundation for evaluating and guiding decision making and a basis for speculative thinking and observation.

All teachers have a philosophy about what they do and why they do it, whether it has been enunciated or not. A philosophy will determine how a teacher relates to students and consequent discipline structures, the content of what is to be taught, and how it is taught. For a technology teacher, philosophy will answer questions like what is technology and consequently, what is technology education, how can technology best be taught, who should it be taught to, what should be assessed and how, etc. Teachers do all these things and have a rationale for doing them which may be implicit or explicit. The implication of the discussion throughout this book is that it is better for a philosophy of technology education to be explicit, then it can be debated and discussed, and can provide a logical and defensible rationale for educational activities. Samuel Shermis noted that "all educational issues are ultimately philosophical" (1967, 277), and what is needed is educators who understand the issues at their deepest level.

Educational philosophy is generally slow to change, but society is in a continual state of flux. Given that education is a product of social demands, social changes then represent a challenge to existing educational philosophies. A case in point is the emergence of technology as a core component of the curriculum. This curriculum decision reflects social demands, in that the nature of society has changed over time to become significantly technological, and this represented a challenge to the prevailing technical education philosophy. Technology education is the responsive philosophical change to this social phenomena.

Technology education derives elements of its philosophy from statements of general education, and from those relevant sections of society and the natural world that are related to technology. For example statement four of Australia's goals of education relates quite specifically to technology education. This statement is that education should respond to the current and emerging economic and social needs of the nation, and provide those skills which will allow students maximum flexibility and adaptability in their future employment and other aspects of life. In the derivation of a specific philosophy for technology education, these skills which will allow for maximum flexibility later in life must begin to be identified.

The other source for a philosophy of technology is those elements of society and the natural world that have to do with technology: those that design and create technology, those that use it and those that are effected by it, the raw materials used, and the effects on the natural world. Most sections of society are included in these categories. This fact provides a significant rationale for the importance of technology education in that it is so pervasive, but also creates a problem in that such a study of technology would be very broad.

CONCLUSION

As Technology Education has been around in some schools and in some countries for a long time, it is surprising that there is still no consensus about what school technology should be, how pupils learn when they study it, and what are effective teaching strategies. Yet in many countries, technology is challenging a number of traditional characteristics of schooling – the decontextualization of knowledge, the primacy of the theoretical over the practical, and the organization of the curriculum along disciplinary lines.

There is a great degree of diversity throughout the world in technology education. This diversity ranges from the absence of core technology education (Japan) to its compulsory study by all students (Israel), an instrumentalist approach (Finland) to a basically humanistic approach (Sweden), a focus on content (USA) to a focus on the process (England), an economic rationalist philosophy (Botswana, China) to a more liberal philosophy (Canada), a staged and well supported implementation of change (New Zealand) to a rushed and largely unsuccessful initial implementation (England), integrated with other subjects (science in Israel, IT in Australia) or as a discrete subject (Scotland).

While the nature of technology education developed within a country must be designed to serve that country's needs, and build upon the unique history of technical education resulting in a relevant technology education program, what happens in the technology classroom is dependent on the teachers' beliefs about technology in its broadest socially oriented context.

REFERENCES

Archer, B. (1986). *The Three R's in Technology in Schools*. A. Cross and B. McCormick (Eds.) Milton Keynes: Open University Press.

Anderson, C. (2012). *Makers: The New Industrial Revolution.* New York: Crown Business, 2012

Australian Education Council (1989). *Common and Agreed National Goals for Schooling in Australia*. Melbourne: The Curriculum Corporation.

Bellamy, E. (1897). *Equality*. New York: Appleton.

Bronowski, J. (1964). *Science and Human Values*. London: Pelican.

Butts, F. (1980). Curriculum for the educated citizen. *Educational Leadership*, October, p. 6–9.

Chaplin, M. (1987). Technology and the humanities. *The Weaver*, *5*(2), 2.

Crawford, M. (2009). *Shop Class as Soulcraft*. New York, Penguin.

de Camp, L.S. (1963). *The Ancient Engineers*. New York: Doubleday.

Ellul, Jacques. (1965). *The Technological Society*. London: Jonathon Cape.

Educational Policies Commission (1944). *Imperative Educational Needs of Youth*. Wash D.C.: National Educational Association.

Feibleman, J. (1982). *Technology and reality*. The Hague: Martiness Nijhoff Publishers.

Frey, R. (1989). A Philosophical Framework for Understanding Technology. *Journal of Industrial Teacher Education, 27*(1), 23–35.

Goodman, Paul. (1968). *People or Personnel*. New York: Vintage Books.

Government of India. (1986). *National Policy of Education*. http://www.educationforallinindia.com/

Hogan, G. (1991). President writes. *Technology and Design Education 2*(3), 6.

Kitwood, T. (1980). *The world refashioned for human use*. NUQ, 483–504.

Knight, G. (1982). *Issues and Alternatives in Educational Philosophy*. Berrien Springs, MI: Andrews University Press.

Mesthene, E. (1970). *Technological Change*. Cambridge, Mass.: Harvard University Press.

Muller, H. (1971). *The Children of Frankenstein*. Indiana: Indiana University Press.

Mumford, L. (1934). *Technics and civilization*. Chicago: The University of Chicago Press.

Pacey, A. (1984). *The culture of technology*. Cambridge, Mass: MIT Press.

Pannabecker, J. (1991). Technological Impacts and Determinism in Technology Education: Alternate Metaphors from Social Constructivism. *Journal of Technology Education, 3*(1), 43–54.

Playfair, L. (1861). Photogrpahy at the Industrial Exhibition of 1862. *British Journal of Photography*, August 1, 263–264.

Scott, P. (1987) The empire of total technology. *The Times Higher Education Supplement,* September 4, p. 2.

Shermis, S. (1967). *Philosophic Foundations of Education*. New York: D.Van Nostrand Company.

Singer, C; Holmyard, E. & Hall, A. (Eds) (1958) *A history of Technology*. Oxford: Clarendon Press.

Walden, D. (1981). The two faces of technological utopianism. *The Journal of General Education, 33*(1), 24–30.

Weinberg, Alvin M. (1966). Can technology replace social engineering? *University of Chicago Magazine*, *59*, 6–10.

AFFILIATION

P John Williams
University of Waikato
New Zealand

MARC J. DE VRIES

2. PHILOSOPHY OF TECHNOLOGY

INTRODUCTION

Why would technology teachers need to know about technology? Often they are practical people who would like to do practical things in class. To many of them philosophy probably sounds like the most vague and abstract thing there is. Probably it makes them think of what Voltaire, one of those people doing philosophy, once wrote: “If he who hears does not understand what he who speaks means, and if he who speaks himself does not know what he means either, that is philosophy” (Morris 1999). It sounds like definitely something to stay far away from. Yet, I will try to argue in this chapter that the philosophy of technology is something technology teachers may be interested in for good reasons. Perhaps the simplest argument runs like this: teaching about something assumes that you know what it is. The question ‘what is….?’ is a philosophical question. Therefore the answer to this question given by philosophers should be relevant for teachers. In our case the ‘something’ is technology. By no means a simple matter to define. Yet, it is important to know what it is because technology educators are constantly asked to justify what they do. Probably no other school subject is so much forced to account for its content and practice. For that reason it is important that technology teachers can draw from a sound theoretical basis to defend the position of their subject in the curriculum (De Vries 2009).

Another reason why teachers would want to get to know more about the nature of technology through philosophy of technology is that international developments cause constant revisions of curricula. If such revisions are not based on a thorough understanding of what is essential and thus needs to be preserved, these revisions will not likely appear to be improvements.

In this chapter I will present the main domains in the philosophy of technology and for each of them show how they are relevant as a contribution to the theoretical and conceptual basis that technology education needs. In the next section I will show how technology education curricula often have biases towards certain characteristics of technology, but also how more and more these curricula tend to become rich blends of different characteristics. Finally, I will draw some conclusions about the way philosophical ideas can become practice in technology education.

P. J. Williams (Ed.), Technology Education for Teachers, 15–34.

DOMAINS IN THE PHILOSOPHY OF TECHNOLOGY

The philosophy of technology is a relatively young academic discipline. The philosophy of science, for instance, is much older. For some reason, philosophers for a long time neglected technology as a possible object for reflection. But in the past decennia the philosophy of technology has gone through a rapid catch-up operation. An often cited book that describes the short history of philosophy of technology and offers a survey of its current domains of interest was written by the American philosopher Carl Mitcham and is titled *Thinking Through Technology*. I will use his description of four basic domains to structure this section of my chapter. Mitcham's structure is based on four different ways of conceptualising technology: as a huge collection of artefacts, as a knowledge domain or discipline, as a set of activities and as a field of human and social values.

Technology as Artefacts

The first important domain in the philosophy according to Mitcham is: technology as artefacts. Artefacts are in fact the outcome of technology, but we often associate them with technology itself. "Look around in your home or on the street and you see technology all around you". Artefacts are the most direct way we get in contact with technology. Ask pupils what technology is and they will most likely respond by listing artefacts. In Technology Education, artefacts play an important role. The outcome of a design project is usually an artefact. Also pupils learn about how certain artefacts work. So we do a lot with artefacts in Technology Education. But what makes an artefact an artefact. What makes it different from, for example, a natural object? That is the question that philosophers of technology have posed also. Their answers are quite interesting for educators, as they try to reduce the description of an artefact to its very basic elements. That is relevant for education, because we do not want to start initially with the full complexity of technology, but always try to make it simple first.

One basic way of describing artefacts is by taking the *dual nature* approach (Meijers 2000). In this approach, we recognise two natures in every artefact. I can describe an artefact entirely in terms of its *physical/structural properties*. Let us take a mug as an example. I can describe the mug in terms of its shape, its weight, its colours, its number of parts, its material properties, etcetera. But if an alien would hear my description, he (it?) would not understand what this object is for. He would, perhaps assume that it is used to keep papers on my desk from blowing away when the window in my office is open. Alternatively, I can describe the mug in terms of its *functional properties*. I can mention that a liquid can be stored in it and carried around, that this liquid can be poured out again or drunk from the object, that sometimes the device informs about its content ("coffee" written on it). For an alien that could give rise to all sorts of images of what the thing might look like. He (it?) may think that is square, thin and tall, or whatever. It is only the combination of the two descriptions that would give the alien a full picture of what a mug is. The two descriptions are complementary and cannot be reduced to only one. I cannot derive the functional properties from its physical properties in a non-ambivalent way and vice versa. This makes the artefact different from a natural object, because that has a physical nature and no functional nature (that is: no human being describes a function to it). The stone in the wood is just there without being used for a function. Of course, I can go to the wood, take the stone and start ascribing functions to it, but strictly speaking, then I have turned it into an artefact, even without changing its physical properties. Functional properties are indeed a matter of ascription, whereas physical properties are not. Functional properties have to do with my relation to the product, whereas physical properties are artefact-internal. The mug's weight or size do not depend on my ideas about the mug, but its function does. I can use it is as mug, but also (thank you, alien) as a paperweight.

A somewhat more sophisticated way of looking at artefacts is to recognize that both the functional and the physical nature can be split up in a more detailed view. The Dutch philosopher Hendrik van Riessen (mentioned with a fair amount of honour as an early philosopher of technology in Mitcham's book) showed that each artefact has to function in many different *aspects of reality*. For instance, they function in the spatial aspect of reality that tells us that everything takes up a certain amount of space. This is something designers have to take into account. It also functions in the linguistic or symbolic aspect, because we use names and symbols to identify it. This is also what designers have to think about. The artefact also functions in the economic aspect: it has a price tag and this depends on what value people will ascribe to it. Likewise, it functions in the social, juridical, aesthetical, ethical and belief aspect. The latter group of functions means that we tend to give trust or belief in technologies (or distrust of course). That, too, is something designers have to consider, if the product is to be a success. In total Van Riessen distinguished fifteen aspects of reality (see De Vries 2005). Another interesting element in his framework is that artefacts can function both as *subjects* and as *objects*, just like humans. But Humans can serve as subjects in all aspects and artefacts cannot. In the physical aspect, for instance, in which we focus on physical interactions, they can be both subject (the ball hits the wall) and as objects (the ball is thrown by a human being). But in the economic aspect, artefacts can only serve as objects: they can be bought, but they do not buy. Designers will have to reflect on the way artefacts are passive or active in the various aspects in order to design them in such a way that they can function as desired.

Let us think a bit more about *functions*. I can ascribe different functions to the mug, but there is always the 'original' function of a mug being an artefact from which I can drink my coffee or tea. That is the function the designer had in mind when designing the artefact and the artefact's physical nature was optimised for that function only. We call it the *proper function*. Nevertheless, I can reason that the same physical nature is also suitable for holding papers down on my desk. That is what we call an *accidental function*. In many cases ascribing accidental functions works because indeed the artefact's physical nature does allow it to be used for that purpose. But there are limits to my options to ascribe functions to the artefact. One day I may decide that I will describe the function of 'fall breaking device' to the mug and happily take it with me when I step out of the 10th floor window of a building, only to find out that the mug's physical properties do not allow the mug to be used for fall breaking purposes. In that case, one could speak of an *improper function*. Another observation about the functional nature is that it makes sense to ascribe a broad range of meanings. Perhaps it would be better to say that the functional nature consists of all user-related properties. Then it comprises not only function in the strict sense (what is it for?) but also such aspects such as aesthetic and ergonomic qualities, price (also a property that is not artefact-intrinsic but a matter of ascription), maintainability, etcetera. By taking 'functional nature' in that way, we have captured all the different properties of the artefact in just these two 'natures'.

Coming back to Van Riessen's theoretical framework again, we can also distinguish other types of functions that are useful for designers to consider. Van Riessen identifies foundational and qualifying functions. *Foundational functions* are related to the origin of an object's existence. A stone, for instance, was formed by physical processes and therefore, Van Riessen would say that it has its foundational function in the physical aspect. A tree, however, was formed by life processes and therefore has its foundational function in the biotic aspect. All human-made artefacts have their foundational function in what Van Riessen calls the formative aspect of reality that focuses on the way entities go through a certain process of development. The *qualifying function* is about the object's ultimate contribution to the meaning of reality. For a painting this function is to be found in the aesthetic aspect, because it is ultimately aimed at being admired for its beauty. Of course it also functions in all other aspects of reality (it has a price tag, it takes space, it can be stolen and thus be the cause of a law violation, etcetera). But the aesthetic function is leading in its design. How about a heart pacemaker? The ultimate aim is that it contributes to a happier life and Van Riessen would seek this in the ethical aspect of reality because he sees love and care as the main values in that aspect. But in order to enable the realization of that qualifying function, it is absolutely necessary that the pacemaker produced the correct electrical pulse. Therefore, it makes sense also to define a *technical function*, which indicates the basic functioning of the artefact that is necessary for the realisation of the qualifying function. Clearly, in this case the technical function is in the physical aspect. For a railway train, the qualifying function is in the social aspect (bringing people together) but this can only be realized when the train can fulfil its technical function, which is in the spatial aspect (going from A to B).

A third important concept related to artefacts, next to functions and a physical realization, is the *operation* (or 'function*ing*') of the artefact. That is what the artefact does when I use it to perform the function by putting it to work. By using knowledge from physics, chemistry and mathematics, I can derive from the physical properties how the artefact will behave when I exert certain actions on it. The effects of that behaviour should match with the desired function.

Artefacts of course can be simple and complex. Often, artefacts consist of many parts that work together. In that case, we speak of the artefact as a *system*. Systems are a combination of parts that work together. That is the description that focuses on the physical nature of the system. The alternative way of describing systems is in terms of their functional nature. Then we see how systems process materials, energy and information as input and transform them into output (again consisting of materials, energy and information). Both on the physical and on the functional side we can describe a *system hierarchy*: sub-parts of parts and sub-functions of functions. To emphasise the importance of the functional nature of the system, nowadays we often find the term *sociotechnical system.* Technical systems can only function in a social context. Even in the case of a single-user system, the social context is important as that individual functions in a social context and the artefact is subject to all sorts of social constraints (economic, juridical, etcetera).

Technology as Knowledge

Let us now turn to the second way of conceptualising technology: as knowledge. In other words, technology is something you can learn or study. It took a long time before philosophers got interested in this way of reflecting on technology (Meijers and De Vries 2009). Until recently, philosophers tended to think of science as knowledge and of artefacts as merely the application of that knowledge. Now we realise that in Technology we do not only apply knowledge but also learn new knowledge from that application. This knowledge can have different characteristics than the knowledge we have applied. In this section, we will examine some of those properties. In the artefacts section, we posed the question how artefacts differ from natural objects. Here we will ask ourselves how technological knowledge differs from scientific knowledge.

A lot of what we know in technology is related to artefacts, as they play an important role in technology. From the dual nature description of artefacts we can immediately derive some types of knowledge in technology: knowledge of the physical nature, knowledge of the functional nature, knowledge of the relation between the two and knowledge of operational principles. Knowledge of physical properties is knowledge of things as they are. That is not different from science in which we also describe things the way they are. For functional nature knowledge, though, this is different. We do not describe the way things actually are, but the way they ought to be. The function of a car is to transport from A to B. That is still the function when it stands still or even when it is in the garage for repair. The function does not describe what the artefact actually does, but what it ought to do when functioning. So functional knowledge is not knowledge about what is (as in science) but knowledge about how things ought to be. We call that *normative knowledge*, in contrast to *descriptive knowledge* (as in physical nature knowledge).

We can easily recognise the difference in the following example. For an engineer it makes sense to claim: "I know that this is a good screwdriver". For a scientist, though, it makes no sense at all to claim to "know that this is good electron". That is because the engineer's knowledge refers to what the screwdriver ought to do. For the scientist there is no 'ought to' in the electron's behaviour. Either it does what all electrons do and then it is an electron, or it does not and then it is not a 'bad' or a 'broken' electron, but it is no electron at all. In the engineer's case there can be levels in normativity. He can not only claim to know that this is a good screwdriver (that is, this particular *token*), but also that a certain *type* of screwdriver is good.

Another property of technological knowledge that distinguishes it from scientific knowledge is the extent to which technological knowledge is generalized. In most cases, science tries to generalise as far as possible. Physicists are looking for the 'Grand Theory of Everything'. Engineers are not interested in such a theory as it is way too far from the actual (design) problem they are dealing with (De Vries 2010a). They need a theory that goes beyond one particular situation (otherwise it makes no sense storing that knowledge) but not too far. In order to be useful, technological knowledge is much more *context-specific* than scientific knowledge is.

A third distinguishing property of technological knowledge is that its content is often a matter of (social) *agreement*, more than a matter of a conclusion that necessarily follows from observations, as in science. Of course in the process of determining what theory to accept social processes play an important role, as the social constructivists have shown, but scientists cannot freely decide, for instance, what the electric charge of an electron is. Engineers, on the other hand, can freely decide what the norms for an M3 bolt are. Of course they will have reasons for deciding, but in the end they are free to decide as they want because there is no 'natural necessity' for an M3 bolt to be sized as it is.

A fourth characteristic of technological knowledge is that it is often of a *non-propositional* nature. In science, knowledge is usually expressed in propositions, or sentences that contain a certain truth. Such propositions can be: "the relative density of water is 1 kilogram per litre", or "the electric current in a wire is proportional to the voltage over it". In technology, however, much knowledge cannot be expressed in such terms, or only at great cost. Engineers often express their knowledge in drawings, mock-ups, maquettes, prototypes and the like (Baird 2004; Ferguson 1992). They could try to describe the same knowledge in a tremendous list of propositions but even then they would feel that part of the knowledge expressed in the drawing or whatever was lost in that process. The same holds for knowledge that is usually called knowing-how. I know how to hammer a nail into a piece of wood, but I cannot express this knowledge fully in sentences. This, by the way, has great implications for teaching that knowledge, because then it cannot be taught by writing it in a textbook, as textbooks can only contain propositional knowledge and to some extent knowledge that is expressed in drawings.

A well-known taxonomy for technological knowledge was developed by Walther G. Vincenti (1990), based on a series of historical case studies in aircraft design. He defined six types of technological knowledge, as follows:

1. Knowledge of fundamental design concepts. He distinguishes two sub-types: knowledge of basic parts of a design (for instance: an architect know that designing a skyscraper means deciding about a foundation, a core and a covering), and knowledge of working principles (e.g., of the lever principle).
2. Knowledge of criteria and specifications. Engineers know what type of things to take into account when reflecting on the user/customer.
3. Knowledge of theoretical tools, such as formulas derived from physics and math, or CAD programmes.
4. Knowledge of quantitative data. Vincenti distinguished two types: knowledge of quantitative descriptive data (e.g., the specific heat of a substance) and quantitative prescriptive data (e.g., the size of an A4 paper sheet or the size of an M3 bolt).
5. Knowledge of practical considerations, e.g. knowing how to decide if there is a conflict between safety of the design and cost.
6. Knowledge of design strategies, that is knowing how to approach a design problem.

Although Vincenti makes no effort to argue for the completeness of this list, it does give a good insight into the variety of knowledge that engineers can have. It is not difficult to recognize the four characteristics mentioned earlier in the various types of knowledge Vincenti defined. Another interesting feature in Vincenti's book is that he investigates the sources for technological knowledge. He made up a whole list, containing, for instance, theoretical and experimental work in engineering sciences, but also direct trial and production. Deriving knowledge from natural science also features in this list, but Vincenti then goes on to show that this type of knowledge source only contributes to two of his knowledge types, namely knowledge of theoretical tools and knowledge of quantitative data. This gives him a good reason to criticize earlier writings in which technology was presented as 'applied science'. Evidently, applying science would be a very incomplete source of knowledge for engineers. Therefore, we can claim that technology and engineering are domains of knowledge that are really original and not just derived from science.

Another way to look at the relation between design and knowledge, next to Vincenti's approach, is to see how design and knowledge from science interact. Here, the Dutch philosopher of technology Andries Sarlemijn has done some interesting analysis. According to him one can distinguish three types of technology by observing how science and technology interacts:

– *Experience-based technologies*. In these technologies designers come up with designs without exact knowledge of how they work. It is only when scientists afterwards study the artefacts they come up with and learn from those that such an understanding becomes available and often it does not even lead to improvement

of the artefacts. Examples of such technologies are simple household devices and tools.
- *Macrotechnologies*. In these technologies the development of scientific knowledge interacts with the development of artefacts. Usually it starts with the artefact. Steam engines, for instance, were originally designed without correct knowledge of what happens inside the engine. But as improving the design seemed difficult without such an understanding, engineers called in scientists to investigate this and thus thermodynamics developed as a new area in science. This new knowledge led to improved engines, which called for more advanced knowledge to improve them even further, and an alternation of design and science emerged. They are called macrotechnologies because typically they are devices in the design of which classical theories about behaviour on the macrolevel is involved.
- *Microtechnologies*. In these technologies, no substantial progress is made in design without previously acquired scientific knowledge. The history of the transistor nicely illustrates this. People at Bell Labs had tried to copy a bulb amplifier in solid state, but it did not work properly. It was not until they started applying solid state theories about energy bands that a functioning transistor was developed.

Although there may be exceptions to Sarlemijn's taxonomy, generally it gives a good overview of the variety of technologies. It again shows that technology and engineering are more than a matter of applying natural sciences, which would only lead to microtechnologies.

Technology as Activities

The third way of thinking of technology is by recognising the activities or processes that characterise it. Roughly speaking, three types of processes can be distinguished here: designing, making and using/appreciating processes. The first two are very much the professional domain of the engineers and technicians, the third is something all citizens can be involved in (although many of them also do design and making work, for instance, as a hobby). In the philosophy of technology, so far nearly all that has been written about technological processes is about the design process.

Taking again the dual nature approach as a starting point, how can designing be characterised? Designers begin with a desired functional nature. This is expressed in the assignment that they start with. They may refine it in conversation with customers and users and transform it into a list of requirements. Their ultimate challenge is to come up with a physical nature that can realise this desired functional nature. This activity requires two different types of reasoning. To get from a desired functional nature to a physical nature that enables the realisation of that function (via the functioning or operation of the artefact), one needs *means-ends reasoning*. This is an example of practical reasoning, that is a type of reasoning that leads to an action as the conclusion.

Once a possible physical nature has been designed, one can predict the behaviour of the artefact through *cause-effect reasoning*. This is an example of theoretical reasoning, that is reasoning that leads to a factual proposition as the conclusion.

Much has been written about the process of designing. In the discipline of *design methodology*, the original ambition was to develop prescriptions for designers that would be product-independent and usually based on the phases of analysis, synthesis and evaluation (Cross 1984). Soon, this appeared to be too rough a simplification of the complex design processes that were encountered in reality. Therefore observations of such real processes were done and it appeared that design processes are much fuzzier than one had thought earlier on. Even prescriptions for specific engineering domains were problematic, although in books for engineering students such prescriptions are still present and taught. The more recent insight is that each method has its own *assumptions* in terms of what the designer using it should know and should be able to do. Methods that aim at translating customer requirements into technical specification, for instance, usually assume that companies can identify precisely who the customers are, and that customers know what they want. Both assumptions are by no means obvious and certainly not fulfilled in all situations. In those cases the use of such a method may be problematic.

A trend in design is to take into account the whole product lifecycle in the design as early as possible. This relates to the idea that designers should think of every aspect in the whole lifecycle that offers opportunities to please the customer. This is called *total quality management*. This idea has led to a whole series of design methods, often called *design for X*. For instance, there is: design for production, design for manufacturing, design for logistics, design for cost, design for maintenance, design for recycling. The last-mentioned example is part of *green design* or environment-conscious design.

Not much has been written in philosophy of technology about the production process, but some notions are worth mentioning here. Production can be seen as a transformation of materials, energy and information. When beer is produced in a brewery, various materials are used (water and hops, among others), energy of whatever kind is transformed into heat, and information is processed in the form of temperature prescriptions, timing for the various sub-processes, and monitoring of various properties of the brew. When looking at the role the resources of energy and information play in production, one can distinguish three types of production processes:

– *Manual* production: in this type of production, humans deliver both the energy and the control (information); production happens by bear hand or with tools;
– *Mechanized* production: in this type a machine delivers (most of) the energy, but the control (information) is still delivered by humans; production happens with machines
– *Automated* production: in this type of production, both the energy and the information come from an automaton during the production process; production happens with robots.

Technology as Values

The fourth way of conceptualising technology is: technology as values. This way of reflecting on technology makes connections to metaphysics (what kind of view on reality do we hold?), ethics (values of good and bad; De Vries 2006) and aesthetics (values of beautiful and ugly). It is the way of looking that was the focus of early philosophy of technology, when Continental philosophy still dominated. Continental philosophy was the philosophy as practised by philosophers that lived and worked on the European Continent such as Heidegger, Husserl, Marx and Sartre, to mention just a few. Their philosophies are very much about values. The other main stream in philosophy is analytical philosophy that aims primarily at developing well-defined and logically consistent concepts. Analytical philosophy dealt mostly with the previous three ways of reflecting on technology (as Artefacts, as processes and as knowledge), while Continental philosophy of technology was particularly interested in technology as values. Currently we find representatives of all main streams in philosophy reflecting on technology. We will now show how the various main streams in Continental philosophy have developed a philosophy of technology.

Let us start with the *phenomenologists*. They go in the footsteps of Heidegger and Husserl. Heidegger had a very gloomy view on technology. According to him, technology made us look at reality as a resource. Technology has made us unable to appreciate reality as it is. When we see a tree, our first thought is not: "o, how beautiful", but rather: "how many planks can I make out of that tree?". This is of course a distorted view of realty, but according to Heidegger it is embedded in our thinking so strongly, that "only a god can save us" from it. As Heidegger did not believe in the existence of a god this means a view without hope. A contemporary philosopher of technology who extended this view is Albert Borgmann. According to him, devices have a place between us and reality so that we are much less engaged with reality than before (Borgmann 1984). To heat a room, we no longer go into the forest, chop wood and carry it home, but only slightly twist the thermostat and the commodity of heat is there for us. Not much engagement left there. In a similar way, we do not go to a shop, buy ingredients for a meal and cook it, but we buy a ready-made meal in a plastic box, put in a microwave oven and push the button. Rather than playing an instrument, we insert a cd into the player and – again – push a button. In general, our engagement with reality has been reduced to pushing buttons. This is what Borgmann called the *device paradigm*. He sees only one way out: increase engagement by *focal activities*. Those are activities that do require engagement, such as: cooking our own meal, jogging, or attending a church service. Borgmann realises that our economy does not allow for fulltime focal activities, but he pleas for a two-part economy, one part of which is based on the device paradigm and the other part on focal activities, so that at least we keep being reminded that there is more than devices.

Another phenomenologist is Don Ihde, and he has a more positive view on technology as impacting our experience of the lifeworld. According to him, technology can serve as an intermediary between us and reality in four ways (Ihde 1990). The first way is the embodiment relation, in which a technological device through which we experience reality becomes almost one with our own body. People who wear glasses do not notice anymore. A second way is the hermeneutic relation in which technology makes a translation of reality that we perceive and that needs interpretation in order to be understood correctly. A physician studying an MRI scan has to interpret the picture correctly in order to make a correct diagnosis. Ihde's third way is the alterity relation in which the technology alters reality (or even shapes an entirely new one) that we look at, such as in the case of a computer game or a science fiction movie. The fourth way is the background relation in which the technology creates a background noise or smell or light that we are not aware of but that does influence our perception of reality (that is why we do not see so many stars in the night sky in a city). Ihde claims that as long as we are aware of the way technology influences our perception, this need not be a problem (it can even enrich our perception, because we see things that otherwise we could not see), but misunderstandings can occur when we do not realise this.

Let us now move to the next main stream in philosophy, namely the *Critical Theory* (or Frankfurter Schule). This stream does not focus on the individual's perception of reality, like Heidegger and the phenomenologists do, but on the social dimension of reality. Philosophers in this stream show how technology impacts society and the other way round. They take a neo-marxist approach in that they acknowledge the fact that Marx's expectation that capitalism would necessarily collapse did not happen and that apparently measures were needed to make this happen. One of the philosophers of technology in this stream is Andrew Feenberg. According to him what must happen is that technological developments go in two steps: primary and secondary instrumentalisation (Feenberg 1995). In the first step a socio-technical problem is separated from its social contexts and solved by engineering. In the phase of secondary instrumentalisation, the solution is put back into the social context whereby society can make alterations to the technology and its function. Feenberg gives the example of the French Minitel system, that was originally designed to enable the French government to disseminate information through a network of terminals in shopping malls and other public places, but that was later taken over by hackers to exchange information. Thus a democratisation of the technology took place in the phase of secondary instrumentalisation after the primary stage had resulted in a centralist information system. Feenberg believes this should more or less be the pattern for all technological developments.

Another important stream in philosophy is *pragmatism*. John Dewey was an important representative of this stream. Pragmatism claims that what is true is what works (that is pragmatist epistemology) and what is good is what works (that is pragmatist ethics). Larry Hickman has taken Dewey's ideas about learning by experience and has applied it to technological developments. According to him what engineers do should be the model for all social decision making (Hickman 2001).

Engineers do not have prefixed ideas about what a technology should look like. They try out options and the one that works best is the one they choose.

Finally, I want to mention those streams that are based on religious points of view. One these is *reformational philosophy*, and this philosophical approach has particularly contributed to developing ideas about the nature of technological developments and moral values in technology (De Vries 2010b). In his book *Thinking Through Technology*, Mitcham mentions Hendrik van Riessen as a representative of this stream that in a very early stage of philosophy of technology had already developed many ideas about the nature of technology as a process in which potential sense in reality is opened up (disclosed) in designing and making activities. Egbert Schuurman continued his work by pointing out that different motives can be behind this: motives of lust for control or of care and stewardship. Currently, philosophers of technology in this stream (Hoogland, Jochemsen, Van der Stoep, Verkerk and De Vries, to mention just a few) show how the concept of practices (coherent totalities of human actions directed towards certain internal and external goods) can be used to show how normative issues play a vital role in all technological developments.

This small survey shows the variety of approaches that are present in the 'technology as values' way of reflecting in the philosophy of technology. It is evident that this way of looking at technology offers many options for dealing with social and moral issues in technology education. But also the other three ways of reflecting on technology (as artefacts, as knowledge, and as activities) are relevant for technology education. Let us now turn to the question how philosophy of technology can be used as an input for technology education.

TECHNOLOGY EDUCATION AND THE PHILOSOPHY OF TECHNOLOGY

When we start with the 'technology as artefacts' approach, it is evident that this is one that certainly appeals to pupils. Studies in the Pupils' Attitude Towards Technology (PATT) tradition have shown that many pupils can only think of technology as the large set of artefacts that we see around us (De Vries 2005). In technology we want them to have a more balanced view on technology, but at the same time we have to acknowledge that artefacts indeed play an important role in our daily lives and that it is important that pupils have an understanding of what they are and what they do. A problem here is that there are so many and that most of them are complicated to explain. Here the two natures of artefacts, as conceptualised in the philosophy of technology, can be a useful tool to teach about artefacts.

1. Rather than beginning with the complexity of many artefacts, we can start helping pupils to get a first, basic understanding of artefacts by making them reflect on the physical and the functional nature of the artefact first. The elegant simplicity of the dual nature approach is appealing for teachers as education almost by definition looks for ways in which complex things can be simplified to make them teachable and learnable. Once they have learnt to recognise the two natures

in artefacts we can move on and introduce basic concepts like operation of the artefact and the ways in which the two natures are connected in design work. This approach can be extended to systems in a next step of understanding.

2. In a similar way, the 'technology as knowledge' approach can be used to derive implications for teaching and learning technology. The normative dimension in technological knowledge, as identified by philosophers of technology, for instance, makes us aware of the need to teach not only how things are, but also about how we would like things to be. Pupils must learn to develop ideas about how things can be improved and in what respects. They must also learn to see technology as a matter of decision making rather than a matter of necessities. That is why technological knowledge often is the outcome of decisions rather than of measurements. Using a taxonomy for technological knowledge like Vincenti's can illustrate this for pupils in a practical way. This characteristic of technological knowledge (it's normativity) also brings in ethical and aesthetic issues as a highly desirable component in technology education.

The lessons learnt in design methodology ('technology as activities') can be used to develop design projects that do not suffer from the naïve ideas people had in the early days of that discipline. In technology education, as in the world of real design, we have to acknowledge that design processes are fuzzy to some extent by nature and vary between different types of products and technologies. Still we can find simple flowcharts for design processes in course material and we have to be cautious not to let these make pupils think that design is simply a matter of following the steps one by one. Such flowcharts can fulfil a useful role in helping novice designers to learn how to become more independent of such fixed sequences of steps. The idea of scaffolding in current educational theory supports the idea that flowcharts can serve as a useful support that gradually can be taken away when pupils become more acquainted with design work. Thereby we have to make sure that the flowcharts do not become a straitjacket when we keep using them too long. We also have to be aware of design processes in which knowledge is both used and developed. We have to build in moments in which pupils have to be conscious of potentially useable knowledge they already have, but also moments of reflection that make them aware of new knowledge that they have gained during the design process. This can be both knowledge about the process of designing as well as knowledge of the content matter. Building tall structures, for instance, may have taught them about stability, but we have to make this learning explicit if this knowledge is to be useful for later design experiences.

Finally there is the approach of 'technology as values'. From literature in this approach we can find lots of opportunities to help pupils develop their own normative ideas about how technology should function in society and in their own personal lives. I would like to mention the option of using science fiction movies as a practical means of bringing this into the classroom. Often, pupils have seen such movies but not recognized the sociotechnical issues that are raised (often in an exaggerated way to make it more visible) by the filmmakers. Movies like 2012, the Day After Tomorrow and Waterworld make possible effects of environmental problems visible in a speculative, but impressive way. Movie such as Gattaca, The Island, The Sixth Day direct attention to possible damage to our human identity and personality when technology makes us value human life only on the basis of DNA, organs and other physical aspects of our humanity. Some of these movies are certainly not suitable for younger ages, but even for those children there are sometimes very suitable options for using movies. The charming Disney/Pixar animated movie WALL-E can be an excellent tool for making younger pupils reflect on what an unlimited use of technology can do to our world and to our personalities.

I hope I have made clear that all four approaches to reflecting on technology can have implications for teaching about technology. I think we have only just begun to exploit the rich resources that are available here. Perhaps it was a lack of awareness of these resources that have caused certain biases in the way technology education curricula have been developed in different countries. This is what we want to turn to now: what type of approaches have been used in turning aspects of the nature of technology into curricula in the past in different countries. After having described some approaches in their pure form, I will show how today we find many blends of the different approaches in current curricula for technology education (De Vries 1994).

APPROACHES TO TECHNOLOGY EDUCATION

Orientation towards craft skills

Probably the oldest approach to technology education is the craft-oriented approach. Most technology education curricula have emerged from craft-like subjects in the school curriculum. Still today, we can find technology education is very much like that (Denmark, Austria and Switzerland are examples if such countries). In this approach the focus of technology education is the learning of craft skills. Pupils usually make pre-designed artefacts and the outcome is assessed mostly on the basis of the quality of the artefact, not the process. One could say that in this approach a particular type of activity (‘technology as activities’), namely the manual making process, is emphasized.

Orientation towards industrial production

In this approach again a making process gets all the attention, but here it is the mechanized and automated production process. This approach was dominant in the former Eastern-European countries as production labour was seen as the heart of society in the communist ideology. Pupils were made familiar with the industrial production process. Here, too, they made pre-designed artefacts, but now often in the school version of a production line. This and the previous approach often feature in technology education in a vocationalized version. In such a version the primary purpose of technology is seen as preparatory for a technical study and not for general education. This version is still popular in a lot of countries.

Orientation towards design

This is the third approach in which an activity is the focus, but here it is the design activity. The country with the longest tradition in this approach is, no doubt, England. Primary purpose of the curriculum is to stimulate creativity and design skills through projects in which pupils make and then materialize their own design. Often the range of topics is very wide and certainly not limited to engineering. Food and fashion may also be included. The assessment of the pupils' work is mostly based on the process and to a lesser extent the product.

Orientation towards 'high tech'

In this approach the 'technology as artefact' aspect of reflection on technology is emphasized, and with a preference for the more advanced artefacts, such as computers, robots, automated systems and the like. Pupils learn about the construction and operation of such artefacts and systems. Simulations of such artefacts are often included in the classroom activities. It will be clear that this is a fairly expensive approach to teaching technology. In countries like France and Israel that like to promote themselves as high tech countries this approach is often practiced. The unsuccessful effort to introduce this approach in South Africa shows that it requires a lot of the school's budget and infrastructure.

Orientation towards application of science

This is an approach in which knowledge is highly appreciated, but it is scientific rather than technological knowledge. This approach is often practiced in the school subject 'science' rather than 'technology'. Technology is seen as an attractive context for teaching science. Scientific knowledge is used to explain the operation of technical artefacts. In that sense, it is an approach in which the 'technology as artefacts' reflection mode on technology is the primary focus. We can see this approach in many countries worldwide.

Orientation towards key competencies

The key-competencies-oriented approach is one in which 'technology as knowledge' is the focus, and particularly knowing-how is at the core of the curriculum aims. For some time this approach was strongly supported by industry in Germany, as companies saw skills like cooperating, organising, presenting, taking initiative and responsibility as the key competencies they would like their workforce to have. In this approach pupils do a lot of project work, often with an industrial flavour. Of course there was always a relation with technology content, but the assessment was based primarily on the key competencies.

Orientation towards engineering concepts

Here again we have an approach in which 'technology as knowledge' features strongly. Now it is the more theoretical knowledge that is taught and learnt. It was quite a struggle to find out what basic engineering concepts are, but gradually concepts like 'systems', 'matter', 'energy' and 'information' emerged (Wolffgramm 1994). This approach was popular in Germany and pupils were asked to make theoretical analyses of systems in which they had to identify the flow of matter, energy and information.

Orientation towards social aspects

In this approach it is the 'technology as values' way of looking at technology that gets most of the attention. In the early years of technology education in Sweden this approach was popular. Pupils learnt about social impacts of technology and ethical questions were asked concerning technology and humans. One could also say that many of the STS (Science, Technology and Society) curricula were framed according to this approach. Activities could involve real situations in the local context of the pupils.

Blending of approaches

Due to the increased international exchange of ideas and information, most countries now have a curriculum that no longer has only one of the approaches listed above as its main focus, but rather a blend of different approaches. In the USA Standards for Technological Literacy (ITEA 2000), for instance, one can clearly detect elements from all approaches mentioned above. Also the UK curriculum is definitely richer than design only. New Zealand is another example of a country in which elements from different approaches have been brought together to form a rich and balanced technology education curriculum.

IMPLICATIONS FOR TEACHING ABOUT TECHNOLOGY

In this final section, some practical implications for teaching about technology will be presented. After all, teachers may wonder what the relevance for these philosophical reflections could be for them. Philosophy seems to be remote from what they do anyway, and why would that be different for philosophy of technology? In the preceding sections, some hints for implications have already been given, but they will be elaborated further here. Teachers make day-to-day decisions continuously.

Often the arguments leading to choices have a fairly pragmatic character: what is feasible in the classroom, what would keep pupils involved, etcetera. Those are all valid arguments, but it would be valuable if arguments coming from a philosophy of technology knowledge base would also play a part in these decisions.

What philosophy of technology can do is give teachers themselves a good understanding of the nature of technology. But it is also important that pupils get a good understanding of the nature of technology. In fact, all practical choices concerning activities in classes should be made so that all the activities somehow add up to a realistic and valid image of what technology is. That means that ideally in every activity pupils are stimulated to think about the nature of the artefacts they design, make and/or use, about the knowledge that they draw from in order to do that, about the nature of the process they go through, and the values that are involved. Of course, not each and every project needs to be burdened with such a load, but the fourfold way of looking at technology (artefacts, knowledge, processes and values) can serve as a general guideline in the background for teachers to make decisions about what will be done in classes. For instance, a teacher preparing a project in which pupils will design a simple vehicle that travels a certain distance using energy from an elastic band, could introduce this activity to pupils in such a way that they have to think about how to choose the vehicles properties so that function and physical realisation are complementary. Furthermore, they have to consider what knowledge from physics might be useful, as well as knowledge from technology (e.g., about transmissions). Thirdly, they are challenged to plan their 'design and make' process while considering what steps are usually in a design process and what way to go would be the best in this particular case. Finally, they can be challenged to think about values like being economical with materials, and if the project is extended a bit to include some more theoretical work on real vehicles, they can reflect on values like costs, safety, aesthetical values, etcetera. By preparing the project in this way, the teacher turns the fourfold way of looking at technology from philosophy into a practical guideline.

In the example above, the emphasis is on the design and make process and in the extended version also social aspects are considered. The list of different approaches to technology education can inspire teachers to opt for a richer activity, in which elements from other approaches are also present. Pupils could also explore the engineering concepts of systems, optimization, and resources in doing this project. They may also be stimulated to think about how the vehicles they design could be produced in a factory. In doing the project, specific opportunities for acquiring key competencies could be built in, for instance, by having the students present the end product in a well thought through manner, or have them pay explicit attention to a good division of labour in the group. This way the values of the various approaches are combined and rich learning opportunities emerge.

Apart from these types of planning activities, there are more practical decisions to be made. Let us think about the availability of resources in the classroom. What consequences may philosophy of technology have for that? It would be nice if the fourfold way of looking at technology would be mirrored in the classroom or lab.

That would mean that artefacts would be available for pupils to explore and so develop an understanding of their dual nature. It would also mean that knowledge sources would be available for them to consult and involve in their work. It would mean that space for different types of activities would be available (for designing, making and testing/using/evaluating). It would also mean that values are somehow present. That sounds rather abstract, but there are various ways of incorporating values in a practical way. Safety and sustainability as values in technology can be illustrated by posters, for instance. Maybe there are opportunities to watch DVDs or video clips online about the social and human aspects of technology. One attractive opportunity for that is to use science fiction movies and let pupils reflect about whether or not they would like to live in the world as it is presented in those movies.

Finally, I would like to mention decisions regarding assessment of pupils. Quite often, what is assessed is fairly limited. In many cases the practical abilities of the pupils will be assessed, and perhaps some paper-and-pencil tests will be used to check their understanding of theory. But there is much more to be assessed if we use the philosophy of technology structure. What is not assessed, for instance, is the pupils attitude towards technology and their concept of it. It would be worthwhile to assess those, too. This need not necessarily be done by fancy questionnaires or other formal instruments but, perhaps, could be done better by talking about it with the pupils. Teachers could plan reflective moments in class in which individual pupils are invited to express their image of and attitude towards technology and this can give rise to a discussion, but at the same time gives the teacher an impression of the progress (or lack of that in the worst case) of the pupils' overall thinking about technology.

CONCLUSIONS

In this chapter we have seen how philosophical reflection on technology can take different forms. One can look at technology as a set of artefacts, as a knowledge domain, as a series of activities and as an aspect of our human being in which, by definition, values play an important part. We have also seen how each of these four modes of reflection on technology has implications for technology education. Finally, we have seen how different approaches to technology education can emphasize different elements of these four modes and how more recent developments in technology education have brought about combinations of approaches that result in a curriculum that contains the various modes of reflection on technology. Although any attempt to develop a set of standards or a curriculum framework for international use has been unsuccessful, it is to be expected that the internationalisation of technology education will continue and gradually make technology education curricula look more similar than in the past when countries usually had a rather outspoken preference for a particular aspect of technology. This will certainly be to the benefit of technology education in general. It will cause an increased interest in exchanging materials and making joint efforts to develop curricula and do research. In the end teachers and pupils will have the ultimate benefit of this development.

That way technology education makes its own contribution to the literacy that is needed for today's world.

REFERENCES

Baird, D. (2004). *Thing knowledge*. Chicago: Chicago University Press.

Borgmann, A. (1984). *Technology and the character of contemporary life: a philosophical inquiry*. Chicago: Chicago University Press.

Cross, N. (1984). *Developments in design methodology*. Chichester: Wiley.

Feenberg, A. (1995). *Alternative modernity: the technical turn in philosophy and social theory*. London: University of California Press.

Ferguson, E. S. (1992). *Engineering and the Mind's Eye*. Cambridge, MA: MIT Press.

Hickman, L. (2001). *Philosophical tools for technological culture*. Bloomington: Indiana University Press.

Ihde, D. (1990). *Technology and the lifeworld: from garden to earth*. Bloomington: Indiana University Press.

International Technology Education Association 2000. Standards for Technological Literacy. Content for the Study of Technology. Reston, VA: ITEA.

Meijers, A. W. M. (2000). 'The relational ontology of technical artefacts', in: Kroes, P. A. and Meijers, A. W. M. (Eds.), *The Empirical Turn in the Philosophy of Technology*. Oxford: Elsevier Science, pp. 81–96.

Mitcham, C. (1994). *Thinking Through Technology. The Path between Engineering and Philosophy*. Chicago: University of Chicago Press.

Meijers, A. W. M. and Vries, M. J. de (2009). 'Technological Knowledge', in: Berg Olson, J. K., Pedersen, S. A. and Hendricks, V. F. (Eds.), *A Companion to the Philosophy of Technology*. Chichester, UK: Wiley-Blackwell, pp. 70–74.

Morris, T. (1999). *Philosophy for dummies*. New York: Wiley Publishing Inc.

Vincenti, W. G. (1990). *What Engineers Know and How They Know It*. Baltimore: Johns Hopkins Press.

Vries, M. J. de (1994). 'Technology education in Western Europe'. In: Layton, D. (ed.). *Innovations in science and technology education. Vol. V*. Paris: UNESCO.

Vries, M. J. de. (2005). Teaching About Technology. An Introduction to the Philosophy of Technology for Non-Philosophers. Dordrecht: Springer.

Vries, M. J. de (2006). "Ethics and the Complexity of Technology: A Design Approach", *Philosophia Reformata*, *71*(2), 118–131.

Vries, M. J. de and Dakers, J. D. (2009). 'Philosophy of Technology for Research in Technology Education, in: Jones, A. and Vries, M. J. de (Eds.). *International Handbook of Research and Development in Technology Education*. Rotterdam/Taipei: Sense Publishers, 141–150.

Vries, M. J. de (2010a). 'Engineering science as a "Discipline of the Particular"? Types of Generalization in Engineering Sciences. In: Poel, I. van de and Goldberg, D. E. (Eds.), *Philosophy and Engineering: An Emerging Agenda*. Dordrecht: Springer, 83–94.

Vries, M. J. de (2010b). 'Introducing Van Riessen's work in the philosophy of technology', *Philosophia Reformata*, *75*(1), 2–9.

Wolffgramm, H. (1994). Allgemeine Techniklehre: Elemente, Strukturen und Gesetzmäßigkeiten; Einführung in die Denk- und Arbeitweisen einer allgemeinen Techniklehre, Band 1. Allgemeine Technologie. Hildesheim: Verlag Franzbecker.

AFFILIATION

Marc J. de Vries
Delft University of Technology
The Netherlands

DAVID SPENDLOVE

3. TEACHING TECHNOLOGY

INTRODUCTION

If you are reading this book from front to back then you have already started the process of thinking about the broad implications of 'Technology Education' (TE) and some of the philosophical issues that pose deep questions that you need to consider as a teacher. Equally if you started reading from the back (which is something I tend to do) then you will have considered Assessment, Learning and Design as essential areas for consideration. In drawing this to the reader's attention the intention is to highlight that this chapter (perhaps more so than other chapters) is very much interrelated to all the other topics dealt with in this book, as it is the combination of all these topics that come into play in the form of your teaching persona. Therefore as you go through this chapter it is important to consider how the various elements fit together as all of your thinking, personality, idiosyncrasies and (ir)rationalities will be played out to your audience of learners as you teach. Whilst doing this it is worth pointing out the underlying conceptual framework that has determined the two main themes that have driven the selection of content within this chapter.

Firstly – Shulman's (1987) concept of pedagogical concept knowledge (PCK) highlights the need for teachers to understand the interaction of both subject content and effective teaching strategies to ensure successful learning takes place. Therefore this chapter attempts to draw these areas together to help the reader recognize that effective teaching is much more than merely knowing a lot of content, and that careful consideration of the interplay of content and pedagogical strategies is required in order to deliver appropriate and considered skills, attitudes, concepts and knowledge in an accessible way.

The second theme draws upon twenty five years of the author's experience in technology education and is an attempt to select those perennial themes that are central to the delivery of technology education, in addition to identifying emergent themes which will occupy teachers thinking in future years. The chapter is therefore divided into two sections with the first section dealing with broader teacher knowledge; issues which are both generic but also pertinent to technology education that help contextualise the role of the teacher. The second part will focus upon the more specific nuances of pedagogical knowledge for technology education. Collectively these two sections represent some of the key enduring and emerging PCK issues within technology teaching.

P. J. Williams (Ed.), Technology Education for Teachers, 35–54.

TEACHER KNOWLEDGE

Teaching and Teacher Effectiveness

The world of teaching and economics have never been too closely associated, however as the world has been through a major financial crisis the cost of education has become a key political factor in government financial considerations. Therefore school and teacher effectiveness have become key areas of research growth and although they remain contentious areas, as both terms are highly value laden, increasingly the cost and not the value of teaching is being calculated. As such, it would seem an interesting question to pose at the start of this chapter as to what is the value of a teacher? What is the value of one days teaching – in terms of the payback to a society? Could we even reduce this question to a single lesson? So does a single lesson have sufficient payback to justify its worth and if not a government may legitimately then ask why is it being taught?

Of course many would argue that it is impossible to calculate the value of education and it would be a highly skewed view of education if you only measured outcomes in terms of economic benefit rather than social and cultural value or significance to the individual. The difficulty is that in a period of austerity, teacher reform is very much interested in such forms of payback and as such, discussions of this nature promote questions of the purpose of education and whether some subjects are financially more valuable than others (perhaps TE is one of these subjects) and that some subjects are culturally more important (again we could also argue this for TE as well).

In broad general terms the indicators are that increasing the amount of teaching time outweighs the cost of providing that instruction (Pishke, 2007) and that increased grade performance does lead to increased labour market earnings. Next comes the question about individual teacher effectiveness and teacher impact as it is regarded (Aaronson, *et al*. 2007) that effective teachers make an impact of around 40% difference upon student attainment. Therefore whilst a school building, the principal or resources will all have some impact upon a learner, it is the teacher and student relationship that is considered the most important. Whilst the relationship between attainment and economic return is without doubt important it is also worth noting that the impact upon student dispositions can last a lifetime and cannot be so easily measured. So whilst the clinical figures on attainment are important we mustn't forget that a teacher's impact can be upon an entire lifetime, which we must also remember can be both a positive and negative effect.

In drawing generalizable conclusions, such as the above, to the reader's attention it is important to highlight the complexities in any discussion on effectiveness particularly in relation to the diversity of both the teaching and learning community. It is also to try to raise the awareness that whilst the productivity of teachers can and will increasingly be measured, teachers and students are much more than commodities that can be standardised. So what works in one community with a group of learners cannot always be applied across different communities. There are however some general findings that can give us some ideas as to what may generate effective teaching. Most significant are teachers who are referred to as 'Class Enquirers' (Croll, 1996; Pollard *et al*, 1994) who have been found to generate significant gains in learning through utilizing around four times as much interactive whole class teaching compared to those who are 'Individual Monitors' (those that tend to spend more time in one to one situations).

As indicated, the difficulty is that this does not provide a panacea for all teachers as what was also found was that the interactive whole class methods were not the only reason for high student gains – it was something about the teachers' disposition which encouraged them to use such an approach. Equally the perceived wisdom would suggest that more individual time would have greater gains in student learning, however the correlation isn't always clear. Mortimer (1988) found that individual time tended to be occupied with low-level strategies and general support. Such approaches can give the appearance of student gains when in fact this may be artificial given the high-level teacher support. Indeed to be highly contentious it can even be considered that if you remove the teacher altogether (Ranciere, 1991) then student learning (but not necessarily attainment) can also increase. The point here is not to make the teacher redundant (although do be wary of an economic argument for this) but that we need to conceive of the teacher in a way that if they get it right they can have profound positive effects and can be a significant asset to students learning. However if teachers get it wrong they can have an equally detrimental effect upon students learning and lives.

Perhaps one of the most significant findings related to teacher feedback however is the quality of feedback that a learner engages with. Notice however that I have not indicated that it is teacher feedback given to the learner – in fact the learner providing feedback to the teacher is perhaps more profound. The point being that what has been found is that high quality feedback has a significant effect upon learning, but such feedback can be peer or self identified. The teacher's role in such circumstances is not to act as the 'font of knowledge' but to facilitate students accessing high quality feedback through self-reflection and peer assessment. Again it may go against perceived wisdom but highly effective teaching is about reducing the learner dependency upon the person we call the teacher and shifting responsibility to a group and to the individual.

In 'The Teaching Brain', Battro (2010) extends this concept by suggesting that whilst 'brain based learning' is now part of the vernacular; brain based teaching is an under theorised area. Battro points out that the Latin expression 'docendo discimus', when we teach we learn, expresses a common experience that we all share. So 'brain based teaching' does provide an interesting opportunity to reflect on the dualism of teaching and learning. Most notably – who is the teacher and who is the learner? Therefore the most powerful forms of teaching are when teachers are co-constructors and therefore co-learners together, which prompts the question – what is a teacher for?

Teaching for Collaborative Learning

I once was taken around a school by the principal, and as he was pointing the various highlights of the tour he stopped and cupped his hand around his ear and said “listen”. I apologised and said I couldn’t hear anything and he replied, “exactly, silence, all the students are hard at work”. I couldn’t help but feel slightly sorry for the Principal and more importantly the students in his school as in prioritising silence he clearly had no conception of social constructivist approaches to learning which highlight how language and discussion mediate learning. It slightly perplexes me how silent classrooms are still seen by many as a good classroom as the true teachers art is not to stop talking but to redirect and encourage dialogue in the areas they wish students to learn in. Through the pursuit of dialectic and dialogic processes, collaborative, social and intellectual gains are generated and as such teachers pedagogical strategies should be aimed at engendering discussion rather than extinguishing it. Kruger (1993) has identified how, when students collaborate, they advance significantly more in their understanding, and how through peer collaboration students engage in a whole range of high level skills such as defining, analysis, synthesis, conflict resolution, questioning and evaluating.

As indicated earlier, the art of the teacher is to encourage scenarios that engender learning through social constructivist approaches (Vygotsky, 1986; Wertsch, 1984; Rogoff, 1990), which generate successful communities of learners (Lave and Wenger, 1991). Hamilton (2004, 2007) has demonstrated how cognitive conflict; social construction and metacognition can also be enhanced during collaborative design and technology problem solving activities. Such activities stimulate collaborative learning which Hennessy and Murphy (1999) define as “communicating and working together to produce a single outcome, talking and sharing their cognitive resources to establish joint goals and referents, to make joint decisions, to solve emerging problems, to construct and modify solutions and to evaluate the outcomes through dialogue and action” (p.1).

The essential ingredients for collaborative learning are further acknowledged by Kruger (1993) as

(a) working at the level of ideas;
(b) finding errors, finding differences, agreeing to disagree; and
(c) communicating their ideas to one another, making discoveries about what works, and generating good solutions.

As such, the potential for collaborative learning in technology education is clear as increased cognitive development and increased creativity are rich by-products of stimulating dialogic processes. Collaboration also enhances interpersonal learning (King & Sorrentino, 1983) and self esteem (Bandura, 1997), but in order for teachers to take such opportunities they have to be convinced such pedagogical practices work, particularly if they are unfamiliar with them. Hennessy and Murphy (1999) have stated that despite the rhetoric, collaborative learning is often ignored in technology education whilst Dow (2004) suggest that teachers ‘implicit beliefs’ about learning inform the pedagogical strategies that they employ and as such they tend to teach the way they were taught or the way they feel they learn. Often this is using ‘transmissionist’ approaches to deliver limited skill and knowledge acquisition, which can ultimately represent barriers to creative, designerly and collaborative learning environments.

The Role of Knowledge in Teaching

The content of technology education remains largely ‘ill defined’ and as a consequence the essential knowledge of technology education is often difficult to prescribe or even describe. This can be considered as both a strength and a weakness of the subject. As a contrast, for example, Science education subject knowledge is considered highly prescribed, often leaving teachers little freedom to embrace new topics and theories to the extent that there are examples of the teaching of outdated concepts, simply because they are engrained in the system.

In technology education quite the opposite is true and the difficultly as explained previously is that there is not an established body of skills, attitudes, knowledge and concepts that we can reliably draw upon. The difficulty with this is that progression in learning is often necessarily not mapped out and as a consequence it is not uncommon in technology education for a learner to engage with the same topic several times in their school life, each time being the same content at the same level but a slightly different, but insufficient, context.

The advantage of not having prescribed content is that ownership lies with the teacher who can draw upon their own and their students interests, and recent developments to engage learners with relevant concepts when required. Such an approach requires the teacher to therefore be proactive and take ownership of the curriculum. This represents the current status of technology education in most countries, in that the application and development of knowledge, skills, concepts and attitudes, even where there is national policy, is often patchy and largely dependent on teacher’s individual circumstances and local context.

Technology education is however unusual in that it meaningfully consumes knowledge from all areas of the curriculum. It applies knowledge from Mathematics, History, Science and so on, and as a consequence transforms such learning into useable information to be applied to unique and innovative contexts. Whilst this is a strong rationale for the subject, the lack of clarity over essential learning within technology education ultimately limits understanding and progression. The transformation of such learning in technology education remains an area that is under theorised and underdeveloped, yet is it represents both the uniqueness of the subject and the need for high levels of thinking (for example based upon Blooms taxonomy) related to evaluation, application, synthesis and analysis. In considering this I will briefly examine the context of what it is that learners are expected to be taught in technology education, and also the nature of related knowledge.

Reflection on the Nature of Technological Activity

Having identified that teaching is a highly politicized and complex activity, it is necessary to also acknowledge that this is compounded in technology education by it being a relatively young subject, which does not have an established pedagogy or defined body of content knowledge, skills, concepts, attitudes or processes. The advantage to this is that without such defined approaches, teachers have the opportunity to be open-minded as to the content and processes they employ as the pedagogy and content they engage with isn't entrenched in the system. In fact this is how technology education has evolved over the last forty years: through the optimism and ambition of teachers to enrich the curriculum in natural ways.

The disadvantage however is that without a defined pedagogy for technology education. The learning can at times be hit and miss, particularly as there remains a debate over whether pedagogical strategies should promote a focus on 'technological content' or whether the focus is upon guiding learners through a 'technological process'. It therefore remains a considerable issue in technology education that often the preoccupation with the progression of a task (as in completing a product) does not translate into similar progression in terms of learning, and whilst it can be argued that progression of a task does constitute learning often it may be ad hoc, random and difficult to identify. This is not to suggest powerful leaning moments cannot occur, quite the opposite, but to have an education programme based upon hoping something valuable might occur is contentious, and in an age of increased accountability is unlikely to be mandated. Equally, such an inadvertent approach represents the antithesis of reflective practice (Shön 1983, 1987) and leads to an overly 'pragmatic' delivery and technicised and instrumentalist model of curriculum development.

Given the potential breadth of technology experience ranging from arts, crafts and designerly activity through to technical and engineering type activities, it becomes an interesting challenge for all technology teachers to decide on the 'what, how and when' of their students engagement. Many teachers who are faced with such a challenge have increasingly become disenfranchised from making such decisions as national systems using standardised approaches are increasingly adopted. Such approaches de-skill teachers and present a centralised view of technology based around common norms.

The defining of technology education will be addressed more purposefully elsewhere in this book but an important point to reflect upon is the development of a teacher's 'personal construct', in relation to their engagement with, and delivery and ownership of, the curriculum. This construct is an important prerequisite of effective teaching. Engaging in such reflection enables teachers to participate in an informed debate at school, local and national levels. Banks *et al*. (2004) has described such 'teacher constructs' as a complex amalgam of prior experiences of learning, past histories and implicit beliefs. Within the example given, they describe the 'DEPTH' model; a construct based around three graphically represented intersecting domains related to ‘School Knowledge’, ‘Subject Knowledge’ and ‘Pedagogical Knowledge’. By reflecting within each of these domains and engaging in reciprocal reflection across the domains, beliefs and assumptions can be challenged that may not otherwise be justifiable or sustainable.

Through engaging in a reflective and reflexive approach, all teachers of technology should have a clear, justifiable personal construct of what they believe constitutes ‘effective’ teaching. This view has to be rationalized and contextualized in relation to the environment in which they will be delivering technology education.

Teacher Coping Strategies

The simple saying of ‘comfort the disturbed and disturb the comfortable’ is a useful reminder about the need to mediate feelings and anxieties particularly when dealing with students in complex learning situations where there is often a greater sense of vulnerability for all involved. In drawing the saying to the reader’s attention it is important to note that if delivered incorrectly it can have the opposite effect and the ‘disturbed’ can become more disturbed and the comfortable become more comfortable. I have often noticed such strategies backfire as the teacher, whilst attempting to fire up the disenchanted, merely increases the anxieties of those students who were already anxious.

Over the last decade the concept of emotional wellbeing and emotional literacy have taken on a new significance and most in education would now agree that attempting to address a child’s emotional needs and feelings is as significant as addressing their learning needs (although both can be achieved at the same time). The irony of such strategies is however that many teachers have found the emotional support of their students stressful, and as a result the teachers own wellbeing doesn’t seem to be taken into consideration. Therefore there is a danger when reading this chapter (and the rest of this book) of being overwhelmed by how big and complex ‘technology education’ may seem. Such feelings are not unusual and are quite positive, as it is an indicator that you are grasping both the significance of teaching, the enormity of the task, as well as wondering how you can do your best.

Teacher emotions and feelings are a largely neglected area, but it is essential that teachers develop coping strategies to enable them to engage with the demands that will be placed upon them. Behaviour management, special educational needs, subject knowledge, dealing with colleagues, time management and complex relationships will all place demands upon the teacher which if not addressed appropriately can result in significant physical and emotional strain, and present a challenge to individual wellbeing. Interestingly, whilst governments around the world have spent considerable sums of money on developing student’s social and emotional wellbeing, few have acknowledged the emotional demands upon teachers or put in place strategies to help teachers. As a consequence some teachers simply disengage, they burnout and become disenfranchised, and whilst this is one form of coping strategy it is not a useful long-term strategy.

Whilst there is insufficient space within this chapter to fully explore the issues related to teacher's coping strategies, I want to briefly focus upon one area, teacher emotions, that might help provide teachers of technology education with some understanding of the complexity of their role and an underpinning rationale to help them achieve success. Ultimately our emotions are out-dated legacies of our past, they have not changed significantly for about 30,000 years and whilst society, technology and civilization have evolved our brains are still predominantly operating in the same way. As such our emotions are subconscious directors of our attention that occur prior to our feelings, they are the drivers of our cognitive and physiological attention and are ultimately complex, primitive and difficult to define yet they provide a reflexive ordinance system which influence our everyday behaviour, decision making and creative thinking. Emotions therefore both misguide us and protect us, and it is essential for the teacher to know which feelings to act and rely upon. In the same way that fire fighters have to educate their emotions to not act upon impulse (for example running towards a burning building rather than away from it) then so too do teachers often need to give attention to those students that are the most demanding and that cause them the most difficulty, as they are often the most needy. Therefore by recognising the significance of emotions in both teaching and learning (Spendlove, 2008), teachers become empowered, as they are able to unravel some of the more subtle complexities of the classroom.

Dealing with difficult students, demanding colleagues and curriculum uncertainties can all generate strong emotions and cognitive dissonance. Indeed in creative learning environments such emotions can be heightened further by the increased uncertainty and riskiness, which are essential ingredients of creativity. In such an environment teachers may 'feel' the need to become more directive and conservative in their teaching, and again teachers need to challenge their own emotions in order to facilitate pupil growth. In such environments teachers need to model the very emotional behaviours that they want their students to adopt, such as managing uncertainty and riskiness.

Immordino, Yang and Demasio (2007) indeed confirm the profound effect that emotions have on a multitude of cognitive processes (including attention, memory and decision making). They also acknowledge how emotion is fundamental for the transference of skills and knowledge learned in the classroom into a real-world environment. Jeffers (2008) has argued that teachers committed to preparing students for the future should grant a high priority to teacher and student empathy, by encouraging activities which build connections between students and cultural objects, as well as between students themselves. As such the development of empathy allows students an understanding of the minds of others, which is critical in helping them to engage in the creative learning process whilst producing products that will engage other people's emotions.

There is however no magic bullet for managing the complex emotional demands of teaching and learning, and there is insufficient space to do justice to the topic within this chapter. However recognising how 'we feel' and more importantly trying to untangle why 'we feel' in a certain way in order to use our emotions to foster positive and productive relationships is an essential prerequisite for coping with the demands of teaching.

PEDAGOGICAL KNOWLEDGE FOR TECHNOLOGY EDUCATION

Process or Content?

A perennial debate in technology education is trying to reconcile the tension between teaching the subject content (the 'what') and the processes (the 'how') with which learners engage, particularly in relation to which (process or content) has dominance over the other. In this debate some would argue that the nature of technological content is that it has to be delivered 'just in case', where information is delivered before learners need it, to use as and when required. As such "a problem solving skill is dependent upon considerable domain knowledge" (McCormick, 2002) and therefore the ability to solve (or resolve) a technological problem is constrained by the existing knowledge base and understanding the learner possess.

The alternative to defining content is to define the process of technological activity. In working on a process model approach, teachers avoid teaching content 'just in case' it is needed, and instead define a range of process steps that enable learners to access information 'just in time' and in 'real time' when needed. Implied within this argument is the concept that as you don't know what you need to know until you need it, due to often working in innovate and ill-defined activities, you should not overly define and constrain technological content. A final element to this argument would be that as technology changes so rapidly, trying to define something before it exists is impossible, and equally trying to define what contributes to an appropriate knowledge base would also require an ever changing list to keep up with new materials and technologies. Although these binaries represent extreme positions in the content versus process debate, it can be seen that both sides have merits and this becomes another issue in the complex task of teaching technology.

The pedagogical strategies we favour often derive from the range of social, cultural and psychological experiences of our backgrounds. Teachers have a history in education, an underlying personal philosophy to life and generally have been academically successful and compliant in order to become a teacher. The chances of them stumbling across a student with a similar set of dispositions are therefore low and as a consequence, teaching in the same way as they were taught is unlikely to have similar successful outcomes. The difficulty is therefore: how does a teacher view teaching and learning, not from the viewpoint of their own particular experiences, which has led to their success, but from a broader perspective which values the diversity of all learners? The reality is that it is not an easy task and one of the dangers of teaching is attempting to reproduce one's own individual success without reflecting upon different contexts.

The difficultly, as always with such polarised examples, is that there is a tendency to try to force the argument so that your views can be accommodated by one side or the other. The reality is that neither a process model nor a content approach is sufficient by themselves, and even the most ardent process model supporter would have to acknowledge that content is important at some stage in the process. The translation into practice is where the limitations and complexities to either approach become clear. For example in very creative practices, a content heavy approach delivered before an activity would be seen as stifling. Whereas a highly technical activity, such as electronics, may require some initial content to enable an activity to be successful.

The difficulty comes when all creative activities in technology education become seen as content free and likewise when anything technical is seen as creativity free. This is where both the teacher's understanding, personal philosophy and curriculum demands come into play as the teacher has to decide upon the most appropriate pedagogical strategy for their classroom. Therefore although Dewey's constructivist approach of 'learning through doing' is seen by some as a process rich and content free approach to technology education, the reality is the opposite. Learning through doing is both rich in content and process, and as a consequence doing (e.g. manufacturing) without learning, and learning without doing represent impoverished forms of technology education, which unfortunately are too common.

The central point of this argument is therefore not content versus process. Instead the question is how do we best have a complex interplay of both where learners have access to a body of content and a range of processes to choose from whilst knowing that additional content and alternative processes can be accessed when needed. Such a 'just in time' as opposed to 'just in case' approach to learning represents an 'immediacy of application' producing more efficient and effective learning.

Should we look at how designers work?

For many years in technology education we have looked towards how designers work in their everyday roles to provide ideas for how teaching and pedagogical strategies might benefit from the insights gained. In doing this four major themes have emerged which capture the essence of designer activity, namely: an absence of algorithms; the interaction between problem and solution; a focus on object worlds; and design as a social process (McCormick, 1994). Whilst these four themes provide a useful underpinning rationale for technology education, it has to be recognized that a utopian view of the designer is worth examining as there is significant value to be gained in also scrutinizing the constraints placed upon professional designers. In many ways the celebration and promotion of individual designers and the unpicking of their practice and methodologies can paradoxically be seen as misleading, and may generate misconceptions as very few designers have the freedom to design what they wish in the way that they wish.

Designing as a profession needs to be seen in its entirety and not be represented by an unrealistic celebrity and elite designer ‘A list’ who are allowed to be as creative as they wish. Recognizing that many designers are frustrated by the constraints within which they work should be an important part of technology education. Designers often have to appeal to a mass market, on low margins, with short time frames in a competitive and consumption orientated economy. Whilst many designers wish to be creative, this is frustrated because they often have to be risk averse in order to supply the market and respond to economic demand. Therefore whilst drawing upon some of the characteristics and strategies that ‘successful’ designers employ, the recognition that many designers simply do not have such freedom needs to be an accompanying message. Equally whilst design is generally seen in a positive light, designers are also key players in the over consumption, obsolescent and unsustainable cultures that dominate world economies. This therefore highlights the tension in drawing upon and applying professional design models within a school culture, and questions their application to the nature of technology education. If we want to empower all students to participate in a complex and evolving society as proactive citizens, then we need to both value as well as challenge the status of the designer.

Having identified this misconception, many designers, when allowed, do attempt to work in creative and innovative ways and this is an area that has received significant attention in the technology education community. Most significant has been trying to capture student capability without it being distorted through ritualistic assessment routines, which Atkinson (2000) identified as perversely mitigating against the development of higher order thinking skills associated with designing. Much interest has been related to capturing the genuine process through students portfolio development, seen by many as the means to capturing the integrity of engaging with a genuine designerly process. Unfortunately the ritualization of ‘the portfolio’ can distort genuine engagement into a series of contrived and compartmentalized entities rather than a coherent whole (McCormick & Davidson 1996; Stables & Kimbell 2000; Kimbell 2002; Welch & Barlex 2004; Spendlove & Hopper 2006).

In attempting to draw upon good practice from professional designers Welch & Barlex (2004, 2005) identified a clear distinction in school practice and professional practice. Whilst attempting to achieve the same high quality outcome, the designers perception of the portfolio was conceived as representing their best endeavours through ‘showcasing’ their work. Within a school context this was contrasted by the portfolio representing the steps to achievement. Many professional designers did however maintain an on-going record of the development of their work, and this was maintained in items such as a ‘job bag’, ‘ideas box’ or ‘inspiration box’. In addition a sketchbook is often “used to enhance designerly thinking and creativity. A *job bag* is used to record designing as it is taking place and for future reference. An *ideas* or *inspiration box* is used to stimulate thinking and as a source of inspiration. A *showcase* portfolio is used to present selected items of finished work” (p7).

In research (Spendlove & Hopper 2006) with student teachers we found that we had to break the cycle of reproducing portfolios in the manner in which they had been taught at school. The poor practice they had learnt (and which had given them notional success) was being reproduced by them in their own work despite not being assessed in the same formulaic way. Breaking the cycle was difficult, but through using a playful approach to designing, students were encouraged to keep sketchbooks, inspiration boxes and so on in order realign the creative process as one that serves a purpose rather than being the purpose.

The developments in trying to capture capability through generation of a portfolio remain, with innovative methods (Kimbell *et al*. 2009; Pagram and Williams, 2010) such as electronic and online portfolios offering new ways of capturing and assessing creative processes. However the challenge for teachers is a clear one in that that the portfolio should generate the parts, steps and stages of assessment in a natural way rather than the parts generate the portfolio in a contrived and formulaic way.

Problem Solving and Design Processes: Their Relationship and some General Ideas

Earlier in this chapter some alternative views of teaching were offered regarding the power relationship, which may not be a hierarchical one in that the teacher and learner can be viewed as co-constructors of learning, which offers a powerful and dynamic view of learning. It was also indicated that the teacher's role might be one of reducing rather than increasing student reliance on them. This is particularly relevant when considered in the context of teaching 'problem solving', and the pedagogical strategies that one employs when engaging students with 'the design process'. However in order to engage in any further discussion in relation to these areas, two key points need to be established.

Firstly the concept of problem solving is largely a misnomer particularly in a school context. Problems are rarely solved by acts of designing and use of technology; problems are largely manifested in a different form. A 'problem', if it is a genuine 'problem', doesn't disappear (otherwise it wouldn't be a genuine problem), it is often that we adopt the illusion of no longer being able to see the problem in the same way. For example short sightedness is not cured by the design of spectacles. The problem remains but is disguised by the appearance of a solution. Whilst this may appear to be a philosophical or semantic discussion it is an important one as the danger of an illusionary approach to problem solving is that whilst notionally focussing intently on 'solving' a problem, we fail to acknowledge the further and wider implication that a notional solution creates. Therefore designing a device for the elderly doesn't solve the problem, the person remains old and their status and interrelationship with other people and objects does not change when a device to overcome some barrier is introduced. The problem is merely masked and the unintended consequences and unforeseen issues that arise are not factored into the solution. Exploring such consequences provides a rich range of learning opportunities but is something that can often be forsaken in adopting a blinkered view of problem resolution.

The second key point that needs to be established is that problem solving is generally presented as an authentic process and often closely linked with 'the design process'. Again it may appear semantic but two issues are important to acknowledge. Firstly many teachers will often refer to 'the design process' suggesting there is one fairly unambiguous process by which to design and solve problems. In fact there are an infinite number of processes that can be used to model a procedure to work through. The difficulty is that a multitude of these processes are available but are rarely acknowledged in favour of adopting simplistic models of designing (or problem solving) that are closely aligned with assessment systems. This contrived approach therefore legitimizes incremental steps through a designing activity and may inappropriately suggest a weighting of time and significance for each step through the allocation of assessment marks for each stage. This issue will be dealt with in more detail elsewhere in this book (and is well documented), however the second point related to this is that the notion of a process also suggests that following it leads to some form of guaranteed problem resolution – which it doesn't.

The significance of these issues is the translation into pedagogic practice, where teaching becomes focused upon leading learners through a series of equally artificial and contrived steps. To further compound the illusion, undemanding or preconceived tasks can give the appearance of students designing, and the suggestion to them of the effectiveness and success of adopting such artificial processes. Consequently the 'process' becomes a vehicle for 'learning' in its own right and 'the artificial design process as an educational vehicle is thus born' (Liddament, 1996).

The unfortunate consequence is that teachers create rather than challenge the misconception of 'process' unless they are prepared to engage students in genuine creativity development. It also has to be noted that engagement with an artificial process and illusionary problem solving activity, apart from being expedient in terms of meeting examination requirements (some may say this is sufficient), is also founded on the principle that such redundant activities may serve some ultimate purpose for the students long term interests. Inevitably this therefore once again generates the question as to what is technology education for, as the danger in adopting dysfunctional pedagogical models is that learners neither engage with the broader aims of the subject or the technical, academic or vocational opportunities afforded.

Whilst some of this may appear a pessimistic view it is countered by the fantastic opportunities that many inspirational teachers offer their students. These teachers have a broader understanding of problem finding, learning, technology education, and a clear view of what they wish to achieve and how it will be beneficial to their students. Such teachers recognize that you can engage in a rigorous, creative, designerly and authentic experience which is driven by learning but which also covers institutional requirements in a natural rather than a contrived way. Such approaches are inherently risky in that the teacher models the very attributes they wish to develop in their learners. Without risk there can be no creativity and when learners see their teachers modelling the very dispositions they will require as an adult, the learning approach is reinforced. Such approaches cannot be systematized, but equally do not need to be seen as compromising the curriculum aims or standards.

Styles of Teaching

The concept of a teaching style is slightly ambiguous as it suggests the ability to arbitrarily classify and assign teaching to distinct categories. The difficulty with this is that teaching is an extension of the individual persona and defining a style reduces the complexity of teaching and individuals to a single category or combination of categories. By adopting such a filtering approach, new teachers wishing to develop or adopt a particular style of teaching may only be adopting or developing a highly reduced version of what might be the constituents of a successful style. Therefore any discussion of teaching styles has to be recognised in the context of a reductionist approach.

Kaplan & Kies have defined a 'teaching style' as "a teacher's personal behaviours and media used to transmit data to or receive it from the learner" (1995, p. 29). Such a definition fails to acknowledge the complexity of interactions, behaviours and emotions that are part of a teacher's repertoire. Equally it suggests teaching as a transmissionist act that has previously been identified within this chapter as a barrier to collaborative and creative approaches to learning.

Therefore any discussion of teaching style has to be considered in the broadest sense and within a context that has some clarity over the aims of education. For example many teachers believe in a 'disciplined' (Cothran & Ennis, 1997) style of teaching that encourages obedience. In such scenarios, despite the potential lack of engagement or consideration of the wellbeing of the individual (although I am sure such teachers would argue differently) some would argue that this approach instils a sense of discipline which overrides both content and individual needs. Child centred styles of teaching however may take the opposite view, considering effectiveness in terms non-cognitive outcomes, dispositions and emotional wellbeing. The positive effects of learner centred teaching styles are well documented and are characterised by stimulating, interactive and highly differentiated approaches. Student difficulties are discussed and used as learning opportunities.

However between the two extremes of highly 'disciplined', didactic teaching styles and constructivist, child centred teaching styles are thousands of incremental variations, which are largely dependent upon the teacher's own tacit beliefs. Day (1999) has suggested that ultimately teachers' actions are often based on implicit, tacit knowledge, therefore to change the teaching style you have to change the belief system that a teacher holds. The difficulty is that we are not always aware of these beliefs and as such it is important for teachers to reflect upon the many assumptions both explicit and implicit that they may hold. For example a teacher having a fixed view of intelligence as opposed to a flexible, multidimensional view will go about their teaching role in a very different way depending upon what they believe.

An interesting side to this discussion is the matching of the diverse range of teaching styles with the diverse range of learning styles. One view would be that to maximise the learning potential of a student the teacher's style should be closely matched to that of the learner. This may be almost achievable in a one to one situation but given the diversity of a classroom, the reality would be that both the teacher needs to employ a diverse range of teaching styles and that pupils also need to diversify their learning style as neither of these attributes should be considered fixed.

Interestingly Kolb (1984) considered conversely that a mismatch of teaching and learning styles might be more fruitful to learning in some situations. Equally Zhang (2007) found that creative thinkers didn't always prefer styles of teaching that matched their own. Instead they found styles that facilitated their creativity and complemented rather than reflected their leaning style were preferable. Therefore, rather than attempting to narrow down a teacher's repertoire into a definitive style, we should be encouraging teachers to employ a diverse range of teaching strategies from the didactic to the interactive. At the same time we should also be encouraging learners to learn both independently and in ways that may not intuitively suit them. Such a view does however encompass a belief that education is not merely the transmission of knowledge and skills in the shortest and most efficient way but rather, teaching is the act of reducing student dependency on the teacher and the consequent increasing of student responsibility and ownership of learning. Such an approach may be the antithesis of the increasingly endorsed technicised, instrumentalist, performative and normative approach of teaching, but is one in which performance of the learner is considered beyond a narrow view of school performance.

Pedagogic Implications

Over recent years the concept of mirror neurons (Hurley & Chater, 2005) has been discussed as a metaphor as well as offering a neuroscientific explanation of both empathy and learning. A reduced premise of this theory is that our brains can subconsciously imitate what we see others doing and as a consequence we are hardwired to experience what others are experiencing. Most notably this relates to concepts of emotion and empathy but can also be applied to learning in that we can pick up both the good and bad habits of those around us. The relevance of this is that it presents a strong and convincing argument that teachers should model the dispositions they wish their students to acquire. Within the context of technology education teachers should model the risk taking, problem solving and creative approaches that they wish students to develop. We have all seen the tried and tested projects that teachers have delivered for many years where every risky opportunity has been removed, every problem already solved and every creative opportunity reduced to making limited choices relating to colour, for example. In doing this we expose learners to a pre-packaged and contrived activity, bereft of opportunity and enterprise.

Whilst it can be argued that such procedural tasks emphasize skill development, inevitably such tasks limit learning and as such it is critical that teachers engage in the very dispositions that that they wish their students to acquire. Van Schaik, *et al.,* (2011) extends this by identifying the richness of teachers and students learning together as co-constructors of knowledge working on products for ‘real’ customers. Building upon Vygotsky’s social constructivist interpretation of learning they emphasize that such learning develops a knowledge-rich learning environment (p.63). To extend their theoretical justification further, such learning is also consistent with learning as a “micro-genetic development” which contributes to enculturation into a “community of learners” (p.63) and as such represents a consistency with Lave & Wenger’s (1991) ‘community of practice’ where engagement operates at three levels, notably: Mutual Engagement; Joint Enterprise and Shared Repertoire (Wenger 1998). What this illustrates is that technology education presents a unique and powerful form of learning with a strong theoretical rationale which advocates joint enterprise on the part of the teacher and learner through an enquiry and problem based pedagogy.

Dewey is quoted as saying that “if we teach today as we taught yesterday, we rob our children of tomorrow” and if we fail to acknowledge this mantra in technology education then we will fail to prepare students to engage with the challenges of a modern day society. However whilst the theory is impressive, in practice (similar to ‘fake goods’) it is easy to give the appearance of the above without actually engaging with the ‘real thing’ through offering a pseudo learning experience through collusion and coercion, endorsed through a system of apparent success. The collusion referred to is perpetuated by the pressure to achieve for both student and teacher by measured performance in terms of exam accountability and notional ‘academic’ success. Zizek (2001) represents this as students (and teachers) having a ‘forced choice’, behaving as if they had free choice of procedure when in fact their choice is benign. Therefore we can view the appearance of learning represented as a coerced activity through a series of basic scenarios. For example:

- The student ‘knows’ the design is good and the teacher knows the design is good.
- The student knows the design is bad but represents good measured performance and the teacher knows the design is good.
- The student knows the design is good but the teacher knows the design is bad but represents good measured performance.
- The student knows the design is bad but represents good measured performance and the teacher knows the design is bad but represents good measured performance.

What the limited set of scenarios reveal is that when technology education moves away from the richness discussed above towards a formulaic, contrived activity that gives the appearance of genuine learning, the real product becomes the sense of collusion and illusion that takes place between the teacher and the student. In such circumstances the material product and learning opportunities become of lower priority to the creation of the appearance of genuine learning. The rationale for such an approach represents the safety and security in being able to predict and micro manage an activity, the equivalent of putting stabilisers onto a child's bicycle but never removing them and as such the process becomes expedient and illusionary. Previously I have referred to this process as the' illusion of knowing' (Spendlove, 2010) and using Grossman's (1990) construct of pedagogical content knowledge (PCK) we can further examine (Table 1) some of the occurrences of assumptions of knowing or illusions of knowing that may take place.

Table 1. Illusions of PCK

Grossman PCK	*Potential pedagogical illusion*
Knowledge and beliefs about the goals for teaching a subject at different grade levels	The explicit goals may be articulated through broad statements whilst implicitly these are often distorted through mythemes, historical influences, school norms and shared.
Knowledge of students' understanding and (mis)conceptions of particular topics in a subject matter	The teacher may legitimise misconceptions in the pursuit of more accountable goals.
Curricular knowledge, that is, knowledge about the content of the courses and of the available materials within one field.	Curricular knowledge is adapted and 'narrativised' to make curriculum manageable whilst remaining accountable.
Knowledge of instructional strategies and representations for teaching particular topics	Pedagogical strategies for coercion and collusion to give the appearance of a free choice of procedure.

Whilst Grossman's PCK is clear, it is apparent that illusionary pedagogies can give the appearance of knowing without the learner achieving a genuine understanding of the topic or context. In drawing this to the attention to the reader it is not to apportion blame but to raise awareness of the delicate and complex ecosystem of learning. Equally it is important to recognise that the collusion and coercion identified is not simply something that occurs between the teacher and the student, as the whole school system of education and social structures from government to student operate within a series of often implicitly negotiated illusions through rules, routines and sanctions. Such collusions can be represented on a continuum, and it is often the successful navigation through such a hidden continuum that represents achievement in many aspects of education. However, technology education does seem uniquely placed to challenge assumptions of collusion and coercion through providing genuine and rich contextual learning opportunities.

Reflections

As indicated at the start of this chapter on teaching, it is very much interrelated with the other chapters in this book. However I want to acknowledge that teaching is much greater than this, it is more than a collection of strategies along with subject and pedagogic knowledge. Teaching is ultimately about learning, and whilst teaching is a noble act, the noblest act is to reduce a learner's dependency on a teacher through increasing student ownership and autonomy. This is something that often feels counterintuitive in that potentially doing less is ultimately doing more for the student. This does not imply a dereliction of duty, as the intelligent part of teaching is knowing when this occurs, how to do it and knowing when to intervene.

Some of the discussions in this chapter have questioned the structuralist notion of the professional teacher, whilst other discussions relate to nuances, subtleties and complexities of what it means to be a teacher. Therefore this chapter only represents a tiny part of the complex myriad of being a teacher. Ultimately all the issues that are discussed in this chapter lead to one final question – what does this all mean for 'my' teaching of technology, how can I (the teacher) effectively organize the learning environment to facilitate student learning about technology? Whilst acknowledging that reducing significant topics and debates to a single bullet point is always dangerous, I will now try to summarise what this means in practice with five key points:

1. Teacher effectiveness is difficult to define. However a teacher facilitating high quality student reflection and feedback through collaborative learning activities is likely to have a successful learning environment.
2. Reflection upon the nature of technology education is essential for challenging underlying assumptions and implicit beliefs, which may not be sustainable, or of benefit to learners.
3. It is very easy to give the appearance of teaching and learning without it being effective. It is therefore important that teachers challenge technicised and structuralist views of teaching and engage students in genuine and rich learning opportunities.
4. Traditional views of teaching and learning are being challenged by neuroscience, psychology and philosophy. These evolving areas are providing teachers with valuable, new and interesting emerging insights that all teachers should engage with.
5. How students and teachers 'feel' about themselves and the activities that they engage with has a profound influence on the success of any activity.

REFERENCES

Aaronson, D., Barrow, L. & Sander, W. (2007). Teachers and student achievement in the Chicago public high schools. *Journal of Labor Economics, 25*(1), 95–135.

Atkinson, S. (2000). Does the need for high levels of performance curtail the development of creativity in Design and Technology project work? *International Journal of Technology and Design Education*, *10*(3), 255–281.

Bandura, A. (1997). *Self-efficacy: the exercise of control.* New York, W.H. Freeman

Banks, F., Barlex, D., Jarvinen, E-M, O'Sullivan, G., Owen-Jackson, G., & Rutland, M. (2004), 'DEPTH – Developing Professional Thinking for Technology Teachers: An International Study', *International Journal of Technology and Design Education, 14*, 141–157. Kluwer Academic Publishers, Holland

Cothran, D. J., & Ennis, C. D. (1997). Students' and teachers' perspectives of conflict and power. *Teaching and Teacher Education*, *13*, 541–553.

Croll, P. (1996). *Teacher-pupil interaction in the classroom*. In P. Croll and N. Hastings (Eds.) *Effective Primary Teaching.* London: David Fulton

Day, C. (1999). *Developing teachers: The challenges of lifelong learning*. London: Falmer.

Dow, W. (2004). The role of implicit theories in the development of creative classrooms. In E. W. L. Norman, D. Spendlove, P. Grover, & A. Mitchell (Eds.), *DATA International Research Conference 2004 (pp. 61–66).* Wellesbourne, UK: Design and Technology Association.

Hamilton, J. W. (2004). 'Enhancing learning through dialogue and reasoning within collaborative problem solving', In E.W.L. Norman, D. Spendlove, P. Grover & A. Mitchell, *DATA, International Research Conference 2004 (pp. 89–95).* Wellesbourne, UK: Design and Technology Association.

Hamilton, J. W. (2007). 'Enhancing learning through collaborative inquiry and action', *Design and Technology Education: An International Journal, 12*(3), 33–46.

Hennessy, S., & Murphy, P. (1999). The Potential for Collaborative Problem Solving in Design and Technology. *International Journal of Technology and Design Education*, *9*(1), 1–36.

Hurley, S., Chater, N. (Eds.) (2005). *Perspectives on Imitation*: From Neuroscience to Social Science, Volume 2: Imitation, Human Development, and Culture. MIT Press, *14*, 282–300.

Immordino Yang, M., & Damasio, A. (2007). We feel, therefore we learn: The relevance of affective and social neuroscience to education. *Mind, Brain, and Education, 1*(1), 3–10.

Jeffers, C. (2008). Empathy, cultural art, and mirror neurons: Implications for the classroom and beyond. *Journal of Cultural Research in Art Education, 26*, 65–71.

Kimbell, R. (2002). Professor John Eggleston Memorial Lecture. Assessing design innovation: The famous five and the terrible two. *The Journal of Design and Technology Education, 7*(3): 172–180

Kimbell, R., Wheeler, T., Stables, K., Shepard, T., Martin, F., Davies, D., Pollitt, A. & Whitehouse, G. (2009). *e-scape portfolio assessment: a research & development project for the Department of Children, Families and Schools*, phase 3 report, London: Goldsmiths, University of London.

Kolb, D. A. (1984). *Experiential learning: Experience as a source of learning and development*. Englewood Cliffs, NJ: Prentice-Hall.

Kruger, A. C. (1993). Peer collaboration: Conflict, cooperation, or both? *Social Development*, *2*(3), 165–182).

Lave, J. and Wenger, E., (1991). *Situated Learning*, Cambridge University Press, Cambridge, UK

Liddament, T. (1996). Design and problem solving, in Smith, J. S. (Ed.) *International Design and Technology Educational and Research Conference (**Idater 96**),* Loughborough University, UK

McCormick, R. (1994). 'Learning through Apprenticeship'. In D. Blandow and M.J. Dyrenfurth (eds.) *Technology Education in School and Industry*, pp. 16–36, Kluwer, Dodrecht.

McCormick, R., & Davidson, M. (1996). Problem solving and the tyranny of product outcomes. *Journal of Design and Technology Education, 1*(3), 230–241.

McCormick, R. (1997). Conceptual and Procedural Knowledge. In M. J. DeVries & A.Tamir (Eds). *Shaping Concepts of Technology; From Philosophical Perspective to Mental Images*. Dordrecht: Kluwer.

Morison, S. E. (1936). *Harvard College in the seventeenth century*. Cambridge, Massachusetts: Harvard University Press.

Mortimore, P., Sammons, P., Stoll, L., Lewis, D. and Ecob, R. (1988). *School Matters*. Wells, Somerset: Open Books

Pagram, J., Williams, P. (2010). Digital assessment: A Western Australian experience in a senior secondary engineering course in D. Spendlove & K. Stables, (Eds.) *Ideas Worth Sharing*. *The Design and Technology Association Education & International Research Conference 2010.*

Pischke, J. S. (2007). The impact of length of the school year on student performance and earnings: Evidence from the German short school years. *The Economic Journal, 117*(523), 1216–1242.

Pollard, A., Boradfoot, P., Croll, P., Osborne, M. and Abbott, D. (1994). *Changing English Primary Schools?* London: Cassell
Prensky, M. (2005). Engage me or enrage me. *EDUCASE Review*, *40*(5), September/October, 61–64.
Ranciere, J. (1991). The ignorant schoolmaster: Five lessons in intellectual emancipation. Stanford, CA: Stanford University Press.
Rojas-Drummond, S., Mazon, N., Fernandez, M., & Wegerif, R. (2006). *Explicit reasoning, creativity and co-construction in primary school children's collaborative activities*. Thinking Skills and Creativity, *1*, 84–94.
Shön, D. (1983). *The Reflective Practitioner,* Jossy-Bass, San Francisco.
Shön, D. (1987). *Educating the Reflective Practitioner,* Jossy-Bass, San Francisco.
Shulman, L. S. (1986), 'Those Who Understand: Knowledge Growth in Teaching', *Educational Research Review, 57*(1).
Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*, 1–2.
Spendlove, D., & Hopper, M. (2006).Using 'electronic portfolios' to challenge current orthodoxies in the presentation of an initial teacher training design and technology activity, *International Journal of Technology and Design Education, 16*, 177–191.
Spendlove, D (2008). The locating of emotion within a creative, learning and product orientated design and technology experience: person, process, product. *International Journal of Technology and Design Education, 18*, 45–57.
Stables, K, & Kimbell, R (2000). 'The Unpickled Portfolio; Pioneering performance assessment in design and technology', in the proceedings of *The Design and Technology International Millennium Conference*, Wellesbourne: DATA
Van Schaika., Van Oersa, B., & Terwel, J. (2011) Towards a knowledge-rich learning environment in preparatory secondary education. *British Educational Research Journal, 37*(1), 61–81
Vygotsky, L. (1986), *Thought and Language*. In A. Kozulin (ed.) Massachusetts, MIT University Press
Welch, M., & Barlex, D. (2004, July). Portfolios in design and technology education: Investigating differing views. In E. W. L. Norman, D. Spendlove, P. Grover, & A. Mitchell (Eds.), *DATA International Research Conference 2004* (pp. 193–197). Sheffield, UK: Sheffield Hallam University.
Welch, M., Barlex, D., & Taylor, K. (2005, July). I don't enjoy making the folder: Secondary students' views of portfolios in technology education. In E. W. L. Norman, D. Spendlove, P. Grover, & A. Mitchell (Eds.), *DATA International Research Conference 2005* (pp. 193–197). Sheffield, UK: Sheffield Hallam University.
Wenger, E. (1998). *Communities of practice: learning, meaning, and identity*. Cambridge: Cambridge university press.
Zhang, L. F. (2007). From career personality types to preferences for teachers' teaching styles: A new perspective on style match. *Personality and Individual Differences*, *43*, 1863–1874

AFFILIATION

Dr David Spendlove
School of Education
University of Manchester

WENDY FOX-TURNBULL

4. LEARNING IN TECHNOLOGY

INTRODUCTION

Technology Education never ceases to excite and amaze me as the possibilities for engaging students in authentic ways using 21st Century learning strategies are endless. Not only does it teach students to appraise technology and creatively and innovatively design technological solutions, it offers truly genuine reasons for engaging students in learning in every other curriculum area. What better reason to learn to write a report than to report to the local council why a playground should be redesigned or built, or to undertake a statistical analysis than having to find out which flavours are the most popular in healthy snack food? In this chapter I begin with a 'macro' approach investigating broad theories relevant to learning in technology education then discuss each with application to the technology classroom with implications for teachers and students considered through the identification and progression of learning.

The mixture of practical skills and knowledge and culturally situated learning makes technology unique in the school curriculum. Constructivism, cognitive apprenticeship, and sociocultural learning theory are particularly relevant to technology because they site learning with the learner and promote interaction with people and the environment. Cognitive apprenticeship theory acknowledges the role of a more experienced other, while sociocultural theory acknowledges the role that culturally situated tools (technologies including written language) play in learning. Understanding how students use tools and the expertise of others to construct knowledge and understanding about technology is a critical component to understanding the nature of technology education.

Conversation and dialogue have long been attributed successful to learning. This chapter also explores how dialogue can be used to further thinking and learning. Hennessy states "It is obvious that merely presenting children with new information and experiences in the classroom is insufficient to promote learning" (Hennessy, 1993, p. 11). At present, we are hearing much about 21st Century Learning and Guided Inquiry. This chapter also explores these approaches and what the currently changing nature of education means for technology.

Focus in the latter part of the chapter shifts more specifically to teaching quality technology education and how to enhance students' learning by embracing current teaching methods and exploring new concepts and ideas. It also discusses how

P. J. Williams (Ed.), Technology Education for Teachers, 55–92.

technology can be incorporated into programmes of learning to maximise and advance learning for students. Some elements required for successful planning and implementation of technology are discussed and illustrated. These include learning intentions, formative assessment and progression and their applications to technology education.

RELEVANT LEARNING THEORY TO TECHNOLOGY EDUCATION WITH ASSOCIATED IMPLICATIONS

Sociocultural learning theory

Sociocultural Learning Theory enables the exploration of tools and dialogue and their place in learning. "To understand how individuals learn and develop through participation in the sociocultural world, it is necessary to grant that meaning is more than a construction by individuals" (Rogoff, 1998, cited in Fleer et al., 2006, p. 31). Identification of and using individual's funds of knowledge (González, Moll, & Amanti, 2005), cultural knowledges and ways of doing and knowing from home and community also contribute significantly to learning especially in technology education.

Child development in a sociocultural way of thinking is related to the ways of doing things within the communities in which they develop (Rogoff, 1990). Smith (1998, p. 21) and Rogoff (1990) suggest that within a sociocultural approach children gradually come to know and understand the world through participation in their own activities and in communication with others. This theory has a focus on the role adults and more capable peers play in learning, with an emphasis on peer group interactions and collaborative learning (Daniels, 1996a; Richardson, 1998). Child development occurs through everyday participation in society and reflects the relationship between the child and its community. To understand how individuals learn and develop through participation in the world, it is necessary to understand that meaning is more than a construction within an individual (Rogoff, 1998, cited in Fleer, et al., 2006, p. 31). Learning is related to cultural practices and circumstances of the communities in which they develop (Hedegaard, 2004 cited in Fleer, et al., 2006; Rogoff, 1990). Child development is related to cultural practices and circumstances of the communities in which they develop (Rogoff, 1990), and occurs as the learner interacts with the community in which they live (Fleer, et al., 2006; Rogoff, 1990). Smith (1998, p. 21) suggests that children gradually come to know and understand the world through participation in their own activities and in communication with others. Wertsch (1998) argues that virtually all human action is socioculturally placed, even when the individual is alone because the things they do and use are products of a social community.

Many current ideas about learning are inspired by sociocultural learning theories (Schepens, Aelterman, & Van Keer, 2007). Murphy and Hall (2008) suggest

Vygotsky's fundamental principle that psychological functions such as perceptions and memory, appear first as elementary functions such as rote learning times tables, then higher functions such as understanding and using multiplication, occur through a slow growing understanding of practices and actions that occur where and when people live and work together. Let us imagine it this way. Any change in a child's development appears twice or on two levels, first in the social plane (intermental)- copying without understanding and then psychological plane (intramental functioning)- doing with understanding (Murphy & Hall, 2008; Rogoff & Lave, 1999; Wertsch, 1981; Wertsch, Minick, & Arns, 1999). New knowledge and skills first appear between the child and another person on the social plane and then as they develop understanding, within the child on the psychological plane. The movement from the social plane to the psychological plane is called internalisation. (Daniels, 1996b; Vygotsky, 1978; Wertsch, 1981). An example of these two planes follows.

> Imagine a toddler participating in teeth brushing after eating or before bed. This cultural ritual is practised by the child's family and hence is a part of accepted behaviour patterns known to the child. However, the child may not necessarily fully understand what this action means. This social behaviour is occurring at a social (intermental) level of functioning without understanding. When the child understands why she/he is cleaning her/his teeth the child is said to be operating at a psychological (intramental) level of functioning. Learning actually occurs only when the child moves from the first level of functioning to another (Fleer, 1995).

Sociocultural theory also considers the role of action and tools or artefacts in the construction of knowledge (Wertsch, 1998). Given that child cognitive development is dependent upon an individual child's responses to cultural and societal influences, with sociocultural theory it is important to understand the relationships between doing and thinking, and the cultural, institutional, and historical context in which it occurs (Resnick, Levine, & Teasley, 1991; Wertsch, 1998; Wertsch, Del Rio, & Alverez, 1995).

Action, even when carried out by the individuals acting in isolation, is social because it incorporates socially evolved cultural tools The term cultural tools is used very broadly to include: all cooperatively and socially organised systems such as number systems, language and writing systems as well as technological tools and devices. (Richardson, 1998). Action and activity are a social undertaking and there are two ways it occurs. The first is that an action may involve social activity with one or more people. The other is that activity is culturally situated; with 'ways of doing' determined by the social context with actions carried out on the social and individual levels. The underlying assumptions are that we have access to the world indirectly through our tools (remember this includes language and number systems) rather than directly. External tools enable action and allow the understanding of a particular action (Zinchenko, 1985). In reality action and cultural tools exist in complex cultural, institutional and historical real world settings. These settings then shape the tools when carrying out action. For example, emergence of writing has allowed the development and understanding of the structure and nature of language well beyond the original need of communication (Wertsch, et al., 1995).

CONSTRUCTIVISM- SOCIALLY CONSTRUCTED LEARNING

Constructivists believe that knowledge does not come from a subject or an object rather that people construct their own understandings of the world in which they live. The theory of constructivism suggests that individuals develop understanding within a current framework of knowledge that they already have and can understand. This framework is built up, tested and altered as new learning occurs (Hennessy & Murphy 1999; Hill & Smith 1998). The construction of knowledge occurs through interaction with the environment (Hennessy, 1993; Maddux & Cummings, 1999; Rogoff, 1990; Vygotsky, 1978; Zuga, 1992), with problem solving an essential part of this process. Individuals develop knowledge structures in the memory (schemas) (McCormick, 1997) through experience and instruction that is within the intellectual potential of the students (Zone of Proximal Development- ZPD). In other words, students learn by doing, both independently and guided but only when it is within their intellectual grasp. For example it is unlikely that a five year old could learn and understand multiplication of two, three digit numbers no matter how well structured and child centred the learning was, because the required concepts are well beyond his or her ZPD. It is however reasonable to expect that the same five year old might learn to count to 20. Let us look at the ZPD further.

Zone of Proximal Development (ZPD)

The difference between a child's actual level of cognitive function and development and their potential Vygotsky called 'Zone of Proximal Development' (ZPD) (Vygotsky, 1978). Richardson(1998) defines the ZPD as the 'latent learning gap' between what the child can do on his or her own and what can be done with the help of a more skilful other (Richardson, 1998). Vygotsky (1978) first used the term to describe the difference between the level at which a child can work independently and their potential. It is the child's potential rather than their actual level that is considered (Fleer, 1995; Fleer, et al., 2006). The ZPD can be thought of as the region of activity that learners can navigate with help.

Vygotsky encouraged us to rethink social development to include the socio and cultural context in which a person lives. To understand an individual we must understand their social relationships (Fleer, et al., 2006; Wertsch, 1998) as cognitive development and instruction are socially embedded and we need to study and analyse the surrounding society and culture. Vygotsky provided the concept of ZPD in which a child's development proceeds through their participation in activities slightly beyond their competence, but within their ZPD and with assistance from adults or more skilled children (Richardson, 1998; Vygotsky, 1978; Wertsch, 1998).

Learning Activities within classrooms should be within the ZPD for all students. With support from adults, children will be able to work above their actual level. For this to happen teachers must know their children and plan purposeful activities (Fleer, 1995). A ZPD can include people, adults and children with various degrees of expertise, books, videos, wall displays, scientific and mathematical equipment and information and communication technologies intended to support learning (A. Brown et al., 1993). To work with the ZPD in the classroom implies that the teacher is aware of the developmental stages of the children and is able to make qualitative changes in teaching towards a certain goal (Daniels, 1996b; De Vies & Kohlberg, 1990). In order to stimulate and develop the child's curiosity and thinking, adults need to interact with the child at their potential level not at their actual level (Fleer, 1995). There are a number of strategies and approaches that enable teachers to plan and implement a constructivist classroom. These include scaffolding, co-construction, participatory appropriation, guided participation, and apprenticeship.

Scaffolding

The concept of scaffolding originated from Wood, Brunner and Ross (1976), and has been advanced by Bruner (1996). Bruner (1996) referred to the help which enables the learner to engage in the activity with increased confidence and competence as 'scaffolding'. Scaffolding is an metaphorical umbrella term used to describe all those strategies that an adult uses in order to help children's learning efforts, through supportive intervention (Greenfield, 1999; Wertsch, 1998). Scaffolding consists of selective intervention and adult modelling as they interact with children. (Fleer, 1995; Greenfield, 1999). In the early stages the adult does a great deal of modelling within the appropriate context, and in the later stages, with the gradual withdrawal of the scaffold, the learner becomes progressively independent (Fleer, 1995; Lave & Wenger, 1996). Over time, children will move from the social (intermental) level of functioning to the psychological (intramental) level of functioning, as long as the scaffolding provided by the adult is within a child's ZPD.

Co-construction

To explain the complexity of adult-child interaction and the ways interactions can be framed by adults, Jordon (2004, cited Fleer, et al., 2006, p. 36) uses the term co-construction. The term 'scaffold, although an excellent metaphor, does not however explain the process of internalisation nor the complexity of adult-child interactions nor the ways interactions can be framed by adults. Co-construction demonstrates how intersubjectivity (shared connections and understandings) occurs between an adult and a child. A powerful conceptual tool, co-construction helps us think about how adults and children interact together to support learning and is represented in Figure 1. As you can see the area of shared meaning is extended when the child and adult are equal partners in their interactions.

Participatory Appropriation

Rogoff (1990) uses the term “appropriation” as an essential learning mechanism to represent the movement from the social to psychological levels of understanding. Through shared activities the child develops the cognitive structures that are able to continue independently; this is known as appropriation (Wertsch, 1998). Appropriation is a bi-directional process meaning that learners of all ages and levels of expertise and interests seed environments with ideas and knowledge that are appropriated by learners at different stages and at different rates according to their current zones of proximal development (A. Brown, et al., 1993).

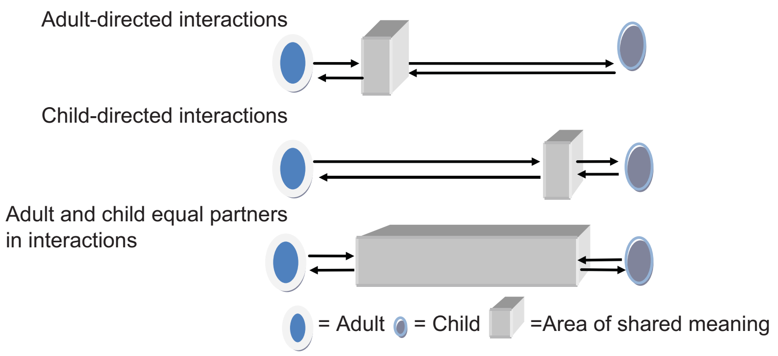


Figure 1. Jordon's Model of Co-construction.

Participatory Appropriation

Rogoff (1990) uses the term “appropriation” as an essential learning mechanism to represent the movement from the social to psychological levels of understanding. Through shared activities the child develops the cognitive structures that are able to continue independently; this is known as appropriation (Wertsch, 1998). Appropriation is a bi-directional process meaning that learners of all ages and levels of expertise and interests seed environments with ideas and knowledge that are appropriated by learners at different stages and at different rates according to their current zones of proximal development (A. Brown, et al., 1993).

Guided Participation

Guided participation involves adults or children challenging, constraining, and supporting learners in the process of posing and solving problems. This occurs through the arrangements of children's activities and responsibilities and interpersonal communication while they are participating and observing at a comfortable but slightly challenging level (Rogoff, 1990). Vygotsky observed that interaction with children in the home is well above what the child is able to understand. Given this, he stated that child and teacher interaction should be at the level of the child's potential and not at their current level (Fleer, 1995). Guided participation involves children and teachers in a collaborative process of building bridges from a children's present understanding and skills to reach new understandings and skills and by arranging and structuring children's participation in activities with dynamic increasing of their input and responsibility. In the concept of guided participation, both guidance and participation in culturally valued activities is essential to children's development of thinking. Learning may be tacit (not obvious) or explicit and vary in the extent to which children and teachers are responsible for its arrangement (Rogoff, 1990).

Apprenticeship

The apprenticeship model of learning involves the successful modelling of expert practice. The notion of apprenticeship is that the learner is initially in a position where observation of an expert is extensive, over time the learner does more and more while the support of the expert is slowly withdrawn. The aim is to give the learners control over their own learning and to engage them in critical analysis. The expert begins by modelling effective strategies or making explicit their tacit knowledge. The critical factor is for the provision of authentic dilemmas which may be real or imaginary (Lave, 1992).

> Ideally, in a community of learners, teachers and students serve as role models not only as "owners" of some aspects of domain knowledge, but also as acquires, users, and extenders of knowledge in the sustained, ongoing process of understanding. Children are *apprentice learners*, learning how to think and reason in a variety of domains. By participating in the practices of learning, they should be enculturated into the community of learners during their 12 or more years of apprenticeship in school settings.(A. Brown, et al., 1993, p. 190).

Situated Learning

Constructivist learning leads naturally to the idea that learning is most successful when situated within an authentic culture, context or practice. The theories of Enculturation, Situation Cognition and Cognitive Apprenticeship explore these ideas further.

Enculturation

Another approach to developing a constructivist classroom is to consider the authentic use of tools and activity by practitioners. Brown et al (1989) and Lave (1996) state that activity, concept and culture are all interdependent and learning must involve all three. In the past students were too often asked to use a tool in isolation, having little idea of the culture of the practice. The culture of a practice will determine the way a practitioner uses a tool. To learn to use a tool as a practitioner does, a student, like an apprentice, must enter the community and its culture Successful learning becomes a process of enculturation (J. Brown, et al., 1989; Rogoff, 1990).

Brown, Collins and Duguid (1989) identify a difference between much present school activity and authentic activity. They believe learning should be a process of enculturation. Much school activity is very different from the activity of practitioners. "When authentic activities are transferred to the classroom, their context is inevitably changed; they become classroom tasks and part of the school culture. Consequently, contrary to the aim of schooling, success within this culture often has little bearing on performance elsewhere" (p. 34).

Situated Cognition and Cognitive Apprenticeship

Situated cognition (Hennessy, 1993) identifies knowledge not as static 'furniture of the mind' but as situated in activity. This means that knowledge or ways of knowing are connected to cultural artefacts or situations, including tools and people (A. Brown, et al., 1993). Hennessy's theory of situated learning (1993) investigates the difference between classroom learning and cognitive practice. "Learning is most successful when embedded in authentic and meaningful activity, making deliberate use of physical and social contexts" (Hennessy, 1993, p. 15). Situated cognition encompasses thinking as a part of a culturally organised activity carried out within a community of practitioners including communities (A. Brown, et al., 1993; Rogoff, 1990). Implications for the classroom are that learning is most successful when students are engaged authentic with activity that reflects their "real current or possible future world" (A. Brown, et al., 1993; Fox-Turnbull, 2003; Lave, 1998; Turnbull, 2002). Lewis (1999) suggests a distinct advantage of the model of Situated Cognition is that it is a useful model for integration of the curriculum.

Johnson (1992) compares cognitive apprenticeship with traditional apprenticeship. "Cognitive apprenticeship uses many of the instructional strategies of traditional apprenticeship but emphasises cognitive skills rather than the physical skills. Traditional apprenticeship contains three primary components: modelling, coaching and fading" (Johnson, 1992, p. 4). Johnson states that one of the strengths of apprenticeship is the importance of real activities performed by the expert and copied by the learner. Cognitive apprenticeship uses these same strategies but during the coaching stage the expert shows the students how to complete the tasks or solve the problem while verbalising the activity. In contrast to many current school models the instruction occurs within a real context. The student learns about the complexity of the expert's thinking, that they make many mistakes and take many changes of direction in their thinking during the problem solving process (Johnson, 1992; Rogoff, 1990).

The theories discussed above highlight the issue of the disjunction between traditional classroom learning and cognition in practice. It is fundamentally important for teachers to understand the acquisition of knowledge and investigate the difference between the knowledge of novices and that of experts.

Sociocultural Conflict Theory

The basic tenant of sociocultural conflict theory is that discrepancy or conflict best sparks cognitive development. A subset of sociocultural theory, sociocultural conflict theory identifies conflict as an essential ingredient of any joint involvement to bring about cognitive change. Doise and colleagues (Doise & Mugny, 1984) have demonstrated in an extensive programme of research, that children working in pairs solve problems at a more advanced level than those working by themselves (regardless of the ability of the partner). Their studies revealed that when coming up against an alternative point of view (not necessarily the correct one) in the course of joint problem solving the child is forced to coordinate his or her own viewpoint with that of another child. The conflict can only be resolved if cognitive restructuring takes place and therefore mental change occurs because of social interaction. Thus the social interaction stimulates cognitive development by permitting dyadic (people working in pairs) coordination to facilitate inner coordination. This does not happen through passive presentation of points of view. When children are actively engaged in defending their particular view, and reasoning with those of other individuals, they experience confrontational socio-cognitive conflict. The mental restructuring that follows allows each partner to adopt an approach to this specific class of problem that is more advanced than that adopted previously when working as an individual (Lave & Wenger, 1996).

In conclusion sociocultural theory considers people's use of cultural tools to make sense of the world and develop cognitively. Constructivist Theory states that people construct their own knowledge as they interact with their social and cultural worlds. The use of culturally situated tools including technological artefacts and language and the use of experts are key factors making these theories particularly relevant to technology education. The literature indicates that interaction with peers and adults, the use of language and solving differences through dialogue is a critical part of the learning.

FUNDS OF KNOWLEDGE

One method of enhancing connection between teachers and students is for teachers to understand and use the cultural community and background of their students and to make use of the many and varied cultural contexts for learning that exist within most classrooms. Gonzalez, Moll and Amanti's (González, et al., 2005) work on funds of knowledge focuses on this. The theory of Funds of Knowledge draws on the perspective that learning is a social process bound within a wider social context. People have knowledge gained through their life experiences. The knowledges that students come to school with can enhance their learning and facilitate useful interactions between knowledge found inside and outside the classroom (González, et al., 2005). Lopez (2010) and Fleer & Quinones (2009) suggest that teachers can make more of the learning in their classrooms if they understand that students bring with them knowledge from their families, culture and background and that teachers can legitimise this knowledge through purposeful classroom engagement, "one can create conditions for fruitful interactions between knowledge found inside and outside the classroom" (González, et al., 2005, p. 20).

Considering the importance of culturally contextualised learning, it makes sense that the experiences children have in their homes and communities will impact on their interactions in the classroom and their abilities to make sense of engagement with tools and artefacts to which they are exposed. Acknowledging, understanding and using children's home and community experiences (González, et al., 2005) can advance students' understanding of the lessons being taught.

Lopez (2010) suggests that "it is the responsibility of each teacher to attempt to learn something special about each child they teach" (p. 2). Generating an understanding of students and their families' Funds of Knowledge is one way teachers can do this. Funds of Knowledge describe the developed bodies of skills and knowledge that are accumulated to ensure appropriate functioning within their social and community contexts (Lopez, 2010). Individuals may be shaped by any number of Funds of Knowledge; for example, family, peer group or other network of relationships (Moje et al., 2004).

Teachers need to maximise the use of interaction and integration to ensure a high level of engagement from a full range of children in any class, each of whom have funds of knowledge to draw from. Gonzalez, Moll and Amanti (2005) found that teachers who actively participated in understanding and getting to know the families of their students renewed their interest in an inquiry model of teaching in which students are actively involved in developing their own knowledge thus facilitating authentic integration of learning. Moje et al. (2004) and Kuthlthau, Maniotes & Caspari (2007) call this integration of knowledges construction of the "third space" as it merges knowledges from peoples' homes, peer networks and communities - the "first space" with Discourses encountered at school and other more formalised institutions such as work or church- the "second space".

Implications for Technology

Technology is culturally and socially situated both in development and in use, although some argue that this is not true, technology is ubiquitous. Mobile phones are the same in Malawi, Mumbai and Manchester. I agree they may be, but are they used in the same manner and for the same reasons? A few years ago, we had a sixteen year old American Field Scholar (AFS) from a small town in Wisconsin, USA, living with us. When she arrived she had no mobile phone, neither did any of her friends back home. We were surprised! She was surprised that most teenagers at her new school had mobile phones as where she was from text messaging was very expensive and mobile phones were only used for calling. It didn't take her long to 'enculturate' into the New Zealand teenage mobile scene with mobiles readily available and texting done frequently. My point is that the ways technologies are engaged with are dependent on a range of factors including availability, cultural practices, and political and economical influences.

Fleer and Jane (1999) argue that technology emerges from within a social context and does not occur in isolation. Constructed within a particular culture, technology takes into consideration the social and cultural needs of the society in which it was developed (Fleer & Jane, 1999; Siraj-Blatchford, 1997) and the moral and ethical values of the technologist. I term this 'best fit technology'. Successful technologies within a culture are not necessarily the more sophisticated or complex, nor are they the most and or least expensive. It is what is most appropriate for that specific person or group of people who are situated within a specific culture (Fleer & Jane, 1999). Take for example electricity development in New Zealand. We have a nuclear free policy and therefore electricity-generating technologies reflect this value and include hydro, wind and tidal generating technologies among others. Technological solutions developed within the context of the community in which needs arise, using local skills, resources and existing technologies are likely to be the most successful (Ministry of Education, 1995). This is not to say that engineers from other places are not interested in and capable of developing such technologies. What I am suggesting is that for engineers living in New Zealand, the motivation is higher to develop nuclear free power generating technologies than nuclear technologies.

It is the practical nature of technology education that aligns it with sociocultural and constructivist learning principles because it is fundamentally about the place and role of technological outcomes in society. People within a community draw on a range of sources of knowledge, to make sense of and manipulate their world to their advantage. When given authentic opportunities to make a difference in their world, students are more likely to become motivated learners. Let me give you an example from my own research. In the process of trying to establish the impact of authentic context on student learning I gave students a task of planning an aid to assist a person with only one arm to do a simple task. Subsequently I embedded the same task within authentic technology practice. Prior to developing their final outcome students completed a number of research and up-skilling activities, similar to that of a technologist undertaking the same practice would do. I also assisted the students to see that the task required of them was a task that sat within the cultural practices of their society. I did this in two ways. The first was in the form of a recorded interview with a young man, Vernon, who lost his arm in a shark attack. In the video, he discussed his accident and the challenges it had brought. He stated his greatest challenge was wanting to do tasks for himself and not having to rely on other people. The second activity was an investigation of aids currently on the market for people with disabilities. Through engagement in the activities, the students realised that their task was relevant to their world and culture. The students redid the original design task with significantly increased success and they were highly engaged and motivated. Many students asked me if I thought Vernon would be able to use or like their aids. One child proudly informed that hers was going to her aunty who had lost her arm to cancer (Fox-Turnbull, 2003).

When undertaking technology practice, Funds of Knowledge assist students to position themselves as an expert and to gain respect or 'mana' (a New Zealand Māori term used to describe a person who has status and respect in their community) from their peers. This was illustrated in a recent study of three 10 year old children who discussed suitable materials for the construction of their project- a microphone prop for a school concert item. One child, Alan, mentioned his dad was a racing car designer and had a workshop at home and would therefore have supplies of materials they could have used for construction. Dougal chipped into the conversation in a competitive manner explaining that his dad had much more than blocks of wood because he worked in the construction industry. "My dad owns a whole yard of everything. He's got like, heaps of stuff. He's got lots of things, yeah. He's a drain layer. He's an excavation worker. He's a construction builder. He has a yard, a whole yard." Understanding potential construction materials is a significant aspect to planning technological outcomes. Although not a confident child Dougal was able to contribute to his group by drawing on his Funds of Knowledge associated with his father's occupation (Fox-Turnbull, 2012).

The Sociocultural and Funds of Knowledge theories are particularly relevant to technology education because of the significance placed on interaction with culturally situated tools. Much technology is socioculturally situated and value laden. This is not to say that technologies are unique and or limited to single countries or cultures, however the success of a particular technology will be determined by whether it is of value to a broad range of stakeholders and consumers, and supported by the necessary education and infrastructure.

LEARNING THROUGH INTERACTION

Adults and/or more capable peers play an important part in learning with an emphasis on peer group interactions and collaborative learning (Daniels, 1996a; Richardson, 1998). Smith (1998, p. 21) suggests children gradually come to know and understand the world through participation in their own activities and in communication with others.

Interaction theory focuses on the oral interaction between two people in which both are contributing. There is ample indication of the advantages interaction offers to learning and cognitive development. Spoken language is one of the tools children use to make sense of the world. It is also a teacher's main pedagogical tool and therefore spoken language deserves special attention (Mercer & Littleton, 2007). Social interaction is significant in shaping children's cognitive development through the social and psychological processes of learning, development, and intellectual endeavour.

Two opposing tendencies or forces characterise social interaction. These are 'Intersubjectivity' and 'Alterity'. Intersubjectivity is the dialogue between the novice and the expert who combine working towards a shared definition of a situation and to move the novice to a state in which a task can be carried out independently (Daniels, 1996a, p. 119). It also concerns the degree to which individuals share their perspective, and in what sense and under what conditions the two individuals engage in dialogue. Resnick, Levine and Teasley (1991) term this information 'transmission'.

Alterity is concerned with the distinction between self and others or how people understand the utterances of others. During social interaction the relative importance of intersubjectivity and alterity may vary but both are at work; the challenge is to 'live in the middle' (Daniels, 1996a). A Vygotskian perspective suggests mental action focuses on intersubjectivity with the expert guiding the novice from the social level - doing without understanding, to the psychological level - doing with understanding and reasoning. Alterity occurs when individuals experience discrepancy or conflict of opinion or perspective between their own and other's views, sparking cognitive development. In dialogue with another, the listener perceives and understands the meaning of what is said and simultaneously takes an active response to it, either agreeing or disagreeing, partially or completely. Listeners adopt a responsive attitude for the entire duration of the conversation (Bakhtin, 1986). Any understanding of live speech is inherently responsive in varying degrees and is imbued with response, elicited in one form or another.

Although Vygotsky's work did not explicitly discuss the adult-child interaction, dialogue using the concepts of intersubjectivity and alterity can help to make sense of classroom interaction and learning that is taking place. When a conversation member possesses a more encompassing view of a task they are able to challenge other members by means of a "one step ahead" strategy by balancing weaknesses and challenging developmental potential. Through a longitudinal study of mother-infant dyads in apprenticeship interactions Lave and Wenger (1996) suggest that it is through challenge and conflict that development can be brought about. As a child requires support it is up to the more capable person to use their sensitivity to produce the right degree of challenge. Interacting with others can facilitate cognitive development under many circumstances however, it is unlikely that all skills acquired at all stages of development originate in social interactions. There is a need, therefore, to establish what type of social interaction promotes what kind of cognitive achievement, at what age and in what manner (Lave & Wenger, 1996). Children's learning is embedded in the context of social relationships and sociocultural tools and practices. Children, as apprentices in thinking require the following important considerations:

- an active role in making use of social guidance
- the importance of routine arrangements of activities
- participation in skilled cultural activities that are not conceived as instructional
- shared understanding with their experts of both the goals of learning and the means by which they are achieved, through explanation, discussion, provision

of expert's models, joint participation, active observation, and arrangement of children's roles (Rogoff, 1990).

There are many ways of interacting with children. Interactions are bound by context and are specific to the immediate situation (Fleer, 1995). Fleer found that often children are not given time to think about what they are doing in relation to a wider context or previous learning and experiences. Skilfully constructed dialogue is one method used to improve interaction with students.

Dialogue

Dialogue is much more than talk, because it must involve relating to others. It is complex and dynamic and often involves very different cultures, perspectives, ideas and people. Dialogue involves the use of words and it requires engagement with people (Mercer & Littleton, 2007; Shields & Edwards, 2005). Mercer and Littleton use a specific definition with a focus on 'the discussion that takes place during the course of education activities' (Mercer & Littleton, 2007, p. 1). Shields and Edwards suggest that dialogue can bring moments of intense connection with another person with feelings of remarkable openness, deeply affirming moments that can be highly exhilarating and powerful.

It is argued that teachers need to engage in quality dialogue with students and their parents to help students make sense both cognitively and experientially of the world in which they live and work (Mercer & Littleton, 2007; Shields & Edwards, 2005). Engagement in dialogue involves trust and some degree of relationship between the people involved. It cannot happen if one person treats the other person as an object. It requires that people be treated with 'total respect' (Sharrat, 1991, cited Shields & Edwards, 2005). The following quote from Mercer & Littleton suggests that the place of dialogue in learning is considerably more important than has been demonstrated in schools in the past. "A sociocultural perspective raises the possibility that educational success and failure may be explained by the quality of educational dialogue, rather than simply by considering the capability of individual students or the skill of their teachers" (Mercer & Littleton, 2007, p. 57). When people work together in problem solving situations they do much more than just talk together, they 'inter-think' by combining shared understandings, combining their intellects in creative ways often reaching outcomes that are well above the capability of each individual. Problem solving situations involve a dynamic engagement of ideas with dialogue as the principle means used to establish a shared understanding, testing solutions, and reaching agreement or compromise. Dialogue and thinking together are an important part of life and one that has long been ignored or actively discouraged in schools (Mercer & Littleton, 2007).

Teachers make a powerful contribution to the way children think and talk and they convey powerful messages about thinking by the way they structure classroom activity and talk to the children. To increase children's ability to use language as a tool for thinking they need to be involved in 'thoughtful and reasoned dialogue' (Mercer & Littleton, 2007, p. 56). Teachers should scaffold useful language strategies to extend their students' thinking and dialogue with adults and peers. Bakhtin (1981) termed this 'dialogic teaching'. When given opportunity to practice using language to reflect, enquire, and explain their thinking to others, students are then able to seek and compare points of view. They are also able to use language to compare, debate and reconcile questions, taking their learning beyond a level that requires only answers to teachers' factual questions. Stith and Roth (2008) present us with the concept of co-generative-dialogues as a space in which teachers and students engage in critical interrogation of shared experiences from their individual perspectives. The goals of co-generative dialogue are to find common areas of agreement and understanding. Students are then empowered to use learning experiences from one situation to be transported and made meaningful in another situation. This is known as knowledge transfer or transportability. It offers efficiency, not having to learn the same concept in different contexts, and independence to learners enhancing abilities to make their own and help others' connections and progression.

Mercer and Littleton suggest that many children are not taught useful ways of using spoken language as a tool for learning and working collaboratively. To improve this, teachers need to engage children taking into consideration their special interests and temperaments (Fleer, 1995) and the knowledge they bring from their home and cultural backgrounds (González, et al., 2005).

Grounding

For two people to communicate both participants need to contribute to the conversation based on a common understanding of the exchange that is taking place or is about to take place (Clark & Brennan, 1991; Mercer & Littleton, 2007). This common understanding is called *grounding,* its purpose is to ensure "what has been said has been understood" (Clark & Brennan, 1991, p. 128). Grounding as defined by Clark and Brennan is a collective process by which participants try to reach a mutual belief of understanding about what is said. They also suggest that grounding, a basic component of communication, is shaped by two main factors: the *purpose* of the conversation and the *medium* (e.g. face-to-face, email or telephone) in which it is undertaken. For students to understand and react to any phrase they must share common understanding of the context of the conversation and the role of the participants, before a share meaning can be determined. For example, the simple phrase "can you do that" has multiple meanings, which depend on context, the roles of those engaged, and intonation. It may mean a simple question- can you do that?, a statement of amazement-, which could be affirming or insulting- can **you** do that!, or can you **do** that!, a request **- can** you do that?, or a demand- can you do that! So what then are the implications for technology?

Interaction and Technology Education

The collaborative nature of technology education makes quality interaction between teachers and students and amongst students critical. Quality dialogue is one way of ensuring this. It is dependent on the ability of participants to reason, challenge, and be challenged. Dialogue has the power to enhance students' experience of and achievement in technology. Theory presented in the previous section that conversation and critical dialogue play important roles in learning (Mercer & Littleton, 2007; Shields & Edwards, 2005). Ideally technological practice is a collaborative activity, with designers and developers collaborating amongst themselves and with stakeholders. Dialogue is an important aspect of this process. In technology, students must be taught to work collaboratively to ensure their practice is reflective of authentic practice and to ensure their process rigorous. Students need to understand that dialogue, differing opinions and compromise is a critical part of reaching a solution. This is particularly crucial when students are working collaboratively to develop a single solution. Consensus must be met. To do this successfully students need to be able to express their ideas and understand other's thinking, with teachers and other experts assisting as necessary. Sociocultural conflict theory (Doise & Mugny, 1984) suggests that disagreement and debate will enhance students' understanding. Children therefore must be taught not only how to articulate and defend their design ideas to others, but also to be open to new and alternative ideas. This was illustrated in the study referred to earlier in which a class of Year 6 students (10 year olds) in groups of three were required to develop props for their school production. As it was an Olympic Games year, the school production was about the history of the Olympic games. This class wrote and performed a five minute snapshot of the 'Olympic Games:1898–1936'. One group elected to develop a 1930s microphone prop for their item, so they could include radio commentary of relevant scenes of the Olympic era. Following some research the group of three, Minnie, Dougal and Alan (not their real names) each sketched a potential design for the group microphone. The researcher in the role of teacher (R) facilitated discussion to determine the type of microphone as she noticed that Minnie had sketched a more modern version than the boys as illustrated in Figure 2. She then facilitated a discussion to assist Minnie's clarification of the design.

R: What type of microphone is it? Is it a microphone that is held in the hand or is it a microphone that stands up by itself?
Alan: Stands
Minnie: I thought it was one that we held.
Alan: No because the old ones were on those things
Dougal: Yeah, on the stand
Alan: Yeah
R: How did you know that Dougal?

Dougal: Because I just know from the learning and stuff like the Elvis Presley one
Alan: Yeah, and they're like quite square and on a stand

Figure 2. Minnie drawing her initial sketch of the microphone.

The extract above illustrates how dialogue assisted Minnie in the clarification of the microphone design and allowed the group to proceed with their design. Dialogue also facilitates the students' understanding about contraction techniques and materials. After the researcher left the conversation above, the three students continued to discuss the microphone and possible construction materials. The final microphone prop can be seen in Figure 3.

Alan: Yeah, I'm pretty sure we'll do the old style mike…
Minnie: And what should we use for that
Alan: Ohh, I thought we'd make a big block of wood or and then maybe get something, wire or something.
Dougal: Yeah, I thought wire too.
Alan: and I thought probably a big block of wood and wire or something crisscrossed over the whole bit and then painted black
Dougal: And not put tin foil on it?
Alan: No, you'd put tinfoil over all the other bits, then it would make it look shiny
Dougal: But before you'd, like you'd need to do quite a few layers of tinfoil
Minnie: What colour should it be
Dougal: Yeah and so it will be silver, the tinfoil?

Figure 3. The final microphone prop constructed by the group.

It can be seen from these two extracts that the students were able to come to a consensus when allowed to discuss their ideas and understandings. Minnie's conceptual knowledge of a 1930s microphone altered significantly and all three children were able to reach an agreement about the construction materials if their microphone prop.

We can see from the section above that quality interaction, particularly dialogue is vital to all learning and particularly relevant to technology education due to the desirability of students undertaking collaborative technology practice. Recently we are seeing a move away from more traditional forms of teaching to a more collaborative, competency based curriculum. Gilbert (2005) talks about new ways of knowing, Bellanca and Brandt (2010) talk about 21 Century Skills suggesting that we rethink how students learn. The next section in this chapter explores thinking about learning in the future and discusses how technology is situated to assist the transition learning in the past to learning for and in the future.

LEARNING FOR AND IN THE FUTURE

Learning in future must look significantly different to that of the past in order to equip students for their rapidly changing lives in the information age. For this reason, we as educators face a huge challenge, including the development of skills in our students vital for 21st Century living such as: critical thinking and problem solving skills. One danger of this however, is that important ' curriculum content' knowledge will be lost (Education, 1998).

Sfard (1998) identifies acquisition and participation as two metaphors that guide learning. The first of these, acquisition, is the more traditional model of learning in which the mind is a vessel, which needs filling with knowledge and concepts much of which is content related. She suggests in recent studies learning is dominated by the participation metaphor in which students learn through interaction with material and people. Learning through participation is more likely to facilitate critical thinking and problem solving as students work collaboratively and cooperatively to advance learning through doing. Ongoing learning activities are never considered separated from the context within which they take place (1998, p.6). The participation model best exemplifies constructivist principles of learning and better aligns with skills students need. It also explains learning in technology education. We need to be aware of concerns mentioned above about specific content. In reality learning will occur though a range of approaches and certainly through both of Sfard's complementary metaphors. Inquiry learning in authentic contexts is one approach that illustrates participatory learning in technology education when taught through constructivist principles of learning.

Authentic Learning

The development of expert knowledge comes from the persistent solving of problems in relevant domains (Bereiter, 1992). Quality technology education programmes should be based on principles of authentic learning in which students develop knowledge and skills through engagement with authentic technological practice. Technology has a great potential to enable students to solve problems in authentic situations and so participating in active and reflective activities. "Technology Education is concerned with complex and interrelated problems that involve multiple variables that are technical, procedural, conceptual and social" (Hansen and Froelich, 1994, cited Jones, 1996, p. 1). Technology in the classroom should largely be a collaborative effort through the development of a single technological outcome by a number of students or as students work with stakeholders to meet their identified needs. When designers (students) engage in conversation they are able to add, challenge and engage with their own and others' ideas and perspectives. Altered design pathways and outcomes will be a natural progression of this interaction. It is the notion of learning through participation and collaborative thinking processes (Hennessy, 1993). It appears that in many school programmes especially at secondary level, students work individually on projects. I believe this should change. We need to explore ways in which students can work collaboratively, while being assessed individually. This could ensure students are participating in authentic practice, to facilitate conversations about learning while at the same time being able to assess for individual learning needs and to facilitate fair summative assessment practices especially when senior secondary school qualifications are at stake.

If students are solving problems using practices that are authentic to a specific practice within a technological field their knowledge frameworks are more likely to be stronger as they are able to make connections to real practice and need (Rogoff, 1990). The disability aid scenario is a case in point. In any community or culture where assisting people with disabilities to live independently is something that is valued, students were able to see that the task set for them is worthwhile and of value. An important message about the nature of activities that children undertake, taken from the theories of authentic learning is that authentic learning engages children and encourages learning (Hennessy & Murphy, 1999; Hill, 1998; Rogoff, 1990). Hennessy and Murphy (1999) discuss the possibility that authentic practice actually happens at two levels; "real" to the students may be both real to their own lives and also real to situations that they may encounter in the future workplace. "Activity is said to be authentic if it is (i) coherent and personally meaningful and (ii) purposeful within a social framework- the ordinary practices of culture" (Hennessy & Murphy, 1999, p. 8).

Another example of engaging students in authentic activity comes from my current research in which the students were asked to design and develop props for their school drama production. It was authentic because the props were needed, there was no money to buy them, and the setting of the production in the early 1900's made items difficult to locate. It was also authentic to the culture of the students in which live. Stage productions were common in their city. Students learned that prop development was a significant part of this practice though listening to a props manager from a local theatre demonstrate and talk about props and their role. Figure 4 and 5 show a range of real props used by the local theatre.

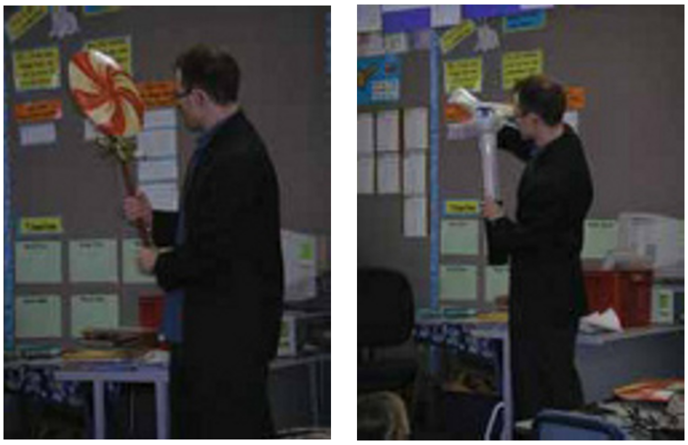


Figure 4. A props manager with two fictitious props.

Figure 5. A fake banana and plastic knife with a retractable blade.

There is strong evidence here that authentic learning in technology needs primarily to be authentic to culture and practice but there is also evidence that authentic learning at a personal level also aids children's learning (Fox-Turnbull, 2003). The knowledge students bring from their home and community (funds of knowledge), will influence what each child identifies as culturally authentic. In other words if the activities students engage in during technology reflect practices that are undertaken within their culture and community I suggest they are more likely to be engaged and motivated. This has implications for teachers as they determine culturally appropriate activities for their students.

Guided Inquiry Learning

Guided Inquiry learning is based on constructivist foundations of learning (Kuhlthau, et al., 2007). Knowledge develops through interaction with the environment (Hennessy, 1993; Maddux & Cummings, 1999; Rogoff, 1990; Vygotsky, 1978; Zuga, 1992). Problem solving is an essential part of this process. The guided inquiry approach reflects the belief that, for learners, active involvement in construction of their knowledge is essential for effective learning (Kuhlthau, et al., 2007; Murdoch, 2004). Guided Inquiry involves systematic learning that proceeds through a number of teaching/learning phases (immersion). It is very different from 'open' discovery learning because teachers have a major and continuing responsibility to structure a range of activities sequenced to maximize the development of skills and thinking processes of the learners. Guided Inquiry uses a wide range of teaching approaches from teachers' exposition to independent student research (Murdoch, 2004). Inquiry methodology and integrated curriculum are also supported by Caine and Caine (1990, cited in Murdoch, 2004) who argue that the brain seeks patterns, meaning and connectedness - methods that move from rote memorization to meaning-centred learning (Murdoch, 2004). Integrated Guided Inquiry involves students in developing deep learning through the process of self-motivated inquiry that strives towards development of 'big understandings' and 'rich concepts' (Kuhlthau, et al., 2007; Murdoch, 2004) about the world and how it functions (Blythe, 1998). Like technology education guided inquiry learning is centred on both process and content (Murdoch, 2004).

Development of higher order thinking is a key concept to constructivism and guided inquiry (Kuhlthau, et al., 2007). The path to developing higher order thinking is assisted through understanding of Vygotsky's (1978) ZPD. From this notion comes the underlying assumption that psychological development and instruction are socially embedded (Wertsch, 1998). Higher order thinking is fostered within the ZPD (Kuhlthau, et al., 2007). In order to stimulate and develop the child's curiosity and thinking, adults need to interact with the child at their potential level not at their actual level (Fleer, 1995). Guided Inquiry is a recent approach that teachers can use to enable them to plan and implement a constructivist classroom that meets the learning needs of individual students.

In the Guided Inquiry process there are distinct phases that students go through, some more difficult than others. Guided Inquiry is instigated through a need for investigation into a pressing issue, fundamental question or troubling problem, which may well be determined by the teacher. Exploration and question formulation then facilitate significant learning. Investigation leading to the collection of significant facts and information follow and task completion and preparation for presentation complete the process (Kuhlthau, et al., 2007). This process is outlined in Kuhlthau's model of the Information Search Process (Table 1).

In the first phase the teacher announces, or the students select a topic of study that requires research and thus initiates the inquiry process. During the first phase the students are involved a range of strategies to motivate and engage them. Learning is more likely to include learning through 'acquisition' than later in the unit. During this phase, it is usual for students to feel confused and perhaps a little lost.

The second phase identifies broad questions the students will be working on. Topics are determined by certain parameters, such as: points-of-interest for the students, assessment requirements, time available and resources or information available. During this time students may feel anxious before selection and possibly elation after. Anxiety can again set in, as they become to understand the extent of the task ahead.

Exploration, the third phase, involves sifting through the information available to narrow their focus. Students need to be well informed about the general topic in order to find an area to focus on. At this phase in the project many students want to drop or change their projects as they come across inconsistencies within the information they find or incompatibilities what they already knew. This is the most

Table1. Model of the Information Search Process

Stages	*Initiation*	*Selection*	*Exploration*	*Formulation*	*Collection*	*Presentation*	*Assessment*
Feelings (affective)	Uncertainly	Optimism	Confusion Frustration Doubt 'bogged down'.	Clarity	Sense of direction/ confidence	Satisfaction or disappointment	Sense of Achievement
Thoughts (cognitive)	Vague			Focused			Increased Self-Awareness
Actions (Physical)	Seeking relevant information Exploring				Seeking pertinent information Documenting		

(Kuhlthau, 2004, cited Kuhlthau, et al., 2007, p. 19)

difficult phase with confusion and confrontation when students can become easily frustrated and discouraged.

The fourth phase, Formulation is a time when students identify ways to focus their topic and information gathering. The next phase, collection, follows naturally with an extended focus on how to present the new understandings. Students' sense of ownership, confidence and interest increases at this stage of the project. The assessment phase concludes the project as both teachers and students judge what is learned about content and process. This is a time to reflect on the inquiry process as a whole. This phase is not to be confused with the formative assessment of content and process that is ongoing throughout the project (Kuhlthau, et al., 2007).

When well taught, Guided Inquiry offers students an opportunity to learn through active engagement in, and reflecting on, an experience thus building on what they already know. This enables them to develop high-order thinking skills through guidance at critical points in their learning. It allows different ways of learning to be catered for and facilitates learning through social interaction with others. Students learn through instruction and experience that aligns with their cognitive development. Guided Inquiry is often mistaken for 'Free Learning". It is not, it requires careful planning, close supervision, on-going assessment and targeted intervention (Kuhlthau, et al., 2007).

When students participate in the development of a technological outcome they go through a number of steps which parallel those outlined in Table 1: Guided Inquiry Information Search Model (Kuhlthau, et al., 2007). They begin by identifying a technological need or problem to solve and investigate related issues. This is the initiation phase, ideas are vague and students seek information and explore relevant contexts. This has been described as the hazy or fuzzy front end of technological development (Coates, 2011) and can be likened to the first phase in inquiry learning. Kimbell's APU model (Figure 6) (1991, cited in Staples. K. & Kimbell, 2005, p. 4) also illustrates the hazy nature of the early scoping stages of technological practice.

As students continue through their technological practice, they move closer to their final designed outcome, haziness clears and concrete ideas emerge, which are subsequently developed. During this time students undertake two parallel, fully integrated and inextricably linked processes; to research, identify and develop necessary skills and knowledge specific to the context of their study and technological outcome. The other is to build and develop their generic technological knowledge and understanding(Jones & Moreland, 2001). Again, comparison can be drawn here to the process of Guided Inquiry as students work through the formulation, collection, presentation phases. Final stages typically include assessment, evaluation and or critical appraisal.

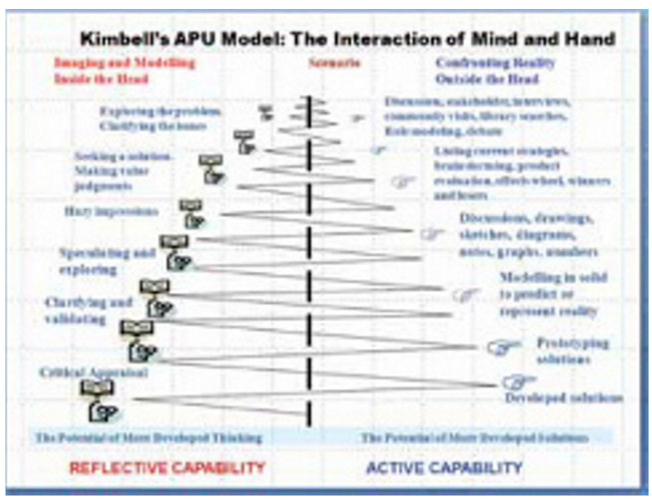


Figure 6. Kimbell's APU Model: the Interaction of Mind and Hand.

AVOIDING 'MUCKY BROWN PAINT'

One of the main problems with Guided Inquiry Learning in schools that my colleagues and I have observed is that if it is not structured and targeted as suggested by Kuhlthau and colleagues(Kuhlthau, et al., 2007), and if teachers do not have the curriculum and pedagogical content knowledge then students are very busy, but learning very little. I call this a "Mucky Brown Paint Syndrome". Let me explain; imagine each curriculum area is a colour of the rainbow. When taught in a planned and structured manner Guided Inquiry enables students to learn and employ specific knowledge and skills from a range of curriculum areas, to help research and solve identified problems and issues as an ongoing part of their inquiry. Imagine vibrant swirls of colour similar to that of a rainbow, each colour, or curriculum area, maintaining its integrity while enhancing and supporting its neighbour as in the first image in Figure 7.

However often the reality is that students are left to their own devices and are free to study or investigate what they wish, how they wish, with very little intervention and guidance from their teachers. Specific skills and knowledge from curriculum areas are not taught and discrete curriculum knowledge disappears. Colours blend, each loses its identity, mucky brown paint emerges as represented in Figure 7's second image.

Figure 7. Preserving the Rainbow and Avoiding the Mucky Brown Paint.

Studies in New Zealand have shown that student curriculum content knowledge has decreased in areas such as science. The following quote illustrates this. The National Education Monitoring Project (NEMP) assesses achievement in each curriculum area every four years. This comment comes from the 2007 science report comments on trends noticed between 1999 and 2007. "The percentage of Year 8 students disliking science at school increased substantially, from 15% in 1999 to 37% in 2007" (http://nemp.otago.ac.nz/forum_comment/2007_reports.htm).

In New Zealand there has also been an increased emphasis on literacy, numeracy and key competencies in recent years (Jones & Compton, 2009) with other subjects usually confined to afternoon "topic time" and often taught through Inquiry (Brears, MacIntyre, & O'Sullivan, 2010). With the introduction of the 21st century, we are seeing a significant shift in teaching philosophy and approaches to learning. Technology education is well situated to maximise its potential and increase its impact as learning in the 21st century moves towards a holistic model of child centred inquiry based learning. One way to avoid "mucky brown paint' is for teachers to identify and purposefully teach specific knowledge, skills and concepts in relevant identified curriculum areas as a part of a planned and structured approach to Guided Inquiry (Brears, et al., 2010).

Integration and Technology

To avoid 'Mucky Brown Paint" when integrating, the integrity of each curriculum area must be maintained. Technology has the potential to become an excellent model for other curriculum areas. This is not to say that skills, knowledge and concepts in other curriculum areas are not specifically taught, nor that technology skills and knowledge are not taught. In an integrated programme centred around the solving of a technological problem and the development of a technological outcome students are given authentic opportunities to measure, speak, write reports, discuss and consider social and health issues, and so on. "In the process of studying technology and learning technological concepts, other areas of the curriculum become more accessible" (Hennessy, 1993, p. 3). Other curriculum areas become accessible through the authentic nature of technology education.

During their technological practice, students have a right to be assisted by teachers who have the necessary generic and specific skills and knowledge to advance their skills, thinking and understanding. Students also need to utilise skills and knowledge learned from elsewhere in the curriculum and from their cultural communities to participate successfully in technology education. Technology Education is problem based student- centred learning. It is an ideal match for Inquiry Learning.

There is a clear difference between craft studies, technical studies and 'manual training', the predecessors of our current curriculum in technology education. When engaged in 'manual training' children were taught and practiced skills in isolation according to a pre-described curriculum. Technology education is different in that skills are taught on a need to know or 'just in time' basis and frequently involves the students working collaboratively in problem solving processes to develop technological outcomes that meet identified needs (Ministry of Education, 1995). It is intervention by design (Ministry of Education, 2007). When considering the above theories and discussion there are very clear implications for technology given this collaborative problem solving.

For example when I was eleven years old, during 'manual', I was taught to cook and sew and yes, as a girl I didn't get to go into the workshop, much to my annoyance! The purpose of the programme was to develop a specific skill set. In order to learn these skills I was allowed to make stuff. Everyone in the class made the same thing at the same time, perhaps with a little variance- my gingham half apron was teal blue with brown cross stitch, my friend's was red with navy blue cross stitching. In technology education students are presented with a problem or opportunity, with the apron scenario it might be parents complaining that clothes get splattered and stained with food when cooking, or a local sheltered home has just opened a new kitchen for residents and needs a set of aprons. After appropriate learning activities have been undertaken, including the introduction and practice of a basic skills set, and interaction with stakeholders, the students design, model and make the required aprons according to the needs of their client. All aprons are designed to meet specific needs. There will be some students who need to be taught further skills and techniques to ensure they are able to create their designed outcome successfully. This latter skill acquisition is call 'just in time' skill acquisition as the students are taught it on a need to know basis.

TECHNOLOGY KNOWLEDGE AND SKILLS

In a number of countries the explicit aim of technology education is the development of technological literacy (de Vries, 2009; Ministry of Education, 1995, 2007; Moreland & Cowie, 2007) and thus providing students with necessary capabilities to live successfully in a technological society. Students also need to be able to use, critique and control technological systems (de Vries, 2009). This includes the knowledge and understandings required to skilfully and knowledgably undertake technological practice. Such knowledge should also include the ability to critique existing technology and to understand its complexity, including how technology interacts with humans and the environment (Moreland & Cowie, 2007). This means students may have to develop a technological solution for a technological problem. Initially the problem is communicated to them, possibly through a design brief. Students then engage in a selection of planned activities as a part of the unit of work to allow them to develop the necessary skills and knowledge to design and develop an appropriate technological solution.

An important aspect of Guided Inquiry is the presentation of their findings. They may also develop a tangible solution for an identified issue. To this end they could be undertaking technological practice by designing presentations and tangible technological solutions, even if the nature of the Inquiry is say social studies or science based. This presents teachers with an unique opportunity to teach both social studies (or science) curriculum knowledge as well as technology curriculum content knowledge such as planning for practice, outcome development and evaluation and brief development (Ministry of Education, 2007).

Teacher Knowledge

Teacher guidance at critical points in learning is vital to enhance learning. In order for teachers to do this they must have critical content and process knowledge, understand the specific needs of their students and identify when to offer guidance and how much to give (Fox-Turnbull, 2003; Kuhlthau, et al., 2007). The Learning in Technology Education (LITE) Research project (Moreland, Jones, & Chambers, 2001) clearly indicates that teacher understanding of technology and teacher knowledge of the relevant technological practice engaged by the students influences the quality of their learning. Formative teacher - student interactions become distorted when there is a lack of subject knowledge. Teachers must teach and assess learning in technology based on a thorough knowledge of the relevant technological practice and knowledge (Compton & France, 2006; Fox-Turnbull, 2006). Shulman (1987) suggests an emphasis is needed to develop a strong teacher knowledge base in the areas of content knowledge, general pedagogy, curriculum, pedagogy content, learners' educational context, and educational ends. Rohaan's (2009) study on the influence of pedagogical content knowledge of teachers also found that sound teacher knowledge had a positive impact on student achievement in technology.

Domain Knowledge and Skills

Moreland, Jones and Chambers (2000) identify that effective teaching and assessment in technology is positively influenced by the development of a knowledge base in four domains: conceptual, procedural, societal and technical. Conceptual knowledge refers to knowledge and understanding of key concepts or ideas and procedures. Procedural knowledge refers to the applications of procedures and processes. Societal knowledge refers to understanding the relationship between technology and people. Technical knowledge is the practical use of tools and techniques (Jones, 2009). Teachers must have specific knowledge within the identified technological practice and generic technological knowledge across a range of technology areas to plan, implement, and assess quality programmes of work in technology education.

Knowledge in technology is often difficult to define. Ryle's (1984) definition of knowledge considers not only 'knowing that' but also 'knowing how' and this is particularly applicable to technological knowledge. Ryle believes there is a distinction between the two. Early philosophers of technology identified that knowledge employed in the development of artefacts was borrowed from scientific knowledge supporting the notion that technology is applied science. However, today most believe that technology is a body of knowledge in its own right. Users of technology also have a body of different technological knowledge. The two categories are particularly relevant to technological knowledge; and could be thought of as 'those who do' technology and 'those who use' technology. De Vries (2005) also considers the knowledge of processes involved in the functioning and or making of the object an aspect of technological knowledge.

Jones and Moreland (2001) state that technological skills and knowledge come from two main categories; the first is knowledge that is context specific and related directly to the areas in which the solution is being developed and includes knowledge in a range of domains: procedural, conceptual, societal and technical. The second is generic technological knowledge, which is common technological development and also applicable across the four domains of knowledge mentioned above.

There is considerable relationship between the Ryle's (1984) categories of knowing that and knowing how and procedural knowledge domain identified by Jones & Moreland (2001). Jones and Moreland's 'technical' and 'procedural' knowledge have direct links to Ryle's 'knowing how' category, with a focus on the practical elements of technological practice. Societal knowledge has a very clear link to users of technology and the interface between technology and people-'those who use' technology and 'knowing that' knowledge.

De Vries (2005) states that artefacts have a functional and physical nature. Designers need to consider both features and how they interact with each other to improve fitness for purpose. He suggests one way to explore technological knowledge is to understand the 'dual nature' of a designed artefact. Technologists have knowledge about the physical nature of an object; this includes knowledge of its material properties such as arithmetical, spatial kinematical, physical and biotic aspects. They have knowledge of its functional nature - what it means to function as a specific object. This knowledge includes the following aspects: sensitive, logical, historical, lingual, social, economic, aesthetic, juridical, ethical, and pistic (strong belief in the power of technology) knowledge. Technologist knowledge also includes the relationship between the physical and functional features and knowing how materials contribute to the artefact's fitness for purpose. For many technologists this knowledge is intertwined and they are unable to separate how they know and are able to do the practical knowledge and skills specific to their field. "When designing an artefact the designer uses these various types of knowledge. It is thanks to this knowledge that artefacts become what they become. One could almost say that the knowledge has become 'absorbed' by the artefact" (de Vries, 2005, p. 38). De Vries (2005) also considers the knowledge of processes involved in the functioning and or making of the object an aspect of technological knowledge. Links can also be seen here to procedural knowledge domain identified by Jones & Moreland (2001) and Ryle's'(1984) knowledge of 'those who'.

Context

Context is a word that is used widely in education and refers to a specific area of study in which learning takes place. Difficulty can occur when individual understanding of the term 'context' varies. 'Context' in technology education has been used to refer to the overall focus of a technological development or of a technological learning experience within technology education (Ministry of Education, 2010, p. 12). When talking about the context of a technological development, 'context' refers to the wider physical and social environment in which the development occurs for example rebranding an airline or wind generation for sustainable energy. When 'context' refers to a technological learning experience, it refers to all the aspects that need to be considered to situate the learning, for example outdoor eating within a school environment or programme development in ICT (Ministry of Education, 2010). Later in this chapter when I discuss the idea of identifying context free learning it is the latter definition of context to which I refer.

PLANNING FOR LEARNING

Fleer and Quiňones (2009) state that to understand and to be able to assess children's technological knowledge teacher need to understand the social and cultural context of their learners. Learning starts from a student's existing knowledge (Harrison, 2009). Having established this, teachers are then able to engage and motivate students by selecting relevant and culturally appropriate technological contexts for learning. When teachers have the mindset that all students can improve and that students bring their culture and experiences to learning they are in a good position to plan effective learning that will engage their students (Clarke, 2008; Harrison, 2009).

The identification and writing clear learning intentions in technology will inform students what aspect of technological knowledge and skills is to be the focus of learning within any one lesson. Consider the knowledge (conceptual, procedural, societal) and skills (technical and information) students will need to undertake an experience which will subsequently enable relevant learning. For quality technological learning to occur each lesson much have a clearly articulated learning intention. To do this, teachers need to be able to identify and articulate key learning to students. It is important to note here that when I refer to 'lesson' I refer to a learning episode, not specific period of time (session). One lesson may occur over several sessions (periods of time allocated to subject areas in a typical schooling situation) or conversely one session may contain several smaller lessons.

Following the identification of the learning intention teachers, must then plan and organise a suitable learning experience. A learning experience is an activity that facilitates learning of relevant knowledge and skills. They need to be purposefully planned and logically sequenced. This is to ensure students have enough relevant information about both the context of their study and the necessary technological knowledge and skills to be able to develop their intended technological outcome and to understand the societal, environmental and global issues that may impact on their decision-making.

Each learning intention and associated experience usually produces some form of tangible (written, oral, visual, dramatic, graphical) evidence of learning and is able to be used formatively by students and teachers for assessment. They may include such things as: posters, charts, interviews, written summaries/ reviews, products systems or environment plans, discussion or oral explanation, concept maps, annotated drawings, 2D and 3D planning, functional and prototype models and or the final outcome. Proof that the predetermined learning outcomes have been met can be used formatively or summatively for assessment when clear specific criteria have been identified.

One of the key strategies in formative assessment is the establishment of pupil generated and owned success criteria (Clarke, 2008). Success criteria describe what successful learning looks like. This may involve a systematic approach when learning is a fixed right or wrong process as in solving a mathematical equation. Or it may set out to describe key attributes of a successful learning example (Clarke, 2005). Co construction of success criteria with students involves enabling effective dialogue and questioning and pupil analysis of what excellence consists of. This does not mean showing students how to just meet, but best meet success criteria (Clarke, 2008).

When teachers are planning and writing units of work they can use this pattern to ensure a clear focus on both technological knowledge and contextual knowledge through the development of technology learning intentions, learning experiences, technological learning evidence, and the co construction of success criteria. In summary to plan a learning episode consider the following:

What is the learning needed?	Learning Intention
What can the students do to learn this?	Learning Experience
How can learning that has taken place be identified?	Technological Learning Evidence
What will successful learning look like?	Success Criteria

Identification of Context Free Learning

When writing learning intentions for specific technological knowledge and skills it is easy to muddle context and technological learning, so that neither become clear- developing 'mucky brown paint' is a risk in this situation in that technological learning gets buried in busy activity related to context. The separation of learning objective and context ensures that students and teacher clearly focus on technological learning. Clarke (2008) suggests separating context from learning intention can have a dramatic affect on teaching and learning. Context, the activity or "vehicle" through which learning occurs (Clarke, 2005, 2008), is however vitally important. Examples of Context free learning intentions in technology are given below in Table 2.

Table 2. Learning Objective with context separated

Learning Intention *Students are learning to*	*Context*
draw 3D detailed plans of a structure using a suitable software programme	A home for a guinea pig
Plan technological practice through the development of a critical path to ensure maximizing all team members use of time	Meals for "International Week" at School
Understand how the physical and functional nature of an outcome impacts on performance	Puzzles for young children
Understand the importance of making a mock-up has, on the quality of a final outcome	School senior ball gown

When technology learning intentions are combined with context or when they are contextualised students can become very focused on the context and may lose sight of the actual technological learning.

Table 3. Learning Objectives Muddled with Context

Muddled Learning Intentions *Students are learning to*
draw detailed plans for a suitable home for a guinea pig
create a critical path to ensure meals are ready for the international banquet
Understand the physical and functional nature of puzzles for young children
Understand why making a toile of ball gown is necessary

By making the learning objective and the context very clear to students, they are then able to transfer skills and knowledge through to other contexts within and across curriculum areas (Clarke, 2008). There are however, some learning intentions within any unit of work that will be focussed specifically on context for example a historical study of ball gowns or understanding the stages of child development enhanced through doing jigsaw puzzles. Again the learning intention must be clearly articulated to students so that they may understand the purpose of their learning.

All these points align with an Inquiry model of learning. Evidence from literature presented here suggests Guided Inquiry Learning, technology education, and formative assessment are perfect partners. Quality technology education exemplifies inquiry learning and formative assessment is the perfect tool for advancement of student learning.

FORMATIVE ASSESSMENT

The process of teachers giving students critical guidance and feedback to enhance learning opportunities involves ongoing formative assessment (Black & Wiliam, 1998). “Formative practice is about providing guidance for learning” (Harrison, 2009, p. 450). Formative assessment consists of four basic components: sharing learning goals. Effective questioning and conversation, self and peer evaluation and effective feedback. These are underpinned by the confidence that every child can improve and an awareness of the value of self esteem (Clarke, 2005). There is strong evidence that formative assessment can raise achievement (Clarke, 2008). Active learning is at the heart of formative assessment and should allow teachers and students to collaborate in all stage of learning from planning, decide context of study, establish intended learning and associated success criteria and critically engage in analyzing learning through classroom talk (Clarke, 2008).

Clarke (2008) suggests that to ensure maximum impact on motivation and achievement schools needs to make their curriculum creative and flexible. Pupil engagement in preplanning and planning will ensure learning is pitched at the correct level, increasing motivation and achievement. Teachers need to present pupils with minimum coverage, as a starting point for discussions. Accessible learning objectives (intentions) should be displayed so that students can refer to them when needed. Learning also needs to be interactive and flexible enough to change direction if students' interests dictate and if curriculum coverage is not compromised.

THE NATURE OF PROGRESSION

Progression in technology is related to understanding and using generic technological knowledge and skills in an increasingly complex and varied way. Progress in technology is not linear, nor is it a sum of individual parts, but rather a holistic process which cannot be assessed in absolute terms (Kimbell, 1997). Achievement in technology is not only about factual knowledge but also a students' conceptual understanding of subject matter and their ability to transfer concepts to future learning and new and unfamiliar situations (Pellergrino, 2002).

Progression is about planning for and managing student progress and requires an understanding of students' current level of technological literacy and what subsequent learning might look like. Progression does not mean that something extra is added or by doing something differently. "Improvement may amount to doing the same thing but in progressively richer ways" (Jones, 2009, p. 410). Jones (2009) defines progression in learning technology in the following categories:

- the nature of technology- the broad understanding of technology and the relationship between technology and society
- student technological practice- brings together different technological tasks and the brings together of knowledge and skills to solve technological problems
- generic conceptual, procedural, societal, and technical aspects- aspects common to more than one technological area
- specific conceptual, procedural, societal, and technical aspects- aspects specific to a particular technological area or context.

In technology education students engage in critical appraisal of existing technologies and employ design processes to develop new outcomes. Design, innovation, invention, form and function are features of technological thinking. Students are required to work reflectively and in an iterative, holistic fashion (Moreland & Cowie, 2009). Moreland and Cowie suggest that young students often have difficulty working iteratively when engaging in technological practice and therefore need significant teacher assistance. Effectiveness of this assistance will depend on teachers' understanding of progression in technology. The categories mentioned above assist teachers in understanding the needs of their students and advancing their learning.

In New Zealand the Ministry of Education has funded the development of Indicators of Progression (Ministry of Education, 2009). In this case progression is based around key components across eight levels of achievement from Years 1 to 13.

These key components include: brief development, planning for practice, outcome development and evaluation, technological modelling, technological products, technological systems, the characteristics of technology and the characteristics of technological outcomes. I suggest that there is some correlation between the Jones' aspects and the Ministry's Indicators of Progression. Table 4 shows this correlation.

Table 4. Correlation between the Jones' (2009) aspects and Indicators of Progression (Ministry of Education, 2009)

Jones' Aspects of Progression	*Definition*	*Relevant Indicators of Progression*
The nature of technology	The broad understanding of technology and the relationship between technology and society	The characteristics of technology and the characteristics of technological outcomes
Student technological practice	Brings together different technological tasks and the brings together of knowledge and skills to solve technological problems	Context specific brief development, planning for practice, outcome development and evaluation Technological modelling with in context Technological products, technological systems
Generic conceptual, procedural, societal, and technical aspects	Aspects common to more than one technological area	Technological modelling (purposes of) Technological products relationship between materials and fitness for purpose Technological systems, "understanding of input, output, transformation processes, and control" (Ministry of Education, 2009) Brief development, planning for practice, outcome development and evaluation
Specific conceptual, procedural, societal, and technical aspects	Aspects specific to a particular technological area or context.	Specific technological modelling Technological products, technological systems Brief development, planning for practice, outcome development and evaluation

International literature on the exact nature of progression in technology education and information of the specifics of what learning looks like across levels and across components or aspects is light. National or state curricula such as New Zealand's national curriculum achievement objectives (Ministry of Education, 2007) and the United Kingdom's Key Stages (National Curriculum website team) goes some way to identifying progression in general terms. For teachers to be able to have a clear picture of students' learning further support documents such as New Zealand's Indicators of Progression (Ministry of Education, 2009) are required. These not only identify and break down learning steps but also supplies clear teacher guidance and teaching strategies. I would certainly agree with Compton and Harwood, (2005) Jones (2009) and Pellegrino (2002) who suggest that more research needs to be done around the notion and specifics of progression in technology education.

CONCLUSION

This chapter began by investigating literature in what I believe to be key theories that influence the nature of technology education. Sections began with a macro perspective through sociocultural and constructivist theory and concluded with micro approach through classroom teaching strategies. Sociocultural and constructivist theories cite the learner at the centre of learning, along with culture and culturally situated tools and their influence on cognitive development. Because interaction occurs as a direct results of a learner based approach theories in this area were also discussed. Guided Inquiry and 21St Century Learning were then summarised because they offer insight into the potential of collaborative, practically based curriculum such as technology education.

Technology is well situated to lead learning into the 21st century with student centred, needs-based programmes. The latter part of the chapter was focussed implementation of technology education. It discussed how and why the macro-theories influence technology education. Discussion in the second part of the chapter was included on the nature of technological knowledge and impact of teacher content and pedagogical content knowledge has on learning. Technology classroom practice including technology process, learning intentions, learning experiences and evidence of learning was discussed. The chapter concluded with the concept of how context free learning can be employed to enhance learning in technology for students along with discussion about formative assessment and the nature of progression.

REFERENCES

Bakhtin, M. (1986). *Speech genres and other late essays* (V. W. McGee, Trans.). Austin, Texas: University of Texas Press.

Bakhtin, M. (Ed.). (1981). *The dialogic imagination* (1994 Ed.). Austin, Texas University of Texas Press.

Bellanca, J., & Brandt, R. (Eds.). (2010). *21st century skills: rethinking how students learn*. Bloomington IN: Solution Tree Press.

Bereiter, C. (1992). Referent-centred and problem-centred knowledge: elements of an educational epistemology. *Interchange, 23*(4), 337–361.

Best, J., & Kahn, J. (1998). *Research in education*. Needham Heights MA: Allyn and Bacon.

Black, P., & Wiliam, D. (1998). *Inside the black box- raising standards through classroom assessment* (1st ed.). London: King's College.

Blythe, T. (1998). *The teaching for understanding guide*. San Francisco: Jossy-Bass.

Brears, L., MacIntyre, B., & O'Sullivan, G. (2010). Preparing teachers for the21st century using PBL as an integrating strategy in science and technology. *Design and Technology Education: An International Journal, 16*(1).

Brown, A., Ash, D., Rutherford, M., Nakagawa, K., Gordon, A., & Campione, J. (1993). Distributed expertise in the classroom. In G. Salomon (Ed.), *Distributed cognitions; pyschological and educational considerations*. Melbourne: Cambridge University Press.

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

Bruner, J. (1996). *The process of education.* Cambridge:: Harvard University Press.

Clark, H., & Brennan, S. (1991). Grounding in communication. In J. M. L. S. D. T. L. B. Resnick (Ed.), *Perspectives on social shared cognition* (pp. 127–149). Washington: American Psychological Association.

Clarke, S. (2005). *Formative assessment in action: weaving the elements together*. Oxon: Hodder Murray.

Clarke, S. (2008). *Active learning through formative assessment*. London: Hodder Education.

Coates, D. A. (2011). Improving the fuzzy front end of product development. Retrieved from http://www.realinnovation.com/content/c090608a.asp

Compton, V., & France, B. (2006). *Discussion document: background information on the new strands*. Retrieved from www.techlink.org.nz.

Compton, V., & Harwood, C. (2005). Progression in technology education in New Zealand: components of practice as a way forward. *International Journal of Technology and Design Education, 15*, 253–287.

Daniels, H. (1996a). *An introduction to Vygotsky*. London: : Routledge.

Daniels, H. (Ed.). (1996b). *The genesis of higher mental functions*. London: Routledge.

de Vies, R., & Kohlberg, L. (1990). Constructivist early education: overview and comparison with other programmes. *National Association for the Education of Young Children*.

de Vries, M. (2005). *Teaching about technology: an introduction to the philosophy of technology for non-philosophers* (Vol. 27). Dordrecht: Springer.

de Vries, M. (2009). The developing field of technology education: an introduction. In A. Jones & M. de Vries (Eds.), *International handbook of research and development in technology education* (pp. 2–9). Rotterdam: Sense publishers.

Doise, W., & Mugny, G. (1984). *The Social Development of Intellect*. Oxford Pergamon Press.

Education, M. o. (1998). *Safety and technology education- a guidance manual for New Zealand schools*. Wellington: Learning Media.

Fleer, M. (1995). Staff-child interactions- a Vygotskian perspective. *Canberra: Australian Early Childhood Association Inc., 1*.

Fleer, M., Edwards, S., Hammer, M., Kennedy, A., Ridgway, A., & Robbins, J. (2006). *Early childhood learning communities - sociocultural research in practice*. Frenchs Forest NSW: Pearson Education

Fleer, M., & Jane, B. (1999). *Technology for children; developing your own approach*. Erskineville Australia: Prentice Hall

Fleer, M., & Quiňones, G. (2009). Assessment of children's technological funds of knowledge as embedded community practices. In A. Jones & M. J. DeVries (Eds.), *International Handbook of Research and Development in Technology Education*. Rotterdam: Sense Publishers.

Fox-Turnbull, W. (2003). *The place of authentic technological practice and assessment in technology education* Unpublished Thesis for Master of Teaching and Learning, Christchurch College of Education, Christchurch.

Fox-Turnbull, W. (2006). The influences of teacher knowledge and authentic formative assessment on student learning in technology education. *International Journal of Technology and Design Education, 16* (Springer), 53–77.

Fox-Turnbull, W. (2012). *Funds of knowledge in technology education*. Paper presented at the PATT 26. Pupils Attitudes Towards Technology: International Conference, Stockholm.

Gilbert, J. (2005). *Catching the knowledge wave? The knowledge society and the future of education*. Wellington: NZCER Press.

González, N., Moll, L. C., & Amanti, C. (Eds.). (2005). *Funds of knowledge* (1st ed. Vol. 2009 Reprint). New York: Routledge.

Greenfield, P. M. (1999). A theory of the teacher in learning: activities of everyday life. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: development in social context*. Cambridge, MA: Harvard University Press.

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Thousand Oaks, CA: Sage.

Harrison, C. (2009). Assessment for learning. In A. Jones & M. de Vries (Eds.), *International Handbook of Research and Development in Technology Education*. Rotterdam: Sense Publishers.

Hennessy, S. (1993). Situated cognition and cognition apprenticeship: implications for classroom learning. *Studies in Science Education, 22*, 1–41.
Hennessy, S., & Murphy, P. (1999). The potential for collaborative problem solving in design and technology. *International Journal of Technology and Design Education, 9*(1), 1–36.
Hill, A. M. (1998). Problem solving in real life contexts: alternatives for design in technology education. *International Journal of Technology and Design, 8*(3), 203–220.
Johnson, S. D. (1992). A framework for technology education curricula which emphasises intellectual processes. *Journal of Technology Education, 3*(2).
Jones, A. (1996). *Recent research in learning technological concepts and processes.* Paper presented at the JISTEC '96, Jerusalem.
Jones, A. (2009). Towards an articliuation of students making progress in learning technological concepts and processes. In A. Jones & M. de Vries (Eds.), *International handbook of research and development in technology education*. Rotterdam: Sense Publishers.
Jones, A., & Compton, V. (2009). Reviewing the field of technology education in New Zealand. In A. Jones & M. de Vries (Eds.), *International handbool of research and development in technology education* (pp. 93–104). Rotterdam: Sense.
Jones, A., & Moreland, J. (2001). *Frameworks and cognitive tools for enhancing practicing teachers' pedagogical content knowledge*. Paper presented at the ASERA.
Kimbell, R. (1997). *Assessing technology international trends in curriculum and assessment*. Buckingham: Open University Press.
Kuhlthau, C., Maniotes, K., & Caspari, A. (2007). *Guided inquiry: learning in the 21St century*. Westport CT: Libraries Unlimited Inc.
Lave, J. (1992). Word problems: a microcosm of theories of learning. In P. Light. & G. Butterworth (Eds.), *Context and Cognition: Ways of Learning and Knowing* (pp. 74–91): Harvester Wheatsheaf, Hemel Hempstead.
Lave, J. (1998). *Cognition in practice mind, mathematics and culture in everyday life*. Cambridge: Cambridge University Press.
Lave, J., & Wenger, E. (1996). *Situated learning: legitimate peripheral participation*. Cambridge: Cambridge University Press.
Lopez, J. K. (2010). Funds of Knowlege. *Learn NC* Retrieved 9 March 2010, from www.learnnc.org
Maddux, C. D., & Cummings, R. (1999). Constructivism: has the term outlived its usefulness? *Computers in Schools, 15*(3/4), 5–20.
McCormick, R. (1997). Conceptual and procedural knowledge. *International Journal of Technology and Design Education, 7*, 141–159.
Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking- a sociocultural approach*. Oxon: Routledge.
Ministry of Education. (1995). *Technology in the New Zealand curriculum*. Wellington: Learning Media.
Ministry of Education. (2007). *The New Zealand curriculum*. Wellington: Learning Media.
Ministry of Education. (2009). Indicators of achievement. *Curriculum Support* Retrieved 9 March 2010, from http://www.techlink.org.nz/curriculum-support/
Ministry of Education. (2010). Technology curriculum support. Retrieved 31 January, 2011, from http://www.techlink.org.nz/curriculum-support
Moje, B., Ciechanowski, M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy:an examination of everyday funds of knowledge and Discourse. *Reading Research Quarterly, 39*(1), 38–70.
Moreland, J., & Cowie, B. (2007). Teaching approaches. In M. de Vries, R. Custer, J. Dakers & G. Martin (Eds.), *Analyzing best practices in technology education*. Rotterdam: Sense Publishers.
Moreland, J., & Cowie, B. (2009). Making meaning in primary techology classrooms through assessment for learning. In A. Jones & M. de Vries (Eds.), *International Handbook of Research and Development in technology Education*. Rotterdam: Sense.
Moreland, J., Jones, A., & Chambers, M. (2001). *Enhancing student learning in technology through teacher technological literacy*. Wellington: University of Waikato.

Murdoch, K. (2004). *Classroom connections- strategies for integrated learning.* South Yarra: Eleanor Curtain Publishing.

Murphy, P., & Hall, K. (2008). *Learning and practice:agency and identities*. London: SAGE Publications Ltd.

National Curriculum website team. Attainment target for design and technology. Retrieved 9 June, 2011, from http://curriculum.qcda.gov.uk/key-stages-1-and-2/subjects/design-and technology/attainmenttarget/index.aspx

Pellergrino, J. W. (2002). *How people learn: contributions to framing a research agenda for technology education* (Vol. 2). TERC Conference Gold Coast, Australia: Centre for Technolgy Education Research .

Resnick, L. B., Levine, J. M., & Teasley, S. D. (Eds.). (1991). *Perspectives on social shared cognition* (first ed.). Washington: American Psychological Association.

Richardson, K. (1998). *Models of Cognitive Development*. Hove, U.K.: Pyschology Press Lrd.

Rogoff, B. (1990). *Apprenticeship in thinking: cognitive development in social context*. New York: Oxford University Press.

Rogoff, B., & Lave, J. (1999). *Everyday cognition: Development in Social Context.* Cambridge, Massachusetts: Harvard University Press.

Rohaan, E. (2009). *Testing teacher knowledge for technology teaching in primary schools*. Eindhoven: Eindhoven University of Technology Library.

Ryle, G. (1984). *The concept of mind*. Chicago: University of Chicago Press.

Schepens, A., Aelterman, A., & Van Keer, H. (2007). Studying learning processes of student teachers with stimulated recall interviews through changes in interactive cognitions. *Teacher and Teacher Education, 23*, 457–472.

Sfard, A. (1998). On Two Metaphors for Learning and the dangers of chosing one. *Educational Researcher, 27*(2), 4–13.

Shields, C., & Edwards, M. (2005). *Dialogue is not just talk- a new ground for educational leadership*. New York: Peter Lang Publishing Inc.

Siraj-Blatchford, J. (1997). *Learning technology, science and social justice: an integrated approach for 3–13 year olds.* Nottingham: Education Now Publishing Cooperative.

Smith, A. B. (1998). *Understanding children's development* (4 ed.). Wellington: Bridget Williams Books Ltd.

Staples. K., & Kimbell, R. (2005). *Unorthodox methodologies: approaches to understandng design and technology*. Paper presented at the PATT15. Retrieved from http://www.iteaconnect.org/Conference/PATT/PATT15/Stables.pdf

Stith, I., & Roth, W.-M. (2008). *Students in action: cogenerative dialogues from secondary to elementary school*. Rotterdam: Sense Publishers.

Turnbull, W. (2002). The place of authenticity in technology in the New Zealand curriculum. *International Journal of Technology and Design Education, 12*, 23–40.

Vygotsky, L. S. (1978). Mind in society: the development of higher psychological processes. In M. Cole, V. John-Steiner & E. Souberman (Eds.). London: Harvard University Press.

Wertsch, J. (1998). *Mind as action: the task of sociocultural analysis*. New York: Oxford University Press.

Wertsch, J. (Ed.). (1981). *General genetic law of cultural development.* Armonk NY: Sharp.

Wertsch, J., Del Rio, P., & Alverez, A. (Eds.). (1995). *Sociocultural Studies of the Mind*. Cambridge: Cambridge University Press.

Wertsch, J., Minick, N., & Arns, F. (Eds.). (1999). *The creation of context in joint problem-solving*. Cambridge, MA: Harvard University Press.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of child pyschology and psychiatry, 17*, 89–100.

Zinchenko, V. P. (1985). Vygotsky's ideas about units for the analysis of mind. In J. Wertsch (Ed.), *Culture, communication, and cognition* (pp. 94–118). Cambridge: Cambridge University Press

Zuga, K. (1992). Social reconstruction: curriculum and technology education. *Journal of Technology Education, 3*(2).

Zuga, K. (1999). Addressing women's ways of knowing to improve technology education environment for all students. *Journal of Technology Education, 10*(2).

ANTHONY WILLIAMS, ROB COWDROY AND LOUISE WALLIS

5. DESIGN

INTRODUCTION

What do we mean by "design" and "designing"?

Design is a many-splendored activity: architects, engineers, graphic designers, industrial designers, interior designers, landscape designers, fashion designers, computer hardware and software designers (and many others) are all designers and they all produce *a design* which is the outcome of a design process (design*ing*). A design is a representational form (eg, a drawing or diagram, a computer image, a model, a prototype), of the intended product (building, machine, garment, advertising image, electronic process, etc). The design communicates the intended product to other people through the documented medium. The design process (designing) leading to a design is essentially a set of thinking processes that are creative in particular ways. Sketching, modelling, experimenting, trial and error, etc, may also be part of a designing process, but they are supporting activities to the chain of thinking processes that are essential and central to any designing process.

Thus, we have four specific terms: *design* which refers to the whole field, *a design* which refers to a representational outcome, d*esigning* which refers to a thinking process, and a *designer* who performs the designing process and produces a design. And in discussion about design we must be careful to distinguish between a design (drawing, model, etc) for a product and the product itself (building, machine, garment, etc).

Design shares a close relationship to Technology; the relationship is almost symbiotic as Design provides the technologies that we use in our society but it also utilises the technologies to create new designs. It does this in two ways; firstly it uses technologies to support the design process such as in the application of computing. Secondly it utilises technology in creative ways to solve problems through application to novel situations. Design and Technology are very much intertwined.

Why is design education important?

Design is crucial to achievement of an "Innovative Society". Many governments have moved their policies on from promoting a "Knowledge Society" to promoting an "Innovative Society"; that is, from a focus on science and the acquisition of knowledge, to a focus on innovation (and invention) which is the *application of*

P. J. Williams (Ed.), Technology Education for Teachers, 93–114.

knowledge to development of new technology. Design is the essential link between the acquisition of knowledge and its application.

At the societal level, design and technology education is crucial to providing students with an appreciation of the opportunities it provides for society but also starts the process of stimulating interest in the activity of design as well as providing the initial thinking processes associated with the domain. Through providing secondary school students with experiences in design and technology, the continuum through to further education is established with the potential for training in the domain on which society and all industries depend. Design and technology learning experiences provide students with knowledge about the processes which lead to such professions as architects, engineers, advertising designers, fashion designers, computer hardware and software designers, and many more. A workforce of professional designers is not only required to maintain these established specialist professions, but also to populate new and emerging specialist fields such as ecological design, energy cell design, artificial organ design, and so on. The value of the knowledge, skills and attitudes that design and technology develops will provide those capacities that not only create the technologies on which society relies, but also the appreciation of the processes that underpin them and how to best manage the future.

DESIGNERS AT WORK

Distinguishing between designers

The products of design differ significantly, and the community distinguishes between designers according to the type of products for which they prepare designs. For instance, we expect engineers to design engines (machines), roads and bridges, but not hospitals and houses, while architects are expected to design hospitals and houses but not machines, roads or bridges. Similarly, and notwithstanding some overlaps, all the other design disciplines are expected to design certain types of products and not others.

The ways in which designers work and the specific design processes used by these various designers differ significantly. Architects, engineers, graphic designers, industrial designers, interior designers, landscape designers, fashion designers, computer hardware and software designers not only produce designs for differing products, their ways of working differ significantly. That is, there are as many design processes as there are design products. Nevertheless, Design is characterised by pro-active and strategic thinking, and there are certain fundamental aspects of design process that underlie all design activity, and it is the knowledge and skills encapsulated in these processes that school students should be exposed to. The knowledge and skills associated with design should be perceived as important attributes for school students, but they also provide an opportunity to engage students in learning through the process of doing, and in the doing they are able to emulate the real design activities undertaken in the design world.

These differences in the diversity of design processes are also reflected in community perceptions about how various designers work: we expect advertising designers to be more “creative” than architects, and architects to be more creative than engineers. By the same token, we expect engineers to be more “rational” than architects and advertising designers. At the same time we expect engineers and industrial designers to be the leaders of innovation and invention (and governments’ Innovative Society policies are based on this perception). But is creativity really so remote from innovation?

Design, innovativeness and creativity

To begin to understand the design activity it is important to have an appreciation of the concepts which are related to it. Creativity is something that is closely related to the concept of design so it is important to at least consider the attribute of creativity and the way that it is perceived to relate to the different types of design activity. Likewise innovation is often considered the outcome of the creative design process.

Creativity is often defined as the development of novel and appropriate solutions to problems. This definition of creativity can be compared with a common definition of design as being a discipline that seeks a balance between form and function, between originality and practicality, novelty and appropriateness. Design, as a discipline, is at the same time guided by existing realities with particular needs, functions and requirements and future opportunities for cultural reproduction, technological advance, innovation and intervention. These extend to not only practicing designers but also in the practices of those not engaged in the design disciplines. The need and find a balance between present realities and future opportunities, between the opposing requirements of appropriateness and novelty, these concepts place creativity at the heart of design. Creativity is, as Hernan Casakin (2007: 22) argues, what enables designers ‘to transcend conventional knowledge domain[s] so as to investigate new ideas and concepts which may lead to innovative solutions’; that is, through creativity, unorthodox and innovative approaches to design problems may be found.

Despite the assumed centrality of creativity in the design process, definitions of creativity are in many respects vague and ambiguous, leading to a lack of clarity in descriptions of the design process. Most design disciplines tend to be associated with one or the other of two philosophically and methodologically different themes: “creative” design methods that give priority to intuitive processes (characteristic of advertising, fashion and architecture) (Rowe,1995), and “scientific” methods that give priority to rational analysis (characteristic of engineering and computer software)(Grabowski,1998). However, no matter which design disciplines or activities are considered, all would maintain that design is inevitably creative. Also, we generally associate the term *design* with *innovation*, and *innovation* with *creativity*. However, this can be misleading: there are many types and levels of creativity (Bergquist,1999) and design engages with only some. Jeffries (2007) saw creativity as fundamental to design but hard to define in design terms, and claimed a consensus that creativity (in design) produces work that has the quality of being both original and useful.

Creativity varies (according to various taxonomies) from basic survival strategies (eg, sharpening a stick to use as a weapon) at one extreme, to purely abstract ideas (without any necessary practical application) at the other extreme (Bergquist, 1999). Design is generally not associated with either of these extremes of creativity, but various types of design can be readily identified with various intermediate levels of creativity, however all also involve at least some rational analytic process (Rowe,1995; Lawson, 1997,1999).

This differs from the general view that creativity in art (or the arts) produces work that is the expression of ideas and emotions, and that is original without necessarily being useful. Another way of considering it is that design is a continuum with *heuristic design* thinking being at the arts end of this continuum and *algorithmic design* thinking at the science end, with the majority of design professions lying between, and engaging varying mixes of heuristic and algorithmic design thinking. The design model used by engineering differs from the design model used in graphic design. Jackling, et.al. (1990) demonstrate this through the development of a design model based on a continuum with boundaries, shown in Figure 1 below:

ALGORITHMIC .... HEURISTIC
Science .... Arts

Figure 1. Jackling's Discipline Model of Design

As with the model developed by Jackling (1990) the "structured" end of the representative continuum relates to engineering disciplines and the "unstructured" boundary to the artistic disciplines.

Roozenberg and Cross (1991) developed two broader models of design;

1. the consensus model (the engineering type of design)
2. generator-conjecture-analysis model (architectural/industrial design)

The above models represent only a few of the range of models developed. In design literature the notions of creativity and design are closely associated with the "illumination" phase of the design process or the sudden perception of a bright idea (Cross 1990; Lawson 1990). The processes of brain storming is based on the notion of creating the environment where a bright idea will occur. This notion may also be considered as removing the block, in order to allow these creative ideas to occur.

It is apparent that various branches of psychology look at the attribute of creativity in different ways according to their understanding of the creative process informed by the theories they have developed. Bergquist (1999) saw creativity as an "encounter," with the merging of divergent information and the procedure through which it is processed. Most theories on creativity see it as a process through which the individual finds a relationship with the environment. Berquist (1999) describes a hierarchical arrangement but suggests a framework, in descending order:

1. conceptualisation;
2. schemata development;
3. physical execution.

While not admitting to design being definitively creative or innovative, Kim and Maher (2008) postulated that designing can be defined as a cognitive activity involving the production of sequential representations of an artefact, both mental and external (Akin and Weinel, 1982; Goldschmidt and Porter, 2004; Visser, 2004).

Major design professions such as architecture and engineering are often referred to as "applied sciences" because their design processes are dominated by application of technology (technical knowledge) to various products and contexts. At the same time, other design fields such as advertising and fashion design are often referred to as "applied arts" because their design processes are dominated by application of art forms (eg, drawing, photography). This "pigeon-holing" of such design professions creates significant identity problems particularly with respect to appropriate design process and to design education.

The Design process consists multiple phases and has been presented many times. Following are two examples of the design process as presented by Washington's National Building Museum and the NSW Department of Education and Training: Design

- Define a problem or need.
- Investigate the circumstances surrounding the problem.
- Imagine potential solutions.
- Plan a feasible solution, often in the form of a model or prototype.
- Produce a final solution, typically reflecting certain limitations or constraints
- (e.g., money, time, materials).
- Evaluate the end product, possibly leading to a cycle of design revisions.

It is important to note that the design process is not linear, and actions do not always proceed sequentially. In fact, the phases of the design process often alternate back and forth and may repeat themselves before arriving at a final product. Design is a constantly shifting, fluid process. (from -http://www.nbm.org/assets/images/youth-ed/school-programs/design_ process_graphic.jpg)

The NSW Department of Education and training describe the design process as:

- Exploring and defining the task involves the activities students undertake to identify and explore a need or opportunity.
- Generating and developing ideas involves students exploring options, considering existing solutions, generating alternatives, representing and refining those ideas and deciding upon options.

- Producing solutions involves finalising design decisions; completing final design representations.
- Planning, managing and evaluating is an essential component of each of the above phases.

(Found at: http://www.curriculumsupport.education.nsw.gov.au/designproduce/images/designcycle_aa.jpg

What these descriptions show is that Design consists of a series of steps or phases. What must be remembered when organizing design learning experiences for students is that the students' age and experience are important considerations. A student of 5 or 6 years of age is able to effectively engage in the design process as long as it is suitably structured for their level, it is important at this age for the student to engage with problems on items they are very familiar with, the older the student the more complex and abstract the design tasks can be.

The implication for teachers in fields which include design is that there are considerations for both teaching and assessing design. Curricula which encourage and support creative thinking are important for the disciplines of design and the application of appropriate pedagogies and assessment strategies is essential, both of which are covered more fully in other chapters of this book.

WHAT IS DESIGN ABILITY?

Defining design ability

To this point we have been considering what design is and how creativity contributes to it. In this section we consider the actual ability that is considered 'design'. Many definitions of design ability have been proposed, mostly from a philosophical perspective, the common themes being around the ways in which designers work, what designers do, and what qualities make up "good designers". Alexioua et al. (2009) saw design as a natural human activity present in many professions. Despite the fact that the activity of design and the activities of art and science are closely linked (Cowdroy & Mauffette, 1998; Cowdroy & DeGraaff, 2005), design can be contrasted to both art and science in that design is considered to be about imagining and synthesising new realities, rather than expressing ideas and emotions (as in art) and rather than analysing and understanding existing realities (as in science). Design is essentially guided by human purposes and is directed towards the fulfilment of intended functions such as (after Cross 1995):

- Producing novel, unexpected solutions
- Tolerating uncertainty, working with incomplete information
- Applying imagination and constructive forethought to practical problems
- Using drawings and other modelling media as a means of problem solving

Also it can be expressed in the abilities portrayed by designers and these would include the ability to:

- Resolve ill-defined problems
- Adopt strategies which focus on achieving a solution
- Employs a diversity of thinking skills
- Uses nonverbal, graphic/spatial modelling media (after Cross, 2006)

Cross (2006) referred to *design cognition*—the ways that designers, think, work, and know. Cross (1995; 1999) also referred to design ability as a multi-faceted skill possessed, to some degree, by everyone, but that it would be reasonable to claim that there are specific ‘designerly’ ways of knowing, thinking and acting. These concepts underpin the rationale for design and technology in the school curricula. The multi-faceted nature of design with its ability to apply both innate and developed creativities to problems creating the opportunity for students to work toward and experience resolution of problems in a technological context should be considered a core of school curriculum, not just an option.

Design as a thinking process

Many consider design as being problem-solving, and that the generic design process is a problem-solving process. It can be thought of in terms of a three-stage model:

1. *an intent* to achieve some outcome,
2. *a directed thought process* (designing) directed towards achieving that intent,
3. *an outcome* (a design) (Cowdroy and Williams, 2002)

Ziesel (1984) also saw design in terms of three activities: *imaging, presenting and testing/problem-solving*, progressing from information and ideas about how things might be, towards ideas about how things might work. Simon, (1996), however saw design as about experimenting and probing (trial and error) rather than producing optimal solutions. Alternatively Schön (1983) saw designing as a kind of “making” which is largely learned and practiced through repetitive, cyclic “action and reflection” where reflection meant progressive and repetitive review of action as it proceeds.

Hudson (1966) saw design process in terms of two kinds of problem-solving thinking — *divergent* and *convergent* thinking. Divergent thinking was characterised by ideation, and fluency which brought together usually unassociated ideas: it moves away from the known and predictable to explore unusual areas. On the other hand, convergent thinking was presented as progress toward production of a single, right answer to a problem; a style of thinking characterised by a logical, analytical approach to problem-solving. According to Alexioua et al. (2009), what distinguishes design (from problem-solving) is the need to define the conditions of satisfaction (or problem space) together with a language of possible solutions (solution space).

Cross (1999), in his study of experienced designers, lists the following aspects:

- *Design is rhetorical,* in that the designer, in constructing a design proposal, constructs a particular kind of argument, in which a final conclusion is developed and evaluated as it develops;
- *Design can be exploratory*, in that a designer typically interprets the design brief not as a specification for a solution, but as a kind of partial map of unknown territory;
- *Design is emergent*, insofar as relevant features emerge and can be recognised as having properties that suggest how the developing solution-concept might be matched to an emerging problem-concept;
- *Design is (often) opportunistic*: where the search is not for an optimum solution to the given problem, and the path of exploration cannot therefore be predicted in advance.
- *Design is abductive*, involving a type of reasoning different from the more familiar concepts of inductive and deductive reasoning, but which is the necessary logic of design – what designers often refer to as 'intuition'
- *Design is reflective*, in the sense of a dialogue or 'conversation' that goes on between internal and external representations and is part of the recognition that design is an ongoing process.
- *Design is ambiguous*. Designers will generate early tentative solutions, but also leave many options open for as long as possible; they are prepared to regard solution concepts as necessary, but imprecise and often inconclusive.
- *Design involves risk-taking*, involving complexity and uncertainty of parameters, direction and outcome.

As can be seen from the above design is a complex activity which needs specific teaching approaches to ensure its development.

DESIGN EDUCATION

Design teaching has an increasingly important role at all levels of formal education: in school, college, tertiary and higher education. Government "Innovative Society" policies are focused on the generation of new technology in the sciences and transfer of that technology into innovations and inventions that advance our society, and recognise the specialist design professions as essential to the technology transfer link between science's acquisition of knowledge and applications of that knowledge in innovations and inventions. The fact that the foundations of these design activities are provided in school is often less well recognized by government. The Innovative Society policies also recognise the importance of design education to achieving training of designers to maintain these established specialist design professions, but also to populate new and emerging specialist design fields such as ecological design, energy cell design, artificial organ design, etc, mentioned earlier, which are at the forefront of innovation and invention. Also as general skills for everyone

Consequently, in many countries there is pressure to reinforce design education, and to develop more flexible programmes that will allow graduates to adapt to new directions and new design fields. There is also pressure to begin streaming earlier in school and towards the design vocations to increase "relevance" of school education to specific career orientations in the design fields.

At the level of the individual, design and technology education in schools provides for the development of pro-active and strategic thinking abilities that are foundations for progression towards the specialist design professions in particular, and all professions in general. The pro-active and strategic thinking that characterise design processes also benefit pro-active approaches to science thinking (Cowdroy & Mauffette, 2003), creativity in general (Cowdroy & DeGraaff, 2005), and to personal development and social interactions, and strategic approaches to career direction and other ambitions.

And those design process skills don't just happen: they must be learned and, as designing processes vary according to product context, it is necessary for us to define what sort of design product we want our students to aim for, ie what sort of designer we want our students to emulate for our particular educational setting and purposes. So the approach may vary from junior and lower secondary schooling where design is taught because of the cognitive skills that all students need regardless of their eventual profession, and upper secondary where the design education may begin to differentiate between the specific design processes required for each of the various types of design fields. Only then can we establish expected design education outcomes, what constitutes quality, the most appropriate teaching methods, assessment criteria, and accreditation and accountability requirements (Rowe, 1995; Lawson, 1997; Maitland & Cowdroy, 2001; Cowdroy & DeGraaff, 2005).

Recent developments in design teaching

Broadly, educational approaches for the range of design disciplines fall into three groups: those evolving from a fine-arts background and generally conforming to a studio-based Beaux Artes educational model; those evolving from a technology background and generally conforming to an applied science educational model; and those who have sought alternative approaches, generally being combinations of Beaux Artes and scientific models such as the Bauhaus educational model. Much school education practice falls into this latter category.

Interest in alternative educational approaches to design education has been gradually increasing since the Bauhaus experiments of the 1930s in Germany and their "migration" to America in the post-war years and then to design education institutions throughout the developed world. In general terms, the purpose for adopting these models for design education was to try and introduce *relevance*: initially relevance to the way designers think and develop their designs and, later, relevance to the context of design practice.

The "Reflective Practitioner" philosophy of Donald Schön (1983) of the University of Wisconsin (Milwaukee, USA), was developed from 1930s Bauhaus principles from pre-war Germany, and focused particularly on architectural and engineering education and the ways that architects and engineers thought and developed their designs. The subsequent introduction of "Problem-Based Learning" by Donald Woods (1985) of McMaster University (Hamilton, Ontario, Canada) for undergraduate engineering design education was intended to develop Schön's ideas further into the practical realities of the ways engineers not only thought about design, but also how they did this in the "real world of professional practice". Woods' approach was a form of experiential learning in simulated workplace conditions, and focused on integration of diverse knowledge and skills, and problem-solving praxis to meet "real world" relevance expected by employers, all brought together through reflection. Reflection is a powerful way of building students' design ability as it makes the student consider what they have done and what decisions they made during the design process which led to the type of outcome they achieved as an outcome of their chosen design process. De Bono's "lateral thinking" philosophy (eg, 1995), and particularly his "six thinking hats" development of that philosophy (1985), both originally aimed at management, have also been adopted as quasi educational theory and contributed to design education, particularly in engineering and other fields towards the science end of the design spectrum.

Elements of these developments have paralleled the changes in the theoretical underpinnings of Design and Technology education as a school subject. As it has developed from a focus on manipulative skills to activities that recognize the importance of concurrent cognitive skill development, it has also been shaped by sociocultural theory and the virtues of reflective practitioners. The location of student activities in contexts that are real and relevant to them, the development of lateral thinking skills and the application of inter disciplinary knowledge to a specific problem, all have parallels in tertiary design education.

The Concept of the Design Studio

Common to all design education approaches has been belief in a particular design thinking process as the most appropriate for the respective design field. Such beliefs have led to a predominance of studio-based (art-like) design teaching in those fields associating with the art end of the design spectrum, and rigorous science-like design teaching in those fields associating with the science end of the design spectrum. Nevertheless, there has been longstanding concern about the polarisation of design methods towards each end of the design spectrum, due to lack of analytic process in art-related design, and the lack of conceptualisation in science-related design.

Around the middle of the spectrum, for instance in architectural education and industrial design education, design and technical content are typically separated, with studio based design teaching, while technical content is taught in either traditional didactic "knowledge acquisition" format or in rigid analytical format. Many attempts have been made in these mid-spectrum fields to achieve an integrated curriculum, e.g. with Problem-Based Learning, or Project-Based learning. While full integration has been only partly successful, these methods have been highly successful in other respects and overall, particularly in achieving design thinking that emulates professionals in the respective field (DeGraaff & Kolmos, 2007).

In the school context, it is the intent to bring these two poles (design and technical content) together in order to provide an holistic educational experience for students. One of the unique aspects, and hence rationale, of this area in the school curriculum is that it provides the opportunity for students to develop innovative and creative skills in a practical context – they can think of ideas and then immediately test those ideas through technical practice.

There is however a tendency to separation in schools, which is encouraged by the fact that there are often workshops (technical) and classrooms (design) used as teaching spaces, there may be separate theory and practical exams, and often classes are timetabled for a single 'theory' lesson and a double practical lesson.

The typical approach in design education primarily employs project-based learning and experiential learning principles, and sometimes PBL. These approaches align with the current learning and teaching paradigm that focuses on the student learning and what the learner does (Constructivism and student-centeredness). However the subtleties of how the teacher engages and interacts with the student through the design and assessment of the project or problem, and provides knowledge and feedback to the student, underpins whether or not the constructivist's perspective or student centeredness is being employed. All of these methods of delivering learning experiences for students are possible in the diversity of classroom settings available to design and technology teachers. The reality is that it is not the physical "place" that creates the learning experiences; it is the mode of delivery. The "place" though potentially important does not dictate. This is not to negate the need for appropriate teaching spaces for the delivery of Design and Technology courses. As these courses are "multi-dimensional" in what they deliver, from the initial idea potentially through to the manufacture and development of marketing strategies, it is important to have the appropriate facilities which will permit this. The facilities create the means but it is the cognitive stimulation which creates the learning and the design outcomes, these are achieved through the implementation of well-developed learning experiences.

Student design ability and learning styles

The teaching approaches used for teaching design are well researched and in practice through a diverse range of design disciplines. Following is an overview of these instruction methods.

Constructivism Students construct or create their own knowledge networks and interpretative frameworks by actively modifying, revising, extending information input and by relating it to what they already know (Nicol 1998: 88)

Constructivism is currently the most recognized and influential learning and teaching viewpoint across many disciplines, but for design education it has significant importance. Constructivism refers to the process of learning and to the personal framework used to judge whether new stimulus is relevant and challenges existing knowledge, sometimes instigating change (Moon 2004:18). Constructivists do not view external input as 'truth', rather as a working hypothesis (Schunk 2008:236). They stress that the meaning is context-bound, cumulative in its nature, and prior knowledge is built on and not transferred (Knowles, et.al. 2005:192, Biggs & Moore 1993:524).

Constructivism draws mainly from concepts of Piaget and Vygotsky's works (Pritchard 2005, Sutherland 1997). In terms of Piaget's work his Theory of Knowledge sought to scaffold learning and sequential development of mental processes. For Vygotsky, his concepts pertaining to the role of social interaction and dialogue in learning and the Zone of Proximal Development was adopted. The Zone of Proximal Development describes the potential 'space' that the student has the capacity to develop with the assistance and collaboration of the teacher. This is an important concept in teaching design as the interaction activity is fundamental to the design learning process, and the ability for students to interact with teachers and peers has significant importance in developing design skills.

It is possible that knowledge constructed by individuals can be inaccurate, and later discoveries may change the student's conception. This implication causes concern for some educators, as constructivists believe that you cannot directly control the student's learning, but rather the teacher can support the learner with appropriate activities and ascertain their level of understanding (Biggs & Moore 1993:22–24). The importance of well-designed learning activities are essential for effective design learning.

The social version of constructivism emphasizes how students can gain new strategies through peer collaboration by interpersonal discourse (Forman and Cazden, 1985). The influential psychologist Bruner (1966) makes the case for education as a knowledge-getting process:

> "To instruct someone... is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for her/himself, to consider matters as an historian does, to take part in the process of knowledge-getting. Knowing is a process not a product" (1966: 72) (as cited in Smith, M.K., 2002).

According to Bruner (1973), learning is a social process, whereby students construct new concepts based on current knowledge. They select information, construct hypotheses and make decisions by integrating new experiences within a social context, not isolated. Based on Bruner's theory (1973), a constructivist curriculum should provide the following:

1. Instruction must be commensurate with the experiences that make the students willing and able to learn (readiness)

2. Instruction must be structured so that it can be easily understood by the students (spiral organization)
3. Instruction should be designed to facilitate extrapolation (going beyond the given information).

Based on the above views, learning is a process of constructing meaningful representation, and of making sense of one's experiential world. Thus learning emphasizes the process and not the final product. Von Glasersfeld (1995) pointed out that "from the constructivist perspective, learning is not a stimulus-response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction" (p.14). Accordingly, any assessment of learning would necessarily have to track the process rather than examining a particular end point.

Student Centered Learning

The aims of student centered learning are to focus teaching on student learning and the student's perspective; take advantage and harness students' motivation to learn; and enable students to determine what they need to learn and how to employ reflective learning practices. The ultimate aim is that the teacher becomes peripheral and the student has the capacity and confidence to undertake learning, be self-directed and autonomous (Boud 1995:24). Broadly, the role of the student centred teacher is comparable to the Constructivists' description above. To stimulate and assist student learning, whereby the learner develops and explores their understanding by responding to a project or problem.

McWilliam (2009) is concerned that the popular notion of student centeredness where the teacher is the 'guide' or the 'facilitator' is a difficult role to achieve and may be misinterpreted. In many instances, depending on the teacher's ability to appreciate the subtleness of this approach, either the student or the teacher may become passive. For example, McWilliam cites the distribution of task sheets, which may be very explicit in their description of the outcomes. In this situation the student is simply led by the detail provided and may not engage fully with the problem. As such the learner becomes passive, following the directions of the teacher, through the task sheet, and not engaging fully or "owning" the design problem. Therefore, McWilliam advocates a combination of approaches, which values both teaching skills and active student learning. He proposes methods to transmit information support for students through designed activities which facilitate co-directing and co-learning (2009: 288). Thus, structuring rich activities, which involves the teacher as much as the learners, without doing it for them or making it less challenging, but fully engaging the students with the problems so they own the solution.

Experiential learning

Experiential learning was first described by Kolb to be "the process whereby knowledge is created through the transformation of experience" (1984: 38).

His work recognised the similarities in the experiential learning cycle with other models of inquiry/research such as creativity (Wallas 1926), decision-making (Simon 1996), and problem-solving (Pounds 1965) (Kolb 1984:33). Weil and McGill (1989) expanded Kolb's concept and described the transformation process further:

> the process whereby people individually and in association with others, engage in direct encounter, then purposefully reflect upon, validate, transform, give personal meaning to and seek to integrate their different ways of knowing. Experiential learning therefore enables the discovery of possibilities that may not be evident from direct experience alone (248).

Boud, Cohen and Walker (1993) and Kolb (1984) also emphasize in their work that experiential learning relies on the context and assumptions that "…learning is a holistic process, …socially and culturally constructed; and … influenced by the socio-emotional context it takes place in" (1993:8–14). Group work is often associated with experiential learning and was influenced by Lewin's and Vygotsky's position that learners benefit from discussion with others due to the debate of multiple perspectives and approaches, which may cause individuals to reassess their knowledge (Kolb 1984). Many parallels can be drawn here with constructivist perspectives.

Most advocates of Experiential Learning stress that experience or action alone does not result in learning, rather it is the critical reflection on the experience and how this is transformed into considered actions (Boud 1995, Moon 2004). This type of learning has been referred to many times in the design education literature. Such references include the apprenticeship model and the adoption of project and problem based learning. Moon (2004) identifies that experiential learning is particularly appropriate for learning when materials are ill-structured or challenging such as design, the goal is meaningful and authentic, and representations or evidence of learning is required (2004: 129).

The application to the design and technology context is clear, founded as it is on a belief in the value of experiential learning. However the principles of experiential learning help to differentiate design and technology education from manipulative skill development, in that the conduct of the action alone does not constitute learning, though it may constitute an ability to copy. It is the critical reflection of the experience that transforms it into learning.

Kolb described the use of group work in experiential learning as generating a vital and creative environment (1984:10). Design teaching should strategically employ group work which can very effectively be accommodated in the initial phase of the project or problem, providing students with the opportunity to expose their design ideas to an audience providing opportunity to receive feedback, but more importantly providing the student with the opportunity and motivation to bring their own design concepts to a point where they can be articulated to others, making them much more concrete than simply concepts. Students are encouraged to learn from each other through both formal and informal group reviews to discuss different positions and options. A ‘pitfall’ identified by Cell (1984) of experiential group learning is that “over acceptance” maybe a characteristic group norm, possibly resulting in inadequate critique of ideas.

Problem-Based Learning (PBL)

PBL is commonly employed in teaching tertiary professional design disciplines, such as Architecture, engineering and Industrial Design (Biggs & Moore 1993:473), and in secondary based Design and Technology . This model starts with the ‘problem’ to instigate and motivate a more powerful learning of knowledge and its application (Barrows and Tamblyn 1980, Boud 1985). Another way this concept is simply expressed is that students’ learn more effectively ‘just in time’ (Chambers 2007). This involves the students receiving information relating to the current aspect of their learning experience when they meet the issue, not early in the design process when the student is unable to relate to the information’s relevance. The timing of information or learning stimulus is important if the student is going to see its relevance to the task at hand.

PBL has been described as an holistic approach to teaching or an educational strategy but not a method (Biggs 2003, de Graaff & Kolomos 2007), PBL relates to the whole structure of the learning experience, the curriculum design with its components of assessment and sequencing of learning experiences as well as the instructional methods which may be used, PBL is not limited to the instructional method which is employed to deliver the learning experience. Savin-Baden and Howell-Major (2004) conclude that PBL is too complex to define due to the variety of learning theories, contexts, cultures and purposes that come together in PBL (56). It has been linked to, and incorporates aspects from Constructivism, Student Centered Learning, and Experiential Learning. Barrows (1986) defined the four goals of PBL:

- Structuring knowledge for use in the working contexts
- Developing effective reasoning processes
- Developing self-directed learning skills
- Increased motivation for learning (in Biggs, 2003)

Biggs (2003) includes a fifth goal added to Barrows’ list: “developing group skills, working with colleagues” (234). Many of these goals encourage the development of high order thinking more than the acquisition of knowledge. Simply, the main objectives of PBL are integration, application and critical evaluation (Cowdroy, Kingsland and Williams 2007).

Essentially, PBL requires the resolution of a problem, which may have more than one correct response as a way for students to develop skills to select and evaluate appropriate knowledge domains through a process of proposition, testing, and reflection to generate appropriate solutions (Barrows and Tamblyn 1980, Biggs & Moore 1993). The problem forms the curriculum. Savin-Baden (2007) suggests that the variety of PBL models can be categorised in two ways. First the curriculum is designed around PBL whereas the second is a hybrid model, where elements of PBL have been integrated into the course or unit (Savin-Baden, 2007, 13). Both these approaches are evident in secondary schools.

Project-Based Learning

Project-Based Learning appears to be another central approach described in design education (Davies and Reid, 2000 and Pearson et al 1999). However, there seems to be little discussion of project-based learning beyond the categorization. The origins of Project-based learning were with the education of architects and scientists before the 20th century as well as the work of Dewey and Kilpatrick in the US (Adderley, 1975:8).

Project-Based learning shares many similarities with PBL in that students solve an authentic and open-ended problem that may be devised by the teacher or the student (Chambers 2007:7). There is much debate regarding the differences and similarities in these approaches (Lee, 2009, de Graaf & Kolomos, 2007, Chambers, 2007, Boud and Feletti, 1991, Boud, 1985, Adderley, 1975). Savin-Baden (2007) characterizes the key difference in that Project-Based Learning is more a teaching technique, while Problem-based learning is a more encompassing approach in curriculum and course design (Savin-Baden, 2007, 19).

An appraisal of Project-Based learning in 1975 (Adderley*)* identified and raised many pertinent issues that are concerns expressed today by teachers. The advantages are the more individual support and development of the student, as well as encouraging more student initiative and responsibility in their learning (Adderley, 1975). This approach allows for different learning styles and rates of progress as the solution is not required in an instance, as the student may negotiate with the teacher to focus on only one aspect of the design process, e.g. the development of the working drawings and specifications, or a model, rather than the final product.

CONCLUSION

Design is of singular importance to the development of an Innovative Society, and to the advancement of industry across all fields, because it is the dominant vehicle for transferring skills, knowledge, technologies, methods of manufacturing, samples of manufacturing to students who can then further develop these into products, processes or application. Inventions must be designed; innovative products must be designed or re-designed; innovative processes require design or re-design of the infrastructure facilities that support them. All design fields are moving rapidly with developments in technology, and new fields of design are emerging and must be populated. Design education must not only keep pace, but must foresee new design needs in existing fields and opportunities to predict the emergence of new fields. Design education will play a vital role in preparing not only designers who can meet the challenges of the Innovative Society, but practitioners in many professions for whom a framework of innovation is crucial to their success.

Design education covers a wide spectrum of fields, from those closely associated with the creative arts to fields closely associated with science. Successful designers in all fields have been shown to have two salient sets of core ability: conceptualisation of outcomes of multiple and complex intentions, and rational analysis of outcomes in terms of intentions. These two core abilities must be integrated into the various design processes that students explore.

And these core abilities and their integration do not just happen: they must be developed through carefully structured educational experiences. Constructivist learning methods have been shown to be the most effective methods for design education, particularly when employed in design and technology workshop learning environments.

What we are considering here is the development of learning experiences in the design and technology area which are not simply taking projects which are drawn from the professional world but are structured learning experiences which are developed by the teacher to achieve learning outcomes, not a project outcome that emulates, for example an industrial product such as design for a house taken from an Architectural context or a copy of an item of furniture. What we should be trying to achieve is a project that is developed from a series of learning outcomes which introduce the students to the multiple phases of design, which may not have as a priority the production of a fully developed design and production process.

When considering design projects for students there is the potential to have the students replicating the same process but just applied to different projects. What the teacher should be considering is the need to provide students with learning experiences which develop the students' understanding of the different phases of the design process. This means that it may not be necessary every time to have the students do a full design process in the production of a project. It may mean learning experiences may focus on only one or two phases of the design process-manufacture process. So the considerations of the design experiences established for students are the scope and the magnitude of learning experiences.

Design learning experiences can encompass the full design process but also it may provide experience of a condensed design process or truncated design process. The focus is on the learning experiences desired rather than the product that is produced by the students. So there is potential for a full design-manufacture project, a shortened design experience as well as the focus on one of the phases of the design manufacture process. These different learning experiences provide students with a better understanding of each of the phases of the design process and the knowledge, skills and values which are inherent in the phases, e.g. environmental issues may be the focus in any one of the phases, but be considered differently, from either a product perspective or a process perspective. These perspectives are gained during the different phases of design.

Teachers have at their disposal a wide range of approaches when developing design learning experiences, following we will consider two approaches which could be used to provide students with differing learning experiences relating to design. The first is the esquisse, the second is the full design-manufacture process but bringing in different emphasis.

In French, 'esquisse' means 'sketch' and come to English usage via the École des Beaux-Arts, as discussed above, where it came to refer to specific phases in a desing project. In the École des Beaux-Arts, the esquisse was an exercise carried out at the beginning of the design process—it was self-contained and conducted within a very short time frame. Students would be provided with a design task that would normally be considered quite extensive but the time allocated to the development of the design outcome was quite short, perhaps one day, the important aspect was that it was completed in one session, so the focus was shifted from the quality of the design outcome to a focus on the design creativity and ability to engage with a range of design decision-making experiences in a short time. The esquisse has the potential to:

- engage students in a process which involves an intense but short design experience;
- provide experience in a group exercise, which develops an appreciation of, the team design approach;
- broaden the individual student's perspectives of the design process because of the confrontational approach of the method;
- increase student confidence as there is not the demand and therefore pressure for a fully developed design product but rather the development of concepts;
- focus student attention on time management;
- encourage a creative approach to design through the need to be both spontaneous and intuitive;
- reflect on their process and decision making as the experience is short enough to allow early revisit to their design sequence and consider critical design path analysis;
- shift the focus to the process rather than the product.

The esquisse also has the value of isolating, and thus emphasising, the criteria of a large project. Within the sometimes formless process of a multi-week exercise, assessment criteria can be infrequently addressed, so this approach allows frequent and focussed attention on the assessment criteria.

This approach to the development of a learning experience, based on the esquisse, can foster student engagement with decision making and focus on idea generation without the pressure to develop it into a finalised product.

The second approach to be considered is the truncated experience, which focusses on one phase, or set of knowledge and skills, associated with the design process. Too often the different phases of the design process are lost in the desire to reach a "good product", the object that the student can show everyone which is well finished and functions well, but may have provided limited learning for the student. In this approach the teacher may set a focus on one aspect of the design process, for example the focus may be on idea generation, design research, communication or documentation.

The following steps in the design project focus on the communication of the design, specifically through the development of drawing skills:

1. Design ideas for concept design: through sketches while generating ideas, this focuses on sketches which document students' design decision making. Sketching as a documentation of brainstorming.
2. Series of drawing exercises focusing on documentation, students using drawing to document their ideas, but with the express purpose of communicating the detail to others.
3. Using drawings to communicate sequences or processes.
4. Spatial sketching requiring students to make exploded views of existing products.
5. Presentation drawings (renderings) of the concept: the students deliver drawings which communicate to potential stakeholders, drawings which include the concept of scale and spatial perception.

Through focussing on communication skills rather than the product the student will develop enhanced capabilities in drawing as a means of communication and documentation.

In the example of communication through drawing we see one aspect of the design process focussed on, and this strategy could be used for other phases of the design process. Through the teacher changing the focus from the end product to aspects of the process, students' attention is drawn to that phase and this provides an opportunity to develop the knowledge and skills associated with that phase without the pressure of having a well developed product as the outcome. This is not to negate the importance of the student engaging in the full design-manufacture process but rather designing learning experiences which allow students to develop skills across the full range of design rather than just production.

Much of this chapter draws from the literature of teaching design at the professional level but conceptually the process of teaching design at the secondary level is by its nature very similar and as such should incorporate similar teaching strategies adapted to those developed and adopted by the design professions in the development of their students. School teachers of design must appreciate the importance of the design process to the development of thinking and problem solving skills which are not covered in any great extent within the range of other curriculum areas in schools. Design education has the potential to broaden students' learning experiences allowing them to more readily take ownership of their learning and employ the skills associated with creativity and practical problem solving, both critical to well rounded citizens of a technological society.

REFERENCES

Adderley, K. (1975). Project Methods in Higher Education, Research into Higher Education Monograph 24 London: Society for Research into Higher Education

Akin, O. and Weinel, E. F. (1982). Representation and architecture, Information Dynamics, [Silver Spring, Md.].

Bergquist, C. (1999). A Comparative View of Creative Theories: Psychoanalytic, Behaviourist and Humanist, Vantage Quest, http: www.enterquest.com.trees.comparative.htm

Alexioua, K., T. Zamenopoulosa, et al. (2009). "Exploring the neurological basis of design cognition using brain imaging: some preliminary results." Design Studies *30*(6), 623–647. Bruner (1966 ***Is this replaced by Smith, M. K. (2002). Jerome S. Bruner and the process of education, the encyclopedia of informal education, Last updated: December 28, 2007, http://www.infed.org/thinkers/bruner.htm.***

Andresen, L., Boud, D., & Cohen, R. (2000). Experience-based learning. In G. Foley (Ed.) Understanding adult education and training. Allen Unwin: Sydney

Barrows, H. S., & Tamblyn, R. M. (1980). Problem-based learning: An approach to medical education. New York: Springer

Barrows, H. S. (1994). Practice-based Learning: Problem-based Learning Applied to Medical Education. Springfield, Illinois: Southern Illinois University School of Medicine

Barrowhs,. S. and Tamblyrn, M. (1980). Problem-based Learning: An Approach to Medical Education, New York, Springer

Boud, D. J. ed. (1985). Problem-based Learning in Education for the Professions, Sydney: Higher Education Research and Development Society of Australia

Biggs, J. B., & Moore, P. J. (1993). The process of learning. Sydney: Prentice Hall.: Prentice Hall

Biggs, J. B. (2003). Teaching for quality learning at university. Buckingham: Open University Press/ Society for Research into Higher Education. (Second edition)

Boud, D. (1995) Assessment and learning: contradictory or complimentary? 35–48 in Knight, P. (ed.) Assessment for Learningin Higher Education, London: Kogan Page/SEDA

Boud, D., Cohen, R. & Walker, D. (eds) Using Experience for Learning Buckingham: SRHE and Open University Press

Boud, D. & Feletti G. (1991). (Eds.), The challenge of problem-basedlearning, Kogan Page, London

Bruner, J. (1973). Going Beyond the Information Given. New York: NortonBiggs, J (2003) Teaching for Quality Learning at University, ed 2, Open University Press, UK.

Casakin, H. (2007). Metaphors in design problem solving: implications for creativity. *International Journal of Design, 1*, 21–33

Chambers, D. (2007). Is the modern NHS fit for nursing students? *British Journal of Nursing*, *16*(2), pp. 74–75

Cell, E. (1984). Learning to learn from experience. Albany, NY: State University of New York Press.

Cowdroy, R. & DeGraaff, E. (2005). Assessment of High-level Creativit. *Assessment & Evaluation in Higher Education, 30*(5), 507–518

Cowdroy, R. & Mauffette, Y. (2003) Assessing Research and Research-Based Learning: an Authenticative Paradigm, proceedings, ATN Evaluations and Assessment Conference, Adelaide, Nov, 2003.

Cowdroy, R. & Williams A., (2002). 'Assessing Design Activity: Issues and Actions', Proceedings of the 7th International Design Conference DESIGN 2002, Croatia

Cowdroy, R., Kingsland, A. & Williams, A. (2007). Achieving Cost-effective Problem-Based Learning: Dispelling myths about Problem-Based Learning. In Graaf, E. de. and Kolmos, A. (Eds.) Management of Change: Implementation of Problem-Based and Project-Based Learning in Engineering. Sense Publishers. Rotterdam/Taipei

Cowdroy, R., & Williams, AP., (2005). Aligning Teaching and Assessment: The Key to Greatly Improved Graduate Quality and Sustainable Teaching Efficiency, The First International Conference on: Enhancing Teaching and Learning through Assessment, Hong Kong, 13th – 15th June

Cross, N. (1990). "The nature and nurture of design ability." *Design Studies*, *11*(3), 127–140.

Cross, N. (1995). Discovering Design Ability. Discovering design: exploration in design studies. R. Buchanan and V. Margolin. Chicago, University of Chicago Press: 105–120.

Cross, N. (1999). “Natural intelligence in design.” *Design Studies, 20*(1), 25–39.
Cross, N. (2006). *Designerly Ways of Knowing*. London, Springer-Verlag.
Davies, A & Reid, A. (2000). Uncovering problematics in de-sign education – learning and the design entity. Proceedings of Inter-national Conference Re-inventing Design Education in the University, pp. 178–184
De Bono, E. (1985). *Six thinking hats*, Penguin, London.
De Bono, E.(1995). *Serious creativity*, Harper Collins, London.
DeGraaff, E. & Kolmos, A. (2007). *Management of Change: Implementation of problem-based and project-based learning in engineering*. Sense Publishing, Rotterdam.
Forman, E. A. & Cazden, C. B. (Eds.). (1985). Exploring Vygotskian perspectives in education, Cambridge, Cambridge University Press.
Fry, H., Ketteridge, S. & Marshall, S. (Eds). (1999). *A Handbook for Teaching and Learning in Higher Education*. Enhancing Academic Practice, London, Kogan Page
Goldschmidt, G. & Porter, W. (Eds.) (2004). *Design Representation*. Springer Verlag, London.
Grabowski, H, Rude, S., & Grein, G. (1998). *Universal Design Theory*, Shaker Verlag, Aaken
Hudson, L. (1966). *Contrary imaginations: A psychological study of the English schoolboy*. London: Methuen.
Jackling, N., Lewis J., et al. (1990). “Problem Solving in the Professions.” *Higher Education Research and Development, 9*(2), 133–149.
Jeffries, K. K. (2007). Diagnosing the creativity of designers: Individual feedback within mass higher education*. Design Studies*, *28*, 485–497.
Kim, M. J. & Maher M. L. (2008). “The impact of tangible user interfaces on spatial cognition during collaborative design.” *Design Studies, 29*(3), 222–253.
Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2005). *The adult learner: The definitive classic in adult education and human resource development (6th ed.)*. Burlington, MA: Elsevier
Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, NJ, Prentice-Hall.
Lawson, B., (1997). *How Designers Think, Ed 3*, Architectural Press, Oxford.
Lawson B., (1999). *How designers think: the design process demystified* (Revised Third Edition), Architectural Press: Oxford.
Lewin, K. (1957). “*Action research and minority problems*”. In Resolving social conflicts. Selected papers on group dynamics, Edited by: Lewin, G. W. and Allport, G. 201–216. New York: Harper & Brothers
McWilliam, E. L. (2009). Teaching for creativity : from sage to guide to meddler. *Asia Pacific Journal of Education*, *29*(3), pp. 281–293.
Maitland, B. S. & Cowdroy R. M. (2001). *Redesigning PBL: Resolving the integration problem*, in Schwarz, P., Mennin, S. & Webb, G., Problem-Based Learning: Case Studies, Experiences and Practice, Kogan Page, London.
Moon J. (2004). *A Handbook of Reflection and Experiential Learning: Theory and Practice*. Routledge Falmer, London
Nicoll, K. (1998). “Fixing” the “Facts”: Flexible learning as policy invention. *Higher Education Research and Development*, *17*(3), 291–304
Pearson, J. Kwan, T. and Wong S. (2003). Investigating problem-based learning in an initial teacher education programme. *International Journal of Learning*, 10, 201–212
Pounds, William F. (1969). “The Process of Problem Finding,” *Industrial Management Review*, *11*, 1–19.
Rowe, C., (1995). *Design Thinking*. MIT Press, Cambridge, Mass.
Roozenburg, N. F. M. & Cross, N. G. (1991). Models of the design process -integrating across the disciplines”, In: Hubka, V. *Proceedings of ICED* 91, Heurista, Zürich.
Savin-Baden, M. and Howell-Major, C. (2004). *Foundations of problem-based learning*. Buckingham: SRHE/Open University Press.
Savin-Baden, M. (2007). *Learning spaces*. Maidenhead: McGraw Hill /SRHE
Schön, D.A. (1983). *The Reflective Practitioner: How Professionals Think in Action*. Basic Books.

Schunk, D. H. (2008). Metacognition, self-regulation, and self-regulated learning: Research recommendations. *Educational Psychology Review*, *20*(4), 463–467

Simon, H. A. (1996). *The Sciences of the Artificial*. Cambridge, MIT Press

Smith, M. K. (2002). Jerome S. Bruner and the process of education, the encyclopedia of informal education, Last updated: December 28, 2007, http://www.infed.org/thinkers/bruner.htm.

Visser, H. (Ed.), (2004). The MAP COMPARISON KIT: methods, software and applications. RIVM report 550002005. Available from: http://www.rivm.nl/milieu/modellen.

Von Glasersfeld, E. V. (1983). *Learning as Constructive Activity*. in Bergeron, J. C. & Herscovics, N. (Eds.), Proceedings of the 5th Annual Meeting of the North American Group of PME. Monteréal: PME-NA.

Vygotsky L. M. I. S. C. (1978). *Mind in Society*. Harvard University Press, Cambridge

Wallas, G. (1926). *The Art of Thought*. New York: Harcourt Brace

Weil, S. W. & McGill, I. (1989). *A framework for making sense of experiential learning*. In S. W. Weil, & I. McGill, (Eds.) Making Sense of Experiential Learning: Diversity in theory and practice (p. 12). Milton Keynes: Society for Research into Higher Education and Open University Press

Westrik, J. & de Graaff, E.: (1994). Development and man-agement of the new PBL-based curriculum in Archi-tecture in: S. E. Chen, R. M. Cowdroy, A. J. Kingslandand M. J. Ostwald (Eds.) Reflections on Problem-based Learning. Sydney: Australian Problem BasedLearning Network.

Woods, D. (1985). *Problem-based learning and problem-solving*. In David Boud (Ed.).Problem-Based Learning in Education for the Professions, HERDSA, Kensington, New South Wales.

Zeisel, J. (1995). *Inquiry by Design: Tools for Environment-Behaviour Research*. Cambridge, Cambridge University Press.

AFFILIATIONS

Professor Anthony Williams
School of Architecture and Built Environment,
The University Newcastle

Conjoint Professor Rob Cowdroy
School of Architecture and Built Environment
The University of Newcastle

Louise Wallis
School of Architecture and Design
The University of Tasmania

THOMAS LOVELAND

6. EDUCATIONAL TECHNOLOGY AND TECHNOLOGY EDUCATION

INTRODUCTION

Technology education is an academic subject area that teaches students the "ways in which human beings change their environments to be better suited to their needs and wants, thereby using various types of knowledge" (de Vries, 2009, p. 1). Developed from the earlier industrial arts and crafts movements, technology education is focused on the products and systems developed by human beings. Wright (2012) describes technology as humans using objects (tools, machines, systems, and materials) to change the natural and human-made environments.

The processes and knowledge of technology are focused in a broad range of sub-content areas which may include design, medical technology, biotechnology, energy & power, manufacturing, engineering, agriculture, information & communication, and construction. In addition, technology can be examined by its characteristics, core concepts, relationships with other fields, influence on history, causes, effects, and development.

Educational technology is the use of technologies for the purpose of student learning in education settings. The technologies are tools used by teachers across all subject areas. According to the International Society for Technology in Education (ISTE), the tools used by teachers may include media, multimedia, hardware, software, electronic gradebook, presentation graphics, electronic references, communication, video and audio authoring, and social networking among many others (ISTE, 2009).

Technology education and educational technology are two separate and overlapping entities within education. While technology education can be thought of as a critical academic subject area, educational technology is a broad term describing the use of technologies by teachers to support learning within their classrooms. With the increasing use of computers and high speed networks in education, the separation between these two fields is getting more difficult to explain to parents and others outside education. Each field has their own standards or curriculum requirements and both support a form of literacy based on technology. Within the sets of standards are objectives developed as benchmarks for differing levels of primary and secondary education. The benchmarks within the standards and the types of technology literacies are very different.

P. J. Williams (Ed.), Technology Education for Teachers, 115–136.

This chapter discusses the contributions that educational technologies can provide to increase technological literacy in technology education, the changing dynamic nature of educational software and hardware, and the implications for technology education teachers.

TECHNOLOGICAL AND EDUCATIONAL TECHNOLOGY LITERACIES

In technology education, students learn to design artifacts and systems by understanding criteria and constraints, using mathematical and scientific principles and tools to solve problems, and create solutions including two and three dimensional prototypes. The result of this work and understanding is a state of technological literacy whereby students develop the ability to use, manage, assess, and understand technology. According to de Vries (2009), technological literacy is important in this technologically infused world in which we live. In addition to the reading and mathematical literacy already taught in schools, students need to be able to learn to use and control technological devices as well. Whether taught as a Design and Technology program in the United Kingdom, Engineering and Technology in the United States, or other formats elsewhere, the goal of Technology Education is to help all students understand technology, the basic content areas within technology, and to develop a positive but critical attitude towards technology. Technological literacy then is an attribute of a citizen who makes wise and appropriate decisions based on knowledge of technology and has the ability to be flexible about emerging technologies (Wright, 2012). This goes well beyond the historical focus on skills development in boys and girls that technical programs were known for.

Educational technology literacies are the content and process skills that teachers and students should have to successfully use technologies in educational settings. The literacies can be divided into five categories: computer, information, integration, information fluency, and media.

- Computer literacy means that an individual has current knowledge and understanding of computers and their use. Computer literacy is a generic focus on one's abilities to use computers which implies their use in and outside of educational settings.
- Information literacy "means knowing how to find, analyze, use, and communicate information" (Shelly, Gunter & Gunter, 2010). Information literacy includes being able to find information from multiple resources, make informed decisions in the selection of relevant sources of information, and knowing how to organize the information into a format to make decisions and to act upon the information or communicate actions. Information literacy is a state both teachers and students should attain.
- Integration literacy is the "ability to use computers, digital media, and other technologies combined with a variety of teaching and learning strategies to

enhance students' learning" (Shelly, Gunter & Gunter, 2010). Integration literacy is directed towards teachers. Being integration literate means that a teacher knows how to select and use appropriate educational technology tools for the purpose of increasing student learning. For example, a teacher has a student outcome of increased visual communication skills written into a lesson plan. One way to meet that objective is for the teacher to have students create and give a class presentation using a student produced PowerPoint with embedded hyperlinks and graphics. A teacher who is integration literate would make that informed decision to use PowerPoint as an appropriate tool for students in this lesson.

- Tied directly to ISTE Student Standard 3 *Research and Information Fluency*, information fluency describes a state where students have mastered the ability to analyze and evaluate information (ISTE, 2007). A student who has informational fluency is one who critically analyzes and questions the validity of resources viewed. Students check the truthfulness of resources found on the Internet. They may research peer-reviewed articles to check on facts that were presented on the Internet in sites like Wikipedia.
- Media literacy describes students who have the ability to create, develop, and successfully communicate information in all forms. The creation of media may be in streamed videos, desktop publishing, PhotoShop, online music creation, websites, or other educational technology means. Media literate students will be leading the way in the future.

Technology education and educational technology are separate entities within education. While separate, there is overlap that can cause confusion about what technology education is (Dugger & Nait, 2001, de Vries, 2009). Technology education students use media and computer tools to help solve technological problems. Technology education teachers and students use educational technologies in the classroom to enhance student learning opportunities.

EDUCATIONAL COMPUTING

In the 1950s through to the 1970s, educational technology took the form of 16mm motion picture film, slides, filmstrips, overhead and opaque projectors in classrooms. Sixteen millimeter motion picture films were used to teach content by showing documentaries about topics, i.e,; how a four stroke engine operates. Slide and film strips often accompanied textbook instructor materials. Overheads were either teacher created transparencies used to demonstrate concepts and share information or transparencies of graphics to supplement textbook material. Opaque projectors were used to project book pages or other documents on a screen. In foreign language classes, students used cassette tape machines to play the foreign language and then repeat back what they heard.

In the 1960s, computers came into use in education at the university level. The first computers were large mainframe computers used for the purpose of reading and typing text (Alessi and Trollip, 2001). In the late 1970s, microcomputers were developed which spread to government, business and education. Initially restricted to typing and dot matrix printing, the microcomputers began to allow interaction of text, graphics, and audio. The Apple II microcomputer was released in 1978 and soon found a welcome place in schools due to the ease of use and software applications for education. IBM entered the personal computer market three years later.

In 1984, Apple started selling the MacIntosh personal computer. This computer did a better job of integrating text and graphics, had a larger screen, worked off of floppie and zip drives, and used a mouse pointer for speed of use and drawing on the screen. Eventually, with the linking to Microsoft Windows operating systems, the IBM compatible computers became more ubiquitous and accepted than Apple computers. Apple computers refocused their efforts on professional graphics and video editing applications in the late 1980s through the early 2000s until their rebirth and explosive growth through the sales of iPods and iPhones. In the early 1990s, educational computing was transformed by the development of the World Wide Web or Internet. From its early days as a resource for exchanging government and academic reports, the Internet has become a pervasive component in many homes, businesses, government, and educational institutions throughout the world.

Early educational systems were based on learner-controlled instruction. Students logged on to a computer and then passively followed prescriptive steps to learn content. Some programs offered assessments built into the computer programs. Today, there are many educational programs. Schools invest heavily in these programs and parents purchase them for home use as well. Due to the increasing capabilities of computers to show high definition graphics, educational software developers are increasing the sophistication of the embedded graphics in their programs, equating the wow factor with increased student motivation and learning. Generalized learning gains from this strategy have not been clearly documented (Alessi & Trollip, 2001).

There are benefits in using educational computing systems. These include reduced learning time, improved learning effectiveness and efficiency under the right conditions, and less expensive delivery of content, particularly in distance education settings. Other benefits include quick electronic updates of materials, access to materials 24/7, access to students with a diverse range of needs, and computer simulations which are safer than real training in dangerous or expensive environments. For example, biotechnology students could study a computer simulation of global warming; by manipulating the amount of green house gases emitted by vehicles and the quantity of green plants, students can assess the effects on global warming (Sims, 2008).

All of these educational technologies are centered around the use of computers and computer networks in education. Computers are electronic devices that operate under a set of instructions stored in memory. They input and process data according to specified rules to produce outputs for use by users. The computer's ability to access, manipulate and organize data in micro-seconds is part of the information processing cycle. Computer systems are divided into two sub-systems: hardware and software.

Hardware is the physical electronic and mechanical equipment in the computer, and may be stand-alone computers and network servers located in school classrooms or mobile devices controlled by students. Mobile devices include netbook computers (lap tops), netbooks, personal digital assistants, or smartphones. Software is the computer applications provided by the computer manufacturer and outside vendors for the purpose intended. These include Microsoft Office (Word, Excel, PowerPoint, Publisher), Adobe Creative Suite (PhotoShop, Illustrator, Dreamweaver, Acrobat Reader), Apple Final Cut Pro, Internet Explorer, and CorelDRAW, and applications for iPhones and iPads.

EDUCATIONAL TECHNOLOGY AND STUDENT LEARNING

In the pre-technology era of education, students learned from direct instruction, rote memorization and traditional testing. With the explosion of educational technologies and personal use technologies, new forms of learning have become natural to today's students. What is the impact of computers on students in the digital age? Described as digital students, they have characteristics not seen before. This includes being hypercommunicators who use multiple tools to communicate, multitaskers who do several things at once with ease, and goal-oriented as they pursue multiple goals simultaneously (Shelly, Gunter & Gunter, 2010). Digital students are different in the way they access, interpret, process and apply information and the way they interact in the technology-rich world that now exists. According to Feiertag & Berge (2008), digital students have become accustomed to instant gratification and communication. The learning style of many of these students is hands-on but not particularly linear. There is an expectation of barrier-free communication with any other individual, known or unknown, and anywhere on the globe. Students are becoming more mobile, supported by increasingly sophisticated information networks (Sims, 2008). Teachers can enhance these digitally aware students' learning opportunities by facilitating interaction with technology and each other in innovative ways. This may include use of online discussion forums, virtual group projects, and multimedia.

Several learning theories have been proposed in explaining how students learn through technology. When educational technologies are used in lessons, they are used as an instructional tool to help meet the learning objectives of the course. Technology is used as a tool in the instructional process, not as an end in itself. Understanding learning theories is far more important for teachers than the educational technologies chosen for their instructional design.

Constructivism explains how students learn through actively constructing knowledge with teachers acting as facilitators in the learning process (Shelly, Gunter & Gunter, 2010, Borich, 2011, Alessi & Trollip, 2001, Strangman & Hall, 2012). There are two schools or approaches of constructivism: cognitive constructivism and social constructivism. Associated with Jean Piaget (1896–1980), cognitive constructivism explains learning as a mental operation that occurs when information is received through the senses. The information is mentally manipulated, stored and then made available for later retrieval. Piaget posited four factors of cognitive development:

- Maturation: biological-unfolding of biological changes that are genetically programmed
- Activity: as child physically matures, the ability to interact with environment increases
- Social experiences: learning from others
- Equilibration: searching for a balance, testing adequacy of thinking processes to achieve that balance.

Cognitive constructivists believe that individuals construct their own learning. Most people incorporate information into their own mental maps, schema or ways of identifying what something is. At an early age, mental maps and schema are rather simplistic and rigid. New information is either assimilated into existing mental maps or accommodated through adjustments. This creates a state of equilibrium in the student that gives them peace of mind. As students grow older, they are confronted by information that is contrary to established ideas and doesn't easily fit into their earlier schema. This mismatch results in a state of disequilibrium which encourages new ways of thinking about information through mental manipulation. Piaget focused on the individual construction of knowledge, not addressing the role of social interaction.

Educational technologies associated with cognitive constructivism include re-usable learning objects which can include visual or auditory interaction with data that are used by individuals at their own pace, such as avatars, intelligence agents, instructional animations, and computer-based drills. Key strategies in constructivism include guided discovery learning, use of collaborative learning models, authentic settings for learning, learner reflection, and learner ownership of learning activities. Discovery learning describes how students explore, experiment, research, think critically and develop answers. This process is enhanced by student access to the Internet and technological tools. Authentic learning occurs when learning activities are based on real-world applications, sometimes referred to as situated learning. Examples using educational technologies are varied. A history class studying the reason World War I started could prompt students to do basic research on the Internet, mimicking what a historian does.

Social constructivism is associated with Lev Vygotsky (1896–1934). Learning is a result of collaboration between a group of learners who construct a shared meaning and knowledge. Vygotsky places an emphasis on language and culture in the learning process. Learning occurs when there is cooperative dialogue between children and those more knowledgeable. It is a social process in which interaction (usually verbal) and negotiation create understanding or solve a problem. The final product is therefore shaped by all participants.

Learning is assisted by the use of tools supplied by the culture. These can be real tools like CNC machines, books, computers, Kindles, or I-Pods. All higher-order mental processes are mediated by psychological tools: language, symbols, etc. Children create/construct their understandings through transforming tools transmitted by others. Learning occurs when the student is in the zone of proximal development. This is an area where a child cannot solve problem alone, but can succeed with adult guidance. The adult provides scaffolding (verbal prompts, structure) to assist students in making the knowledge and skill leap necessary to be successful.

Sometimes cooperative learning can provide this support. Educational technologies can support social constructivism when students use technologies in collaborative social settings, particularly in discussion boards and blogs in online classes and game-based virtual worlds.

Students in a design class could work in teams to design and propose a plan for a children's playground in a local park. A science class studying trajectories could use videotape to document a catapult activity, thereby allowing the students to graph out the trajectory from the video for discussion. In a communication technology class, students could produce a public service announcement video for a local not-for-profit organization. This project would include technology-based planning, storyboarding and scripting, videotaping, editing and distribution of streamed video, all within a team setting.

Collaboration in a complex technological world can go beyond students working side by side in a classroom on a project. Collaboration across geographical boundaries is now possible with the use of SKYPE, Internet chat sites, emails and WebQuests. Those boundaries may be from student to different schools, to experts at work places, or to people in other regions of a country or even across the world to different cultures. On a large scale, use of eLearning games like *massively multiplayer online role-playing games* (MMORPG) can involve thousands of players simultaneously. Constructivist theory supports the use of hypermedia, virtual simulations, and open-ended technological environments to assist students in explore authentic information more freely and to use educational tools to design and construct their own knowledge and skills.

EDUCATIONAL TECHNOLOGY AND INSTRUCTION

Teachers have increased their use of computers and educational technology tools over the past decades due to the increased efficiency and flexibility offered by their use and the potential to enhance student learning. For teachers, this use can be summarized as application productivity. This includes word processing, emails, student management systems for attendance and grading, spreadsheets to keep account of funding, database and letter merge for parent communications, and use of presentation software like Microsoft PowerPoint to create graphically interesting lectures. In communication, language arts, and graphics classrooms and for teachers of technology, PhotoShop, CorelDRAW, Adobe Illustrator, and Microsoft Publisher may be used to prepare sophisticated communications to students, parents and the public. Camtasia, Podcasts, and webpage authoring software like Dreamweaver can be utilized to create class webpages with streamed videos and lesson resources to increase student learning outside of the classroom. Teachers may use assistive technologies, virtual reality programs and ePortfolios to help students with a diverse range of needs. Hard copy textbooks are transitioning to netbooks, allowing for quick student access to pertinent information the teacher determines is needed for learning. This electronic access includes the means for students to do further research based on connections made available through the netbooks.

Computer simulations are computer-created versions of real world objects. They range from three dimensional renderings to highly interactive laboratory experiments, and allow students to observe and manipulate objects, variables, and processes in real time on the computer screen. This helps students to understand abstract and intangible phenomena, change and correct misconceptions, and develop skills and subject matter knowledge (Strangman & Hill, 2012). Computer simulations are useful as a supplement to or a substitute for traditional direct instruction by teachers. Student success in using computer simulations can be tied to teacher preparedness, training and technical support in the use of the instructional strategy (Strangman & Hill, 2012). Computer simulations at higher resolution are very expensive and complex to develop and so most are provided by commercial enterprises.

Interactive instructional CDs contain computer-generated activities that students engage with at their own pace and level. Skills or topics are broken down into smaller chunks for students to master. These methods may be prescriptive tutorials or open-ended hypermedia. In hypermedia, students can follow their own pathway through the material. With the use of computer drills and simulations, students are able to practice their skills and knowledge to develop fluency. Simulations are useful in developing discovery learning skills and in practicing skill sets in a constrained environment. Students can revisit different parts of a simulation repeatedly to develop mastery. This shifts the locus of control to the learner (Strangman & Hill, 2012).

An example of the use of technology to support instructional strategies is the website techtrekers.com that provides teacher-developed instructional simulations for free use by teachers (techtrekers, 2012). The website links to many different simulations including Fraction Maker, Virtual Bike Force Vectors (Science Shareware.com), Fear of Physics, Amusement Park Physics, and Edo, Japan, A Virtual Tour. Teachers will need to explore the value and currency of the sites before writing them into lesson plans.

Virtual reality is a means to allow students to explore and manipulate three dimensional multimedia environments, including gaming simulations, in real time. This may take three forms: desktop versions, web-based versions, and fully immersive versions using stereoscopic head-mounted gear with surround sound. Graphic tools and virtual gaming are more open-ended for students, supporting constructivist learning. Gaming and simulations are useful in providing alternative means to attain course objectives. Virtual reality simulations are found in the real world. For example, home improvement businesses may have virtual home design capabilities. People can indicate the exact size of their kitchen and location of doors and windows. They can then select different styles and sizes of kitchen cabinets. These can be manipulated in the space and then viewed from any direction and height, allowing homeowners a virtual tour of their new kitchen. In an educational setting, aerospace technology can be taught using virtual solar system tours where students can move through the solar system, looking at planets (Strangman & Hill, 2012).

There are many animated gif simulations in educational websites to assist students in understanding challenging theoretical content. Web-based learning allows students to conduct research, explore options, and develop critical thinking strategies in an open-ended environment. The research can be done in class or at home on the Internet. It is important for teachers to model constructive skepticism about the content that is being researched.

CLASS ADMINISTRATION AND TECHNOLOGY

There are other uses of educational technologies by teachers besides instruction. One primary use of educational technologies is course management. Sometimes referred to as Learning Management Systems (LMS), example systems include WebCT, Moodle, ANGEL, Live Text, and Blackboard. These systems allow teachers to centralize resources, student grading, ePortfolios and other learning technologies within one online network for use by teachers and students. Students log into the course, whether fully online or blended with face to face, to obtain electronic instructions, do research, read etextbooks or hyperlinked articles, watch streamed videos, listen to Podcasts, take online exams, post papers, and review their posted grades. While initially time-consuming to upload the course materials into LMS, teachers find that these electronic systems provide efficiencies to reach all students 24/7.

Some Learning Management Systems allow course editors to track student use and internet addresses for online tests. Classroom computer networks may allow teachers to view student computer screens from their teacher desk. Teachers should protect their passwords by creating hard to recreate passwords and not using their passwords in front of students. Online plagiarism software like Turnitin is available to ensure students are writing original papers. The best protection for computers is observation by an aware teacher. Aware teachers move through the classroom, giving truth to the adage that teachers have eyes in the back of the heads.

Computer security is important for teachers to consider. Malicious or ill-informed students can quickly shut down lessons by interfering with computer-based resources. This can take the form of removing hard drives, deleting files and application software, resetting computer and monitor preferences, changing teacher passwords, changing student grades and attendance records, downloading viruses into computers, hacking into school networks, altering or deleting other student's projects, or accessing teacher personnel records. One way that schools can thwart these kinds of attacks is to set computers with virus control firewalls and Internet filtering systems, use time stamps on computer activity, and daily computer resets using programs like Deep Freeze. All documents downloaded from the Internet and student USB drives should be scanned for viruses. The downside to firewalls and Internet filtering systems is that they can be rather heavy-handed, leading to useful information and resources being blocked from student or teacher access. Some schools adopt a more open access approach, and depend on programs of education to ensure responsible use of the electronic systems.

Teachers should also have Acceptable Use Policies (AUP) in their classrooms. These list very specific guidelines for the students to follow. AUPs are an outline of user standards that informs teachers, students, and parents what is acceptable in the classroom. A unit of instruction on the AUP followed by a quiz and the signing of the AUP by students affords some protection to the teacher should an issue arise later. The use of AUPs can help to maximize the benefits of using newer technologies, create a smart technology culture at the school, and help teachers critically examine emerging technology trends and issues (Shelly, Gunter & Gunter, 2010).

Some common issues that could be addressed in Acceptable Use Policies include:

- Use of computers, networks and Internet is a privilege, not a right,
- Consequences of accessing objectionable content from Internet,
- Courteous writing in emails,
- Copyright rules,
- Safety of personal information, and
- Disciplinary action for violations of AUP.

EDUCATIONAL TECHNOLOGY AND ASSESSMENT

Assessment is an area of education that is impacted by educational technologies. Teachers can set up pre and post tests, primarily multiple choice, as online exams. In virtual classrooms, students can take the online exams from home and at the time of their choosing within the stated exam window. A specialized type of computer-based testing is called adaptive testing. Used as an instruction and formative assessment strategy rather than as a summative assessment, adaptive testing is a system whereby the computer responds to the answers given by students. If a student answers all questions correctly, the computer recognizes the level of understanding and switches to more sophisticated questions. If the student does poorly on the questions, the computer provides questions at an easier level until it determines mastery of the content by the student. There are problems with computer adaptive assessment systems. These computer programs are based on statistical assumptions of the content. If a student understands the subject matter but would better show this understanding by other means, the computer cannot truly measure the level of understanding. Additionally, content related feedback and diagnosis from these programs is limited (Alessi & Trollip, 2001).

Besides providing information about learning to students and teachers, computer-based assessment has other benefits. School districts like the ability to obtain electronic assessment information at the individual, course or program level from a central office. When teachers submit grades electronically, it is possible for the research department of the school to access those grades and develop learner profiles by individual student, by class, by program or by school. This information is useful in planning at the district level. There may be teacher resistance to this access by schools as it might be felt that teacher success cannot be quantitatively calculated from these computer-based scores. Teacher evaluations and job tenure could be affected by this information in the future.

In laboratory-based subject areas like science, technology education, and art, assessment of performance and skills is problematic using traditional testing alone, whether paper and pencil or online. Most societies expect students to be able to demonstrate practical performance and competence in addition to their theoretical knowledge. Performance assessment asks students to create a product that demonstrates their knowledge or skills. It may take the form of students creating a portfolio of work accomplished throughout the school year. Teachers use multiple data-gathering strategies including on-demand assessments, examples of student work, and teacher formative assessments to evaluate the student. Performance-based assessments generally require that trained teachers carefully evaluate the assessments and provide reliability across evaluators.

It has been suggested that performance assessments more closely link assessment and instruction, more accurately measure the mathematic, scientific and technological skills and knowledge, and allow a more complete picture of student achievement. Performance assessments are designed to demonstrate the student's thought processes and strategies to solve problems. Performance-based evaluation is often limited by the costs in collecting evidence, the difficulty of ensuring validity and reliability of the results obtained, and the inherent challenge of assessing student learning processes in the areas of decision-making, critical thinking, reflection, reasoning, and problem solving.

EDUCATIONAL TECHNOLOGIES AND TECHNOLOGY EDUCATION

Educational technologies, particularly computers, have been used extensively by technology education teachers and students since they became ubiquitous in schools in the early 1990s. Often, the technology teacher and students become technology ambassadors within their schools. When the school's instructional technologist is busy, technology teachers and students may be the next people called to troubleshoot and fix computer and network problems.

How is educational technology being used in technology education classrooms in ways different than other content areas? While technology teachers also create lessons in PowerPoints, write emails, and use student electronic gradebooks, due to the nature of their technology-based assignments, it is more likely that technology teachers will embrace and use educational technologies beyond a basic use. Practical projects lend themselves to portfolios which can easily be submitted as ePortfolios, WebQuests, or streamed documents. ePortfolios are web-based locations for students to post work for teacher review and to develop a record of their progress. They are useful in demonstrating student self-reflection and higher-order thinking. ePortfolios support the basic work flow cycles of collect, select, reflect and assess for projects (Garrett, 2011).

Developing problem solving and critical thinking skills is at the heart of technology education today. The days of teaching a student a prescriptive way to solve a problem and thereby guaranteeing that the students' future career skills are set for life are gone. Changes in technology hardware and software occur too rapidly. One of the skills employers are looking for in their future employees is the ability to problem solve technological problems without direct supervision. In addition, the ability to think critically is expected in the work world. According to Scott (2008), critical thinking is a desired competency in technology education classrooms. It is the use of thinking skills and strategies to increase the likelihood of a positive outcome. These skills include investigating arguments, conducting research, collecting information, analyzing the information, thinking outside the box, and communicating well-reasoned arguments. In a technology education setting, the development of critical thinking skills has been found to increase subject matter learning and to increase student ability to analyze and present arguments (Scott, 2008).

The International Society for Technology in Education (ISTE, 2007) defines *Standard 4 Critical Thinking, Problem Solving, and Decision Making* as "students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources". The four benchmarks are:

a. Identify and define authentic problems and significant questions for investigation,
b. Plan and manage activities to develop a solution and complete and project,
c. Collect and analyze data to identify solutions and/or make informed decisions, and
d. Use multiple processes to diverse perspectives to explore alternative solutions.

In order to be fully prepared to compete globally, students need to develop new skills in being adaptable, flexible, having initiative and self-direction. With increasingly global work teams, respect for cultural diversity and clear communication skills are both important. Finally, being accountable and productive while exhibiting leadership skills is important to employers (Shelly, Gunter & Gunter, 2010). Students develop these skills in collaborative teams working on technology projects.

Modeling and three-dimensional visualization are important abilities to be developed in students in design and technology education classrooms. This is due to the shift in research and development to bring products to marketplace quicker through the use of technological tools. Parkinson and Hope (2009) describe modeling as a type of conceptual knowledge that is symbolic and systemic. Humans have the ability to create abstract representations of objects and manipulate them visually. This may take the form of internal visualizations or by drawing three-dimensional models. Using educational technologies allows humans to develop their abilities in visualizing designs. Technology allows us "to analyze, generalize, and synthesize perceptions, observations, actions, and knowledge; as well as make leaps of the imagination, to see possibilities, to take risks, to try out ideas, and to be innovative (Parkinson & Hall, 2009, p. 259). Whether through sketches, completed drawings, or full prototypes, design and modeling supports development of student problem solving and critical questioning abilities.

Augmented reality (AR) is a new technology-based program that allows students to superimpose virtual objects over the real world, thereby providing multiple perspectives on designs. Augmented reality devices can superimpose a virtual overlay of three-dimensional data (virtual images) on to a real world context (object, environment, specific location), helping students through experiential and location-based learning. This process is most useful in design and engineering classes. Software packages with universal formats are available for teachers to use in their classroom. For example, Google SketchUp can be used with virtual designs to create a simulated use of a product. The ability to add depth to a 3-D design assists students in error detection, engineering analysis and troubleshooting (Thornton, Ernst & Clark, 2012).

Engineering analysis is made possible through the use of educational technologies, particularly computers. Computers are an engineering tool with the primary benefit of the ability to rapidly perform functions like calculations. Engineers and technologists use computers for computer-aided design, word processing, communications, research, graphing, process control, simulations, data acquisition and analysis (Hagen, 2009). In technology education classrooms, projects that simulate authentic engineering projects may utilize computers for the purpose of design and predicting or investigating failures. Spreadsheets, equation solving, programming languages, specialty software and finite element software are types of computer uses in these settings. Examples of specialty software include heat exchange analysis, AC/DC circuits, pneumatic flow simulations, hydraulic flow parameter calculations, and many others for the manufacturing world. Finite element software are programs that help engineers analyze systems with irregular configurations, variable settings and materials, and atmospheric conditions. This type of engineering analysis is more likely found in a university setting than in secondary education.

Technology education equipment is sometimes based around the use of computers and specific applications. Examples of commercially available curriculum include animation, structures, desktop publishing, fiber optics, aerodynamics, and web design. Computer applications to run robotics (Vex, Lego Mindstroms, Boe Bots) are popular in technology education programs. Software abounds now with virtual reality simulations to take the place of expensive and dangerous hardware. Flight simulators, for example, allow students to learn the basics of flying without the danger and costs of flying a real airplane. Intensive research on technologies is possible with Internet search engines that can result in comprehensive student reports with graphics, hyperlinks, and tables.

CO^2 race car projects are common in technology education programs across the world. Based originally on student paper and pencil designs, cutting on a band saw, and finishing with sand paper, the CO^2 race cars can now be designed and created using computer technologies. Three-dimensional design is possible with software from multiple sources. Using spline tools to create the shapes of the cars lends itself to more creative and thoughtful design work by students. Once the program is written, the software code can be translated into machine readable code to mill the vehicle on a computer numerical control (CNC) machine. Whether using a multi axis CNC router or milling machine, the balsawood base car is cut separately on the left and right side or rotated. Once completed, the car can be mounted into a wind tunnel hooked up to a Vernier Force Gauge to test the aerodynamics and wind resistance of the designed vehicle. Based on the computer printout, students can make informed decisions about how to change the car model to lower the wind resistance further. These computer-designed cars are very different than the traditional band saw cut cars.

In design classes, students learn the basics of two and three dimensional design. This may take the form initially of mechanical drafting techniques and can lead to sophisticated design and modeling using AutoCAD, MasterCAM, and SolidWorks. An extension of this type of educational technology would be teaching and developing CAD/CAM knowledge and skills to produce and manufacture products. At the highest level, stereolithography, 3D printers and CNC routers are used to create prototypes from computer code. This work mimics what is being done in industrial design companies. Companies are increasing their capabilities by using CAD scripting language for design automation, knowledge-based engineering applications and movement of data between design applications (Lowe & Hartman, 2011).

In a traditional industrial arts class, the teacher may assign a project with prescribed steps, materials, and plans. These projects may have been a bird house, spice rack, picnic table or some other woodworking project. Students passively followed the set plans. Projects were assessed on their similarity to the teacher's demonstration model. With a new focus on design and problem solving, technology teachers today are more likely to present a design brief to students with an open-ended problem, a list of criteria and constraints, and access to a wide variety of materials and equipment to work with. If a student is asked to design a part with tight tolerances, the use of a table saw, band saw or other traditional woodworking tools would not be appropriate. In a comprehensive laboratory, the student would likely design the part in a three dimensional software program. Once approved by the teacher, the student could create the prototype in two ways from the digital plans: mill it down or build it up. The first way is to start with a solid block of material like wood or machinable wax. The program is translated into machine readable code to mill the block down to the final shape. The other option is to translate the program into a machine readable code to use with a specialized printer to print the prototyped part from layered plastic or corn starch-based material. This activity fully uses the technologies of the industrial design field to help prepare students for potential future careers in engineering design.

A new area of growth in technology education in some countries is the content area of gaming. Utilizing visualization and problem solving curriculum, students develop conceptual knowledge and procedural skills in designing and developing online games (Clark & Ernst, 2009). Gaming is a growing industry that develops computer and Internet based virtual games that individuals and groups of people can play on their computers and TV systems at home. While gaming may appear to be a form of entertainment and therefore easy to dismiss as superfluous, the attributes of design and modeling, both static and dynamic, are fully utilized in the development of games. Some of the skills developed by successful student designers are analytical thinking, cooperation, multitasking, and problem solving under tight deadlines. These are important skills in any industry. Gaming curriculum is reported by Clark and Ernst (2009) to include the development of logic, analytic skills, kinesthetic and hand-eye coordination, computer proficiencies, and visualization and communication skills in students. The curriculum is best suited to a project-based, cooperative setting with portfolio-based assessment.

INTEGRATED CURRICULUM

Technology education teachers can and do collaborate with other subject area teachers. While new trends toward engineering, Science, Technology and Society (STS), and Science, Technology, Engineering and Mathematics (STEM) integration have taken center stage in research and publication in the field of technology education, collaboration with other subject areas has been ongoing for some time. Technology education is a natural place to apply language arts, science, mathematics, arts, and even foreign language content around an engaging technological project. Students can develop stronger reading and writing skills due to the motivation from exposure to technical writing to enhance project success. Educational technologies like the Internet, blogging, and emails require students to use writing skills in their research and questions to experts. This access to instant information is enhanced when students use the formal technical language from the field.

The role of technology teachers is changing with the increased sophistication of educational technologies. Teachers may be expected to become mentors to both students and colleagues in the use of technologies. Teachers participate in developing and adapting technology knowledge. Technology integration occurs when teachers use their new knowledge to enhance their teaching and student learning. With the plethora of new technologies, teachers need to be able to track technological changes and evaluate those changes to determine the most effective use of technologies in their classroom (Okojie, 2011).

Research has shown that teachers who improve their knowledge and skills with instructional technology improve their teaching and collaboration with school colleagues (Nilenhauser & Knezek, 2011). This voluntary collaboration with other content area teachers can lead to increased student learning gains. Students are engaged by educational technologies in multiple classes that could be integrated through technology-based projects. This collaboration assists students in making connections between the multiple content areas they are exposed to each day in school.

The educational technology enthusiast teachers can collaborate across the world in new and innovative curriculum despite cultural and language differences. Online teacher communities are another way that teachers are engaging in lifelong learning. Sharing lesson plan ideas and technical tips helps teachers to adapt to technological change. Whether through blogs, chat rooms, email or website postings, teachers may find answers to questions quickly, thereby saving crucial planning time in the classroom. The professional dialogue could come from anywhere on the globe, making the relevance of the information potentially more up-to-date and productive for teachers (Duncan-Howell 2010).

Fostering imagination, creativity, and interdisciplinary learning using technology is important to technology teachers. According to ISTE (2007), student Standard One *Creativity and Innovation* states the 'students will demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. The four benchmarks under this standard include:

a. apply existing knowledge to generate new ideas, products,
b. create original works as a means of personal or group expression,
c. use models and simulations to explore complex systems and issues, and
d. identify trends and forecast possibilities.

Interdisciplinary examples provided by ISTE for meeting this standard include:

- having students design and develop a digital learning game,
- creating and publishing an online gallery of technology projects that demonstrates an understanding of differing historical periods, cultures and countries,
- identify a complex global issue, develop a systematic plan to address the issue, and communicate a sustainable solution using educational technologies, and
- create media-rich presentations to class on the appropriate and ethical use of digital tools and resources. This last assignment could be a presentation showing manipulated images that lead to a critical thinking discussion about the ethical role of digital technologies in the current media age.

MAKING INFORMED TECHNOLOGY CHOICES

How should technology educators choose educational technologies for their laboratory? With the overwhelming number of new educational technologies, commercial products, and online websites making claims about their use and efficiencies, it is easy for a teacher to make an inappropriate choice. With tight budgets in education common, the opportunity to correct a mistake in a technology acquisition is generally not possible. There are ways to help teachers make informed choices. Bart (2011) describes a S.E.C.T.I.O.N.S. decision-making model. The first consideration is the clientele: the students (S) in the classroom. What are their demographics and psychographics? Do they have a preferred learning style? Students with a kinesthetic learning style would respond to hands-on technologies better than text-driven. Are they technologically advanced? If a teacher is in a high needs urban school with students lacking in technology resources at home, that would impact decisions made on hardware and software.

The ease of use (E) of the technology is a second consideration. A vendor could talk a teacher into purchasing the most sophisticated software used by aeroengineers but if the teacher isn't trained or doesn't know how to use the technology, then it is of very limited use in the classroom. Cost (C) is a third consideration. The cost is generally more than a one-time charge. The cost of upgrades, maintenance plans, training, tech support and instructor learning time all need to be figured into the actual real costs.

The fourth consideration in the S.E.C.T.I.O.N.S. model is the teaching (T) style of the teacher. If a teacher tends towards hierarchical direct instruction, then the inclusion of educational technologies beyond a LCD projector and teacher computer would be inconsistent. Educational technologies should be matched to the learning objectives and assessment strategies. If a teacher chooses online testing, then that requirement would specify the type of software applications required for the class. Interaction (I) looks at how the technologies will engage and motivate the students in the classroom. If the teachers' lesson requires the students to share their solutions of an open-ended problem through social media and blogs, then having computers in the classroom linked to the Internet would facilitate the teachers goals.

Organization (O) relates to support the teacher and program will receive from their administrators. Technology teachers who like to push the technology window through innovative use of educational technologies could be supported or hindered by administrators, depending on the school culture. Consideration eight, novelty (N), addresses the use of brand new technologies in classrooms. The first users or innovators of change may find that the technologies they chose needed some maturing and vetting time before they were purchased by the schools. Because they are untested, they could place the technology teacher at risk in their job security or administrator support.

The final consideration is speed and security (S). In an earlier section of the chapter, a discussion of security with students occurred. Speed of technology equipment can be understood as the ever-increasing speed of software and hardware. A teacher could purchase the most up-to-date computer system available and find by the time it is delivered, newer models have come out with faster speeds and more features (Bart, 2011). In addition, a teacher could purchase specific software and subsequently find it is incompatible with the school's network operating system.

Shelley, Gunter, and Gunter (2010) discuss other information that should be considered by teachers in purchasing educational technologies. Will the computer or software be compatible with your current technologies? Can you work on projects at home and then seemlessly continue to work at school? Teachers may find that the school purchase department is looking for the least expensive technology, not realizing that they may be cutting out crucial capabilities in the system needed in the classroom. Access to the Internet in the classroom may be incompatible with the minimum broadband requirements of specific equipment. Should the school buy new or refurbished equipment, or lease? Should the school purchase an extended warranty plan? The answers to these questions can impact how much and what type of educational technology equipment is purchased and what applications can be in the classroom.

ISSUES AND FUTURE TRENDS

Computers and information technologies have changed radically from their beginning in the 1940s with the creation of the world's first computer, ENIAC, at the University of Pennsylvania Electrical Engineering School. ENIAC weighed 30 tons and required 174KW of power to run. In the 1960s, it was normal to see a roomful of tall computers using tape rolls and punch cards to showcase modern society. It is both exhilarating and scary to realize that similar computing power can now safely fit on a small mobile device. Digital students are used to accessing information in any form at any time from their laptops and mobile smartphones.

This is not to say that there aren't problems and concerns with educational technologies. One major concern is digital inequity between countries, regions, and within communities. The world is now considered to have a 4th world, which has no technology access. The 4th world may represent an entire country or groups of people who have been bypassed by technology access. The 4th world neither produces nor consumes what is considered significant or valued in our globalized and technologically connected world. Due to this factor, there is a danger that people from this area do not experience any development. The new world power elite are those who control technology. Some of these inequities are being addressed by private associations and not-for-profit organizations. Bill Gates is trying to distribute millions of $300 Internet-connected computers worldwide to balance the digital divide. Connectivity is increasingly wireless based on a digital infrastructure supported by business models or national goals. In rural areas or third world countries, these resources are difficult to come by and non-existent in the fourth world, leading to the inequities of digital haves and have-nots. Within a schools' student population, there are equity issues related to available bandwidth and the processing speed of home computers. Students with fiber optics Internet have a huge advantage over other students in downloading speed and access to applications.

Other school related issues include the increasing number of virtual schools, especially at the secondary level. While convenient to students and cost effective to school systems, teachers have to resort to technological tools like Turnitin.com to know who is writing and submitting the papers they receive. Some school administrators are trying to limit or control access to the Internet as a way of censoring content. In their zeal to maintain open access for all, school libraries and media centers find themselves in conflict with school administrators over policy. Finally, copyright laws must be adhered to by teachers to prevent lawsuits. Working with students who are used to downloading anything off the Internet, it can be challenging to teach students how to credit their sources.

Instructional technologists and technology teachers annually face issues about what type of computer systems to install in their classrooms and how often they need to be upgraded. With many software applications designed for PCs, MacIntosh computers are increasingly finding their niche in communication technology classrooms using graphics-based programs. Sometimes purchase decisions are made at the district level, with little consideration of the needs of the end user. Teachers may be able to influence purchase decisions based on what applications are best suited to their classroom and program. In order to help teachers plan ahead for new technologies, it is important to read the journals from the field and to attend professional development conferences. Visits to the exhibit and vendor areas can be helpful in making informed decisions. The information technology coordinator for the school is a good resource as they may have a broader view of what works or doesn't work throughout the educational system. In addition, there are published evaluations of educational technology in websites, educational publications and on blogs. Online blogs may be the best choice for information because teacher bloggers can give real information about a product's advantages and disadvantages.

Teachers should review software for specific capabilities which should lead to increased student learning gains. The priority is that the software has valid and current content matched to the student outcomes or course learning objectives. There should be documentation and technical support that is readily accessible during school hours. The software should have correctly identified ability levels. Finally, the software should work intuitively (be user friendly) for students and teachers.

Technology trends create issues when planning for future classrooms. These could be categorized into three broad areas: international collaborations, web design, and use of mobile technologies by students. The website ePALS.com is a place where teachers can find other teachers with similar content areas, interests and connectivity. As a former high school technology teacher, this author developed and implemented a collaboration with a Japanese teacher that lasted five years. Called the Japan Florida Teens Meet Project (JFTMP), American and Japanese high school students were paired up to work on collaborative projects, all based on the *Standards for Technological Literacy* (ITEA, 2000, 2002, 2007). Projects included a scale model International Space Station constructed out of balsawood and an anti-tobacco dramatic video filmed in English and Japanese. Students periodically met by ISBN phone conferences to share ideas and be co-taught by the two teachers. With the low cost and easy accessibility of SKYPE now, these types of transnational collaborations can develop technological literacy and respect for cultural diversity in students (Jenkins & Loveland, 2000).

Some technology teachers are developing program websites on their school server in order to communicate with students, parents, and local leaders which requires teachers to develop skills in webpage design. Careful development of navigation pathways is a critical component in website usability. Bringula and Basa (2011) report that educational website developers who focus on information content have more successful websites. Content can be understood in terms of its relevance, depth and breadth, accuracy, concurrency, and consistency. The design factors of aesthetics, selection of graphics, and visual elements all contribute to the success of educational websites.

With the increasing cost of educational technologies and support, schools have begun to think outside the box in terms of how to use educational technologies to enhance student learning. This may take the form of online curricula, distance learning, netbooks, and mobile technology use by students. Social media such as Facebook, MediaChalk, and SKYPE are making their way into classroom lesson plans. Social media can enhance technological literacy if it motivates students to develop their writing and communication skills, particularly for those with a diverse range of needs in reading and writing. Social media provides a stress free but highly motivating location for these students to work on their writing and communication skills without the pressure of academic scores.

Schools are increasingly signing agreements with Google to support Cloud web-based applications in their districts. There is also an increasing demand for high speed connectivity on school campuses (Quillen, 2011). All of these trends become opportunities for technology teachers to take the lead in developments on campus that enhance the sophisticated use of educational technologies.

CONCLUSION

Teaching technology education, like all school subject areas, can be enhanced through the use of educational technologies. Educational technology and technology education, while separate entities within education, share many commonalities, and as a result, provide synergies for teaching. With the increasing use of computers, software, high tech equipment, and technology-based assessment tools, technology education is changing from industrial skill development into a broader technology model based on problem solving and critical thinking. Teachers who rely on traditions of direct instruction may find that it is more difficult to effectively teach the digital age students who populate their classrooms. With the current plethora of digital knowledge needed to understand and effectively use educational technologies, teachers may not be able to remain the expert in the classroom. Rather than rejecting technologies which seem too advanced, a technology teacher might consider empowering students to help teach the new technologies, thereby increasing their own knowledge and expertise while providing leadership opportunities for students. For technology teachers around the world, technological change is the opportunity to help ensure technology education remains relevant and supported.

REFERENCES

Alessi, S., & Trollip, S. (2001). *Multimedia for learning: Methods and development, third edition*. Needham Heights, MA: Allyn & Bacon.

Bart, M. (2011). Determining the best technology for your students, your course, and you. Teaching with Technology. Retrieved April 4, 2012 from www.facultyfocus.com/articles/teaching-with-technology-articles/determining-the- best-technology-for-your-students-your-course-and-you/

Borich, G. (2011). *Effective teaching methods: Research-based practice, seventh edition*. Boston, MA: Pearson Education, Inc.

Bringula, R. P., & Basa, R. S. (2011). Factors Affecting Faculty Web Portal Usability. *Journal of Educational Technology & Society*, *14*(4), 253–264.

Clark, A., & Ernst, J. (2009). Gaming in technology education. *The Technology Teacher, 68*(5), 21–26.

de Vries, M. (2009). The developing field of technology education: An introduction. In A. Jones and M. de Vries (Eds.), *International handbook of research and developments in technology education*. (pp. 1– 9), Rotterdam, The Netherlands: Sense Publishers.

Duncan-Howell, J. (2010). Teachers making connections: Online communities as a source of professional learning. *British Journal of Educational Technology*, *41*(2), 324–340.

Feiertag, J., & Berge, Z. (2008). Training generation N: How educators should approach the net generation. *Education + Training, 50*(6), 457–464.

Garrett, N. (2011). An e-portfolio design supporting ownership, social learning, and ease of use. *Journal of Educational Technology & Society*, *14*(1), 187–202.

Hagen, K. (2009). *Introduction to engineering analysis, third edition*. Upper Saddle River, NJ: Pearson Prentice Hall.

International Society for Technology in Education. (2008). *National educational technology standards (NETS).* Washington, DC: Author.

International Society for Technology in Education. (2007). *National educational technology standards (NETS) and performance indicators for students*. Washington, DC: Author.

International Technology & Engineering Educators Association (2000, 2002, 2007). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

Jenkins, J., & Loveland, T. (2000). Educational Opportunities in the Global Village. *International Journal of Educational Reform 9*(4), 369–372.

Knezek, G., & Niederhauser, D. (2011). Collaboration makes the ed tech world go round. *Learning & Leading with Technology, 33*(6), 36–37.

Lowe, A., & Hartman, N. (2011). A case study in CAD design automation. *The Journal of Technology Studies, 37*(1), 2–9.

Okojie, M. (2011). The changing roles of teachers in a technology learning setting. *Journal of Instructional Media. 38*(1), 17–25.

Parkinson, E., & Hope, G. (2009). Conceptual learning in and through technology. In A. Jones and M. de Vries (Eds.), *International handbook of research and developments in technology education*. (pp. 1–9), Rotterdam, The Netherlands: Sense Publishers.

Quillen, I. (2011). New technology may offer fresh vistas for savings and for educational benefits. *Education Week*, *30*(16), 20–22.

Scott, S. (2008). Perceptions of Students' Learning Critical Thinking through Debate in a Technology Classroom: A Case Study. *Journal of Technology Studies, 34*(1), 39–44.

Shelly, G., Gunter, G., & Gunter, R. (2010). *Integrating technology and digital media in the classroom, 6th edition.* Boston, MA: Course Technology, Cengage Learning.

Sims, R. (2008). Rethinking (e)learning: A manifesto for connected generations. *Distance Education, 29*(2), 153–164.

Strangman, N., & Hall, T. (2012). *Virtual reality/computer simulations: Curriculum enhancement*. Washington, DC: National Center on Accessing the General Curriculum, U.S.

Office of Special Education Programs. Retrieved March 29, 2012 from www.cast.org/system/galleries/download/ncac/ncac_VR.pdf

Techtrekers, (2012). Educational Simulations. Retrieved March 28, 2012, from http://www.techtrekers.com/sim.htm.

Thornton, T., Ernst, J., & Clark, A. (2012). Aumented reality as a visual and spatial learning tool in technology education. *Technology & Engineering Teacher, 71*(8), 18–21.

Wright, R. (2012). *Technology & engineering, sixth edition*. Tinley Park, IL: The Goodheart–Willcox Company, Inc.

AFFILIATION

Thomas Loveland
School of Business & Technology,
University of Maryland-Eastern Shore

RICHARD KIMBELL

7. UNDERSTANDING ASSESSMENT ITS IMPORTANCE; ITS DANGERS; ITS POTENTIAL

INTRODUCTION

In the last 20 years or so, the remorseless international trend has been towards more and more assessment. The intricacies of student assessment were once the preserve of a few specialists … but progressively it has become big news and big business. Businesses producing tests have flourished. Results are published in the national press with banner headlines – frequently (in the scandal-mongering elements of the press) about failing schools. Parents fight over access to 'good' schools – where pass rates are high. And politicians bemoan 'falling standards' because (oddly) more children are getting good grades.

For the best – and worst – of reasons, assessment has become a huge industry. The Bush administration in the USA instituted a programme called 'No child left behind' (NCLB). The ostensible motive was to ensure that all children progressed properly through their schooling. But how do we know that children are making appropriate progress? Well obviously we test them. And the result was an absolutely enormous increase in the quantity and cost of assessment.

> "States are likely to spend $1.9 billion to $5.3 billion between 2002 and 2008 to implement No-Child-Left-Behind mandated tests." US Government Accounting Office (2005)

But for the majority of this chapter I shall be drawing from the experience in England, and here, in 1990, we were the first nation to mandate a National Curriculum for all children from 5–16 years of age. It identified what should be taught, and established lots of 'attainment targets' that enabled everyone (including of course the children themselves) to see what they had achieved and where they were heading. How do we know when children have achieved them? Well obviously we test them. And – once again – the result was an absolutely enormous increase in the quantity and cost of assessment.

English children are tested longer, harder and younger than anywhere else in the world, according to an influential report that compares school standards in 22 countries (Times, 2008).

As England increasingly eliminated its manufacturing base, along with the associated tradition of apprenticeship, and committed itself to being a knowledge

P. J. Williams (Ed.), Technology Education for Teachers, 137–166.

economy, the pressures for students to stay on at school – and go to university – increased. In the 1960s about 12% of the population went into higher education. Now it is about 50%. Perhaps this is all good news. But access to university courses in England is competitive and depends upon students' performance in Advanced level examinations. So one certain beneficiary of the trend has been the assessment companies.

> Secondary school spending on exam fees has shot up by an inflation-busting 6.7 per cent, or £17.7 million, in a single year to a total annual bill of £281 million. (Times Education Supplement, 2010)

In such a tested world, it seems a matter of simple equity to ensure that schools should provide a level playing field for all learners. We don't want some good, some just OK, and some bad schools. We want to know that all schools are performing satisfactorily. So how do we do that? Well in the UK, we set up OFSTED – the Office for Standards in Education – to inspect schools and, inter alia, to inspect examination pass-rates, which costs another £m 207 every year.

But what about the quality of the assessment process itself – the design of the tests, their administration, marking and analysis? Surely we need to be confident about that too? The Qualifications and Curriculum Development Agency (QCDA) manages the National Curriculum tests, and Ofqual oversees the private assessment companies that run the school-leaving exams for 16, 17 and 18 yr olds. There goes another £m 128 each year for QCDA and £m 18 each year for Ofqual.

In the last 20 years in England, the costs associated with assessment have risen FAR faster than budget allocations to schools. There is an old aphorism that advises that you don't fatten the pig by constantly weighing it. But this is only a half-truth. We might not fatten the pig being weighed … but you can be sure that we are fattening the pig that designs weighing machines. Assessment is a good business to be in. It's a real booming industry. And as with all booming industries, there are as many shady dealers as there are serious professionals. For this reason alone, if you are interested in children, learning and schools, you have to understand assessment.

There are, of course, many better reasons for understanding assessment, principally concerning its relationship with learning and teaching processes and in this chapter I will outline some of the technical requirements that will enable readers to decide what counts as good assessment – and equally what might fail that test. Thereafter, I will introduce a radical new approach to assessment that has been the subject of research and development for the last 6 years – and that has the potential to reform our current practices.

WHAT ARE YOUR MOTIVES?

In the foregoing section, the reader may have noticed a few different motives underpinning the drive for more and more assessment. It's worth elaborating on these so that we can better understand where we are.

Formative assessment

When I attended primary school, my teachers would quite commonly give us short exercises that might have been tests. I remember the writing ones in which the teacher would read a short passage (a phrase at a time) and we had to write it out with all the appropriate spelling and punctuation. The purpose of this 'test' (if it was one) was principally to help the teacher to see how everyone was getting on with writing, spelling and punctuation; what we were having trouble with; and how her latest bits of teaching had changed things.

At that time, in the vast majority of schools in England, this informal testing activity was the ONLY assessment that was conducted before age 11. It was ***formative*** assessment, designed to help the teacher and the learner to clarify where things stood. Formative in the sense that the information gathered helped the teacher to inform (and thereby form) the next steps of the learning journey. This formative assessment is not just restricted to tests, for every single exchange between teacher and learner (every question and answer, every comment and response) is an opportunity for the teacher to glean a bit more information about what the learner understands and can do. It is the stuff of day-to-day classroom practice. Teachers have well-tuned antennae for picking up all the informal clues that indicate significant changes in learner behaviour.

Summative assessment

But at age 11, I experienced a significant change in the assessment game. We were to be *sorted* into categories for different kinds of secondary schooling. There were verbal and non-verbal reasoning tests, and some reading and maths tests – but I don't recall the details. Collectively they were described as 'intelligence tests' – as if they were somehow exposing my underlying intelligence as opposed to my learned habits and skills. Interestingly, I neither passed nor failed. Those of my friends who did really well ('passed') went on to Grammar school where they experienced a very academic learning style and the expectation was that most would go to university. Those who did poorly ('failed') went on to Secondary schools that had a more practical learning style and most left school at age 14. A few of us did neither (we 'half-passed') and went on to a form of secondary school that was first introduced in the 1944 Education Act; *Technical* schools. 'Passing' and 'failing' the 11+ tests has to be understood in a particular way, since the 'pass' mark was not determined by any academic/learning reasoning. It was determined by how many school places were available in Grammar schools and Technical schools. So the 'fail' category was simply defined by the residual number. About 20% of the cohort went to Grammar schools, I was one of the 10% that went to Technical schools and the remaining 70% went to Secondary schools. It was Harold Wilson's Labour party administration that (in 1966) replaced this system with 'Comprehensive' schooling.

The point of the story is just to illustrate a different motive for assessment. This was not the informal, helping, testing done by my teacher. This was *sorting* testing run by an external agency – common tests to all 11 year-olds – and used to categorise children and in the process to determine their life chances. It was ***summative*** testing: testing at the end of a period of schooling and summarising the consequences.

As I progressed through the Technical school I experienced a fair bit more of the informal (formative) teacher-based assessments. And then at age 16 and again at age 18 more rounds of summative assessment. These examinations were run by an external agency (a university examination board), and this is significant. These examination boards were essentially running a progressive filtering/sorting system for future intakes of university students. The exams did not claim to be 'intelligence tests' – but rather leant on the subject-based bodies of knowledge and skill that had been taught up to 16 and 18. It was ***summative*** assessment for selective purposes.

Diagnostic assessment

We all left school at 18 and many of my friends went into various kinds of employment and apprenticeship – typically associated with the dock-yard in Chatham where we lived. It was a huge employer and ran another form of assessment. It was a form of ***diagnostic*** assessment – mostly skill-based – to determine where each person was best suited. The main entry points were to the engineering plant (metal bashing), the drawing office (draughting), and the fitting and finishing plant (wood bashing). We all made our initial choices – but were then put through a series of assessment tasks to determine whether we had the right levels of capability for entry. Some account was taken of my A level passes in Technical Drawing, but there were some significant differences in the kinds of drawings that we had to do for the dock-yard tests, that were presumably tuned to the needs of drawing bits of ships.

But in the end I opted not to join the dockyard, but instead to engage a somewhat different set of skills as a teacher.

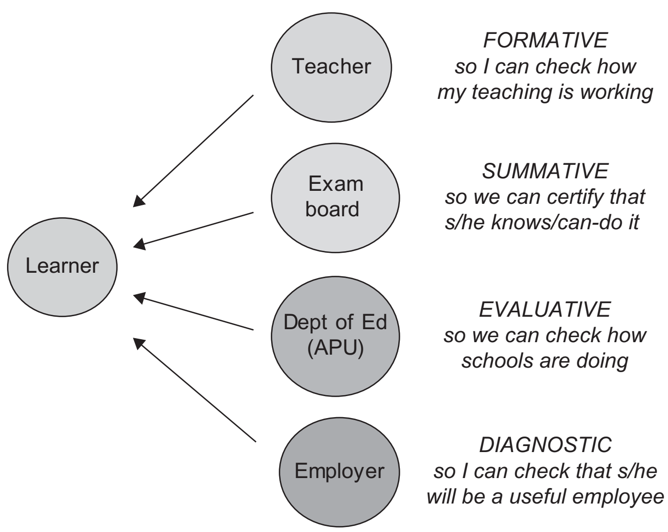
Evaluative assessment

Throughout my teacher-education, and my subsequent practice as a teacher and lecturer I experienced many versions of the three kinds of assessment discussed above; ***formative***, ***summative***, and ***diagnostic***. But it was in the mid 1980s that I experienced yet another dramatically different form of assessment. I won a contract from the UK Department of Education and Science (DES) to develop assessments for the Assessment of Performance Unit (APU). The point about APU was that it was NOT trying to find out about children's performance. It was a research branch of the DES and its brief was to find out about the functioning of the *schooling system as a whole.* There had been APU projects in science, maths, and English language and in each case the project teams had to develop tests that could work anywhere in the country – regardless of the curriculum being studied. They then had to report about performance levels stratified in many ways. Girls performance as against boys; performance in this kind of school or that kind of school; in this local authority and that one; in city/

urban schools and rural/country ones; noting how performance was varied by this kind of curriculum or that one. APU science was attempting to say something about the *nation's* understanding of and capability in science. This is ***evaluative*** assessment.

At Goldsmiths College we were asked to do this job in relation to design & technology (d&t) and we were given a very precise brief. We could test just a 2% sample of the student population. We were looking at performance at age 15, so a 2% sample amounted to about 10,000 students. There was a strict limit to how much testing time was available with each student – one hour – and of course it's impossible to test everything about d&t in an hour. But that was the point about APU. The approach was to develop a test framework – then develop test items and activities – and together these might amount to 30 or 40 hrs of tests. No student did more than a small sample of the tests – and the picture of national performance is built up by amalgamating all the data from all the tests. With ***evaluative*** assessment, the purpose is not to find out about students – in fact we had to have such a 'light touch' on schools that most schools didn't even know it was going on. The purpose was to find out about the system as a whole – so a stratified sample of 700 schools was chosen – and 12 students were chosen at random in each of those schools (using dates of birth in the age 15 cohort) regardless of whether they were studying d&t. And at the end we could report on the differences in performance in schools where students were doing d&t as against where they weren't. This was before the National Curriculum, at a time when d&t was on optional subject.

So, by the end of the 1980s, the four kinds of assessment outlined in the diagram below were all well established parts of the educational landscape in England.



Margaret Thatcher tended to divide opinion in the UK; people either loved or hated her. But whatever your view, she had some really interesting effects on education. Despite being a very active and committed privatiser – selling off huge amounts of state industry to the private sector – her effects (oddly) on education were the reverse of this, centralising and pulling ever more power into the Department of Education. And as (in 1990) she was finally removed from office for being too much of a radical free-marketeer, the ultimate centralising achievement of the National Curriculum was established. By any standards this is an unusual juxtaposition of policy.

But the National Curriculum (NC) was not just a set of learning programmes, it carried with it a massive panoply of testing. From its inception, every 7 yr old, 11 yr old and 14 yr old was to be tested in every subject. And this was in addition to all the testing of 16, 17, and 18 yr olds that was already underway.

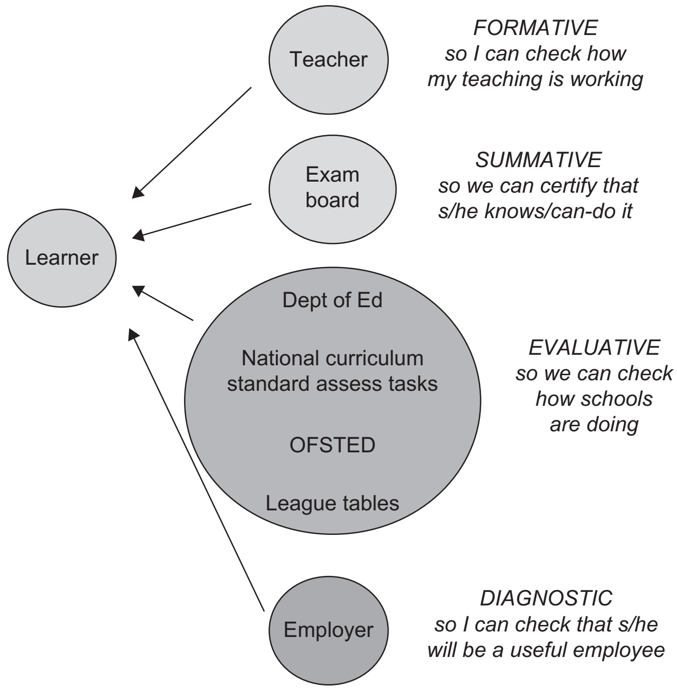
So, the logic was that if we have all these test data we will know all we need to know about performance (eg in d&t) in every region of the country, and every LEA and in this type of school and that type of school. So, all the *system evaluation* things that APU was designed to do could now be done by looking at the results of NC tests. But the big difference of course was that APU did it through its very 'light-touch' sampling approach. NC testing did it with a blunderbuss – testing anything that moved – as often as possible. Whilst teachers and learners barely knew APU existed – except from their published reports – every teacher and learner felt battered by the barrage of testing that was instituted with the national curriculum.

But there is a limit to even teachers' tolerance, and – famously – in 1992 and again in 1993 teachers simply refused to have anything to do with the NC Standard Assessment Tasks (SATs). So after millions of pounds of test development was undertaken – and thousands of tons of tests papers were distributed to schools – teachers simply put them in the rubbish bin. If one school had done it they would have been in trouble. If one Local Authority had done it they would have been pilloried. But when ALL schools did it, the Department of Education was in trouble. The hapless Secretary of State for Education was sacked and the whole testing regime was reconsidered and reduced.

The over-riding reason for the SAT's boycott was the sheer volume of testing to which children were being subjected. Primary teachers in particular – through their normal formative assessment process – felt that they knew all about their children. And the SAT's tests seemed to them to add nothing to this.

In secondary schools, teachers believed that the tried and trusted 16+ and 18+ examinations were working OK. The Department of Education's APU was barely noticed, and virtually all employer-based diagnostic assessments were outside schools and therefore invisible to teachers. So prior to 1990 and the National Curriculum, the regime of formative and summative assessments seemed reasonable and sufficient.

The transformations brought in through the 1990s had the effect of dramatically increasing the extent of ***evaluative*** assessment. The NC SATs at ages 7, 11 & 14 were completely new and involved *every* child and teacher. OFSTED, the Office for Standards in Education, had been established in the mid 1980s but was now beefed up and was busily inspecting all schools – and publishing all the test results from every school. And this resulted in the publication of league tables of schools – effectively creating a market in schools.



There is no more conservative pressure on schools than parents, and armed with such league tables, active, middle class parents began pressuring for entry for their children into the 'best' performing schools. Schools at the bottom of the league were under a very different pressure. They became subject to OFSTED's Orwellian label 'Special Measures'.

I have attempted in the image above both to illustrate this massive transition in assessment policy and practice and to identify the focus of it. For whilst teachers felt that ***they*** were the focus of all this evaluative assessment – in reality they were not. Children were the focus. In addition to all the pre-existing formative and summative assessments, they were now ***additionally*** tested with all the NC SATs. Moreover, if they did badly in these tests, whilst they did not directly suffer any penalty, the school did. So the children were effectively being offered up – like latter-day gladiators – to be tested on behalf of their school. And if they did badly the school might be closed, or put into Special Measures, or experience some other ghastly fate. The morality of this policy seemed to me to be utterly bankrupt.

But just as bankrupt was the policy adopted by many schools. Whilst NC SATs had a big influence on primary schools, secondary schools increasingly became judged on another measure – the number of passes achieved by students in the 16+ GCSE exams. The General Certificate of Secondary Education is a traditional summative form of assessment, and students typically take GCSE exams in 6 or 7 subjects. Good passes (grades A-C) in 5 of these subjects (including English and Maths) has become a benchmark against which schools are judged. If a school gets 50% of the cohort to achieve five passes at grades A-C, then its OK. If they get 100% to achieve it – then it is very good. But if only 20% achieve it then the school is in trouble. And of course this generates another league-table of schools for parents to study.

But lets be clear what is happening here. The GCSE grades are ***summative*** assessment grades for individuals. They are then aggregated and presented as school-based percentages for ***evaluative*** purposes. So influential are these league tables, that some schools go to very great lengths to make sure that as many of their students as possible get five GCSE's at grades A-C. As an example a school well known to me sets a 'mock' exam 12 months ahead of the real exam, and this provides the school with a reasonable guide to who will get A B C D E etc. They then reasonably assume that with 'normal' teaching through the rest of the year, the ones that got A-C in the mock exam will achieve similarly in the real exam.

It is the next step in the argument that is so dangerous.

Since their aim is to have the greatest effect on the overall school result, then the logic is to concentrate any *extra* efforts on the D group, because they are the group that could reasonably be expected to become Cs. That way we can elevate our % 'pass' rate. Of course the associated argument is that to put extra effort into the group who got below D would be a less beneficial idea, since not many of them will get up to a C within the 12 months. So that group can just have the normal teaching diet and take their chances. In short, schools that adopt this policy allocate teaching (and other) resource effort onto a small group of students; those who currently fall just below the line.

Such schools might be judged to be behaving rationally. As with all target-driven organisations, they are placing resources where they are judged to have the greatest effect on the key statistic that defines the target. But for me it illustrates the slippery ethical slope which such assessment policy encourages. Are we doing this for the children – to raise their grades and life chances – or are we doing this for ourselves, to protect us from the consequences of poor results? But if they claim that its all about helping the life chances of those children – what about the opportunities for those further up and down the scale. Don't all children have equal rights in the dispensation of educational resource?

Assessment in all jurisdictions is ultimately political. It forces us to declare what we value and believe in. And, since we are all subject to the will of national politics, wherever there is a mismatch between our personal values and those exhibited by ruling governments, things get very uncomfortable. Then – more than ever – it is important to be clear about what makes 'good' assessment.

(for additional discussion of the issues above, see Gipps 1992, Kimbell 1997, Garmire and Pearson 2006, and Satterly 1989.)

MAKING GOOD ASSESSMENTS

In the foregoing section, we have considered the variety of ***motives*** that drive assessment policy. Whether this be the teacher checking informally (with a question here and there) on how things are going; or an examination body setting and marking a formal examination; or an employer conducting an entry test; or the Dept of Education conducting a broad-brush review of the nation's performance. These are not only very different motives for assessment – they also result in very different kinds of assessment tasks.

It is worth examining this matter a little to see what is involved in making a good assessment. And not surprisingly the matter looks rather different according to the standpoint from which you view it. I propose to outline three such positions:

- the test developer (eg an examinations body)
- the test marker (eg the examiner)
- the test administrator (eg a teacher)

Test development

Since this book centres on technology, let us suppose that I am designing a technology test. The first big issue then is to be sure that we are testing the right thing.

> "draw an electrical circuit that contains a light bulb that can be switched on and off, and explain current flow through the circuit"

This looks a bit technological – but immediately I am confronted by the problem that I am testing ***more than*** technology. Specifically, learners who struggle with reading won't even be able to get started, and those with poor writing skills probably won't be able to 'explain' things at all well. This is not a technology test – it's a reading and writing test. Or – at the least – it is ***also*** a reading and writing test. So, if I get a poor result, does that mean I don't know the technology – or that I can't read and write well?

The first harsh reality of conventional assessment practice is that if learners want to do well at tests (in whatever subject) they had better be good at reading and writing. It would be worth pausing for a moment and thinking for yourself about how you could set the same technological challenge in a way that *removes* the confusion that arises with reading and writing. I promised – in the introduction – to outline a radical new approach to assessment and one of its special qualities is to address this issue. We will come to that later.

Anyhow, the technical issue we are getting at here is test ***validity***. For a test to be valid, it must test the quality that is purports to test – and not other things. Another illustration of the validity issue might be if I was trying to design a problem-solving test in which I want learners to show me how they problem-solve their way through a task. There are all kinds of ways of doing that, but some are more valid than others.

I would argue – for example – that a multiple-choice, tick-box style of test would be an invalid way of assessing my problem-solving ability.

But this illustrates another thing about validity. It's a matter of judgement. So when test developers want to know if they have created a valid test, they typically assemble a group of experts in the subject and ask them to rate the validity of the question. "Does this count as a good technology question / activity?" Validity is typically a matter of expert judgement, and assessments that are judged to have low validity are not useful.

The test marker

A very different challenge arises when we approach the marking issue. Suppose I have decided that my question above is OK for the test, and the question has been completed by all the learners – with variable levels of competence. My challenge is to make judgements about those levels. Perhaps I'll mark it out of 12, and divide the marks as follows:

– identification of components 4
– quality of the drawing 4
– quality of explanation 4

NB. I trust readers have noticed that the design of marking schemes is also a ***validity*** issue.

I then mark all my learners' work. Because I'm in a school with a big technology department and all the classes are getting the same test, all the other teachers are doing the same marking with their classes. And we find that Jan's class has done (on average) much better than mine. Is this because Jan's class is better than mine? Well one way to check is for Jan to cross-mark my group and me to cross-mark hers. And we find that there is a lot of disagreement between us.

It seems that we are using different standards to make the judgements. The first part of the marking (identifying components) is almost exactly the same – they either are there or they are not. But when it comes to judging the 'quality' of things it's a bit more fuzzy, and Jan has been more generous than me in interpreting learners' drawings and explanations. This is the ***reliability*** problem.

Reliability is best thought about as ***repeatability***. If I make a judgement about a piece of work and the person who cross-marks it ***repeats*** that judgement, then it has a certain reliability. If *every* teacher in the school makes the same judgement, then the marking has high reliability. But if we all disagree, then the marking has low reliability.

Unlike validity – which is largely a matter of judgement – reliability can be expressed as a statistic. If we have lots of markers doing the same exam, we can produce a statistic that defines exactly how reliable the marking is. Inter-marker correlations is one such measure, and tends to be on a scale from -1 to +1. If a marking team ends up with +1 the marking is *perfectly* reliable (everyone agrees). If it ends up with -1 it is *perfectly* unreliable (everyone disagrees). If it ends with zero it means that the marking was random…. a bit like throwing all the papers in the air and seeing which hits the ground first. But most of the time the statistic is (say) 0.8, which means that there is a reasonable agreement between markers. If the measure falls below 0.5 (some would argue 0.7) then the reliability would quite properly be questioned.

Assessments with low reliability are also not useful.

The conundrum of validity and reliability

Validity and reliability are key concepts in the design and marking of assessments. To be a good assessment, the test question/activity has to be highly *valid* and the marking has to be highly *reliable*. The problem is that they tend to cancel each other out. Highly valid tests tend to be less reliable in their marking, and highly reliable marking tends to be associated with less valid tests.

Two extreme cases can be used to illustrate the issue.

Case A is a technology project conducted over an extended period – and in which the learner designs a product, manufactures it and tests its performance against a set of criteria established in the specification at the outset.

An expert validity panel would probably judge that the performances demanded by the test (the project) are exactly those performances that are central to being good at technology. So it scores highly on validity. But the marking proves difficult. It is such an individual piece – and all the other learners' projects are equally individual – that teachers tend to disagree about the marking. Especially when we ask teachers from other schools, where standards might be somewhat different. So the reliability of the marking is low.

Case B is a multiple-choice test of technological capability. A series of questions is posed about what you would do when designing and making a new product, and in each case four choices are offered. You have to pick the right answer.

An expert validity panel would probably have all kinds of difficulties with this test. It's not testing the learners' capability but rather asking then to make some choices about what they 'might' do in some theoretical settings. Technologists know that technological problems come in sets, and tend to be interrelated (I could do *this,* but if I did, then how will I be able to do *that*). But this test just isolates each decision-point as if it's the only thing that matters. It's unreal. So it gets a low validity score. But the marking is easy. Once the test designer has identified that each question has a 'right' answer, the marker just goes through and ticks every one that is right. Or maybe – on a large scale – a piece of software does all the marking automatically. So there is no disagreement between markers (except for occasional slips or lapses) and the reliability of marking is high.

The history of assessment has been that we are forced to choose between valid tests that are unreliable, or invalid tests that are reliable. And the problems don't end there, for we have also to consider the administration of the test.

The test administrator

The key issue for test administration is whether it is ***manageable***. Most school students are familiar with examination rooms full of desks in rows, and with test papers being handed out by severe looking invigilators. Examination bodies have complex timetables so that all students across the country sit English Literature on the same morning (its no good doing them on different mornings or someone might tell tomorrows lot what the questions are). Then the papers need to be collected and sent off so the marking process can begin.

It gets a bit more complicated however if practical examinations are involved … as for example with an examination of trumpet performance. Typically, exam bodies have teams of roving assessors who sit through hours of tortured playing in one school – and then move on to the next one. This is rather less manageable, especially if we are talking huge distances – as for example with schools very thinly spread across the Australian bush or Botswana's Kalahari dessert. But it might still be judged to be just about OK – but are the schools (or the candidates) expected to pay for the examining costs?

A different manageability problem arises if the assessment requires access to particular pieces of equipment (eg technology apparatus or computers). The rules of the game have to be equivalent for all, so if the examination specifies that a scientific calculator is required – schools need to be sure that everyone has one – and the *right* one (not one with extra facilities that give a student an unfair advantage).

The manageability problem can get very complex with computer-based assessments. Does a school have dozens of identical computers – with exactly the same software? And can they all be accessed at the same moment or will it crash the school's network. When the Qualifications and Curriculum Authority in England designed a set of ICT tests for schools – for reasons of simple software licensing they decided that they had to completely recreate an exams version of the Microsoft suite of Word, Excel etc. It was a massive expense and never worked (so was never used) but it caused a terrific row in the ever-interested press. And the underlying reason for it was all about manageability.

So these are the three requirements of a good assessment:

a. It must be valid; it must test the qualities that it is intended to test – and not others.
b. It must be reliable; in the sense that the markers all agree on judgements of quality.
c. It must be manageable; it must be possible to run the assessment in a way that is fair to all.

THE PROBLEM OF JUDGEMENT

At the heart of the assessment process lies the business of making judgements. Is this a B. or does it just make it into the As? There are occasions when this is not a matter of judgment – when for example a grade boundary is defined by some simple quantitative factor (to get a C candidates must mention 5 issues) and in these cases its usually a relatively simple matter of counting up. But in the vast majority of cases, assessment involves making a qualitative judgement on some scale.

Norm referenced assessment

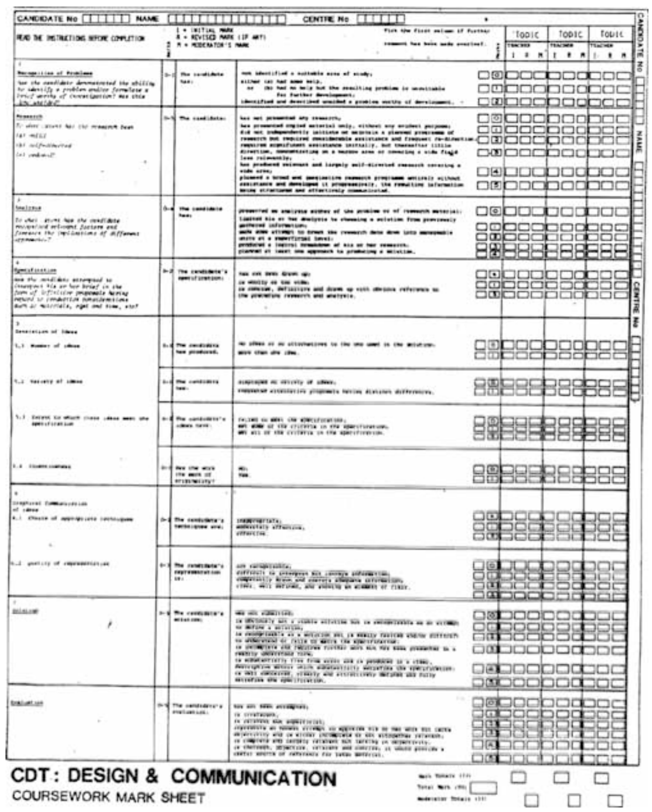
The illustration below is from 1970 and shows the 1st ever form of assessment used to judge the quality of design-based project work.

	0	1	2	3	4	5
Situation & brief						
Investigation						
Solution						
Realisation						
Testing						
Totals						

The process of design and development was broken into five phases. The first was about identifying how well the design situation (context) had been reviewed and the project brief derived. Thereafter candidates were judged on the quality of their response to the demands of investigating, developing a solution, making it, and testing it. In each case the judgement was on a 6 point scale; 0–5, and the evidence that markers had to go on was all in students' design portfolios. So in the end, all these portfolios were judged out of 25 marks.

The approach was pretty straightforward and worked for many years – until the mid 1980s in fact. In retrospect of course there are some obvious problems with it, mainly to do with how markers might standardise their judgements. In my school I might say that a candidate gets 4 out of 5 for investigating – because she is almost my best investigator. But in another school – where slightly different standards apply – she would only get 3/5. There was nothing in the form to identify what *qualities of performance* are essential for achieving 3 or 4 or 5 marks. Given this lack of guidance, the only yardstick I have is the group of students themselves. So perhaps my best one gets 5 and my worst one gets 0 or 1. This is classic ***norm referencing***. Making assessment judgements by reference to the quality (the norm) within a group of candidates. So in effect candidates are measured against each other.

Criterion-based assessment



In 1985 England introduced a whole new model of assessment at 16+; the General Certificate of Secondary Education (GCSE) that i referred to earlier. The assessment form illustrated here is one of those 1985 forms and shows how much more sophisticated (wordy and complicated) things had become. Readers do not need to see the detail of the words. It is sufficient to note that the process still involved making judgements in the same categories as before (investigating, design solution, evaluation etc). These broad steps are shown in column 1.

But the big difference was that in column 4 were listed a series of ‘can-do’ statements that identified what level of performance was expected in order to achieve the marks.

In the illustration below I have blown up the list for ‘evaluation’ which I have arrowed here.

Quality of evaluation (0-5 marks)

The candidates evaluation……
0 has not been attempted
1 is irrelevant
2 is relevant but superficial
3 is an honest attempt to appraise work, but lacks objectivity and is incomplete
4 is complete and largely relevant, but lacking objectivity
5 is thorough, objective, relevant and concise

Note that candidates are still being judged on a 6 point scale, but the performance level is somewhat defined.

I say ‘somewhat’, because – in reality – what is meant by ‘relevant’ or ‘superficial’ or ‘objective’? For these are ***normative*** words. How relevant does it have to be to be relevant? How objective? How concise? I might argue… ‘In *my* school that piece of work wouldn’t be thought to be thorough….you must have lower standards in *your* school.’ So whilst having these guidance statements was a bit helpful (it showed that evaluation was about being relevant, concise, thorough and objective), it did not really tackle the reliability problem of actually making a judgement.

Nonetheless, this kind of assessment form proliferated in the mid 1980s and was hailed as a step forward towards fairer assessment. This was ***criterion-based assessment*** – where objective standards replace the former practice of norm referencing. There was just sufficient truth in this to make it believable. In 1985 I wrote the teachers’ guide for the introduction of the GCSE examinations in Craft Design & Technology, and in it I drew attention to this first generation of GCSE assessment forms to illustrate the shift from former days.

> ...this form is criterion-referenced, and the performance required to achieve a particular mark is therefore specified in advance in the list of criteria on the form... (Kimbell for SEC 1986)

I was younger then – but I remain embarrassed by my naivety. In mitigation – I can claim that there was some truth in what I said – and I did believe it. But it was only ever a half-truth… as I will show later. Before that however, we need to see the full development of this shift to criterion-based assessment, and for that we move on another 5 years to the introduction of the National Curriculum in 1990. Here performance was again defined against virtually the same categories – investigating, design development, making, evaluating – but now the ***numbers*** in the assessment form have disappeared altogether. Rather, we have a series of Statements of Attainment (SoA) that define levels of performance on a 10 level scale, 10 being the top of the scale.

"Design & Technology" Statutory Order 1990

	Attainment Target 1 IDENTIFYING NEEDS AND OPPORTUNITIES	Attainment Target 2 GENERATING A DESIGN PROPOSAL
level 1	[illegible]	[illegible]
level 2	[illegible]	[illegible]
level 3	[illegible]	[illegible]
level 4	[illegible]	[illegible]
level 5	[illegible]	[illegible]
level 6	[illegible]	[illegible]
level 7	[illegible]	[illegible]
level 8	[illegible]	[illegible]
level 9	[illegible]	[illegible]
level 10	[illegible]	[illegible]

Outcomes-based assessment

Just half of the Statements are shown here; those for attainment targets 1 and 2. There were equivalent lists for attainment targets 3 and 4. Readers should not worry that they can't read the text. The reason for including this illustration is to show why these National Curriculum assessment forms got bigger and bigger – while the text got smaller and smaller. Thousands of words (with associated tick-boxes) were used here to create about 150 individual 'can-do' statements to define performance at particular levels.

This is ***outcomes-based assessment.*** At the outcome of a learning experience (a design project) we identify what kinds and levels of performance have been achieved.

As an illustration, one of the Statements of Attainment in the 'developing a design proposal' category asks us to judge learners in terms of whether or not ….

"the pupil uses specialist modelling techniques to develop a design proposal"

I invite readers to speculate about what level this is. Is it level 10 (where eg. the modelling might be modelling with CAD), or level 5 (where eg. the modelling might be with technical LEGO), or level 2 (where eg. the modelling might be with plasticene). It could of course be any of them. So interpreting these Statements (making meaning out of them) proved very difficult indeed.

The delusion of ***criterion-based*** assessment, and of ***outcomes-based*** assessment, is that it is possible to define performance levels sufficiently precisely so as to make the judgements un-contestable. Additionally of course, there is the problem of ***manageability*** – to which I referred earlier. This first round of NC assessments (with 150 Statements of Attainment [SoA] just for technology) involved teachers making 150 yes/no judgements for every student. And primary-school teachers had to do it for every subject … thousands of SoA. It was utter madness, and perhaps readers can see why schools just threw the Standard Assessment Tasks in the bin. The boycott of SATs was primarily because the whole thing was SO unmanageable. But underlying that was the secondary factor that all those detailed SoA were so imprecise that you can make them mean anything you like. They tell you nothing about the child that you didn't know already.

There is an interesting story that illustrates the point. At the outset of the NC adventure, a great deal of time and energy was spent on defining these excellence criteria (SoA). The technology Working Group – there was one in each subject – agreed that a good starting point would be to refine a clear statement for level 10 – the ultimate descriptor of what we might expect the most able design & technologist to achieve. The argument ran that if we had such a clear starting point it might then be possible to work up towards it incrementally; moving step by careful step towards this descriptor of ultimate performance.

So this level 10 descriptor was drafted, and debated, and redrafted and debated, and edited, and debated and finally it was honed with infinite precision. The group was happy with it as a statement describing the excellence that should be characterised as level 10; the best performance that can be expected of 16 year old learners in technology.

And then they showed it to teachers. And the *primary* teachers said – "Yes that's what my children do"! Having read the descriptor, they interpreted it into something that was meaningful to them, and were quite comfortable with saying that this properly describes what their 11 year olds were doing.

It is this process of ***interpretation*** of criteria that lies at the heart of assessment error, and it is worth some discussion.

MAKING MEANING WITH NORMS AND CRITERIA

When (in 1992/3) England's NC assessments started to fall to pieces, all kinds of attempts were made to try to make an unworkable process a bit more workable. One of these processes was to tell teachers that the 10 point scale was not really for them; that it was an overall system thing. ***Their*** responsibility (if they were primary teachers) was to look at the SoA in levels 1,2,3,and 4. Then secondary teachers could look at levels 5–10.

Note what is happening here. We are ***norming*** the Statements of Attainment. We are saying to teachers 'think of these SoA as describing the kinds of performance *normally* achieved by 6/7/8/9/10 yr olds'. And then we went even further by saying that only the *very best* primary school performers might achieve level 5. This is exactly norm referencing. Pick your very best performers – and they are level 5.

The fact that we elaborated this process with lots of words and descriptors does not disguise the fact that we reverted to a process of norm referencing. Judging learners against each other. The approach broadly worked and defused the political crisis.

The central confusion in this process lies in the assumption that we ***either*** use normative judgement ***or*** criterion judgement. The reality is that we use ***both simultaneously***. The criteria tell us something about the ***kinds*** of performance we ought to be looking for, and norms guide us in the matter of the ***quality level*** of the performance.

Of course if teachers all have idiosyncratic norms, (apply different standards) then this is no use because the judgement process would be very unreliable. So assessment organisations do all sorts of things to standardise our norms. They typically publish exemplars, saying that ..”this piece is worth a level 3” .. and ..“that one is level 4”. But there are so many different ways of being good (and better) that exemplars only ever scratch the surface. They help – but not much. What needs to happen is that – progressively – we generalise our personal standards. Initially the teacher will have his/her own standards. If all the teachers in a school collaborate in an assessment process – then individual teacher norms gradually morph into school norms. If schools collaborate in an assessment process then that gradually generates regional norms (perhaps School Board norms in the USA). Ultimately, genuinely national norms can result from an assessment process involving teachers cross moderating their judgements on a national scale. Once again the radical new assessment approach that I promise to reveal soon makes this all very possible.

The teachers I observed struggling in 1990, 91 and 92 did not understand that they had a critical role to play in *defining* national standards. We had moved so far down the road of criterion-referenced assessment that we had come to believe that all you need for assessment is good criteria. Teachers thought (as did the Secretary of State) that the standards were defined in the words of the SoA. They were not. Nor could they be. But the arrogant certainty with which they were presented, recognised no role for teachers to act as agents in *defining* the national standard. The SoA provided the bearings, but they did not – could not – define the range. They therefore did not amount to anything that could be called a “standard”. Accordingly, instead of empowering them to do this important job well, teachers were utterly intimidated and had no idea that ***they*** held the key to defining the standard. If only we had presented it to teachers in that way, the sad story of NC assessment in England might have been very different.

COMPARATIVE JUDGEMENT

If you ask any primary school teacher which child in their class is the best reader, or the most musical, or the weakest with number, they will tell you. They know the children well and have no difficulty in telling you about their strengths and weaknesses. In assessment research projects – over and over again – the thing that teachers are invariably good at is ranking.

Ranking uses a ***relative*** scale, whereas typical assessment approaches require us to use ***absolute*** scales. It is easier for a teacher to say that child A is a (relatively) better reader than child B, than it is to say that child A is (absolutely) reading at level 4. We have seen how this latter difficulty arises through the uncertainty of what level 4 *means*.

Imagine yourself in a house, moving from room to room. Some are warmer and some are cooler. You would have no difficulty at all in saying that room X is (relatively) warmer than room Y (assuming that it was). But if I ask you to do that on an absolute scale – what is the Celcius temperature in room X and room Y – then all sorts of error would creep into your judgements. And for exactly the same reasons as with educational assessments. You are not sure exactly what 25 degrees or 28 degrees is (what they feel like).

Laming explains this phenomenon:

> When someone comes to make a judgement …the point of reference is most often taken from past experience. Different people have different accumulations of past experience and for that reason make different judgements about the same issue. We call that difference a 'point of view'… (Laming, 2004 p18)

And having studied countless examples of people making judgements, his startling conclusion is that … *"there is no absolute judgment. All judgments are comparisons of one thing with another"*.

What Laming is saying is that we (teachers) are good at making relative judgements. The teacher who is making judgements about (eg) their 'weakest' reader is judging against the yardstick of the other children and can make direct comparisons of one with another. Such a judgement would be **both** criterion-based **and** normative. The *criterion* forces us to focus on reading (or maybe a sub-set of it) and the comparison enables us to make the judgement. Such comparative judgements have been shown time and again to be very accurate. And for two reasons.

First, it's accurate because the evidence is right there in front of you (I don't have to refer to some coded absolute reference in my head). But secondly – and critically – because the personal standards of the teacher have been eliminated as a variable. Referring back to the room temperature example, I might be hot-blooded or cold-blooded and if I was trying to judge rooms on an absolute scale, then my personal metabolism would seriously undermine my assessments. If I am a person who feels the cold I will probably under-estimate the absolute temperature. But if I am using a ***relative*** scale then my personal metabolism is irrelevant. I don't need that to make my decision. I know this is hotter than that, and we will both agree about that regardless of the fact that you are hot-blooded and I'm cold-blooded, and even though neither of us can tell you the 'real' temperature.

If I'm only making relative judgements, then my personal hot/cold-bloodedness disappears as a variable. And with is goes 90% of the error that attaches to my judgements.

COMPARATIVE JUDGEMENT FOR ASSESSMENT

It is time to make good on my promise and describe the new approach to assessment that can go a long way to solving some of these underlying difficulties. An assessment research & development project – project ***e-scape*** – ran at Goldsmiths University of London from 2004–2010 and it developed the notion of comparative judgement into a quite new methodology for school-based assessment. From the outset it seemed like a promising idea, if only because – theoretically at least – so much of the error of assessment judgements disappears when assessors use a *comparative* methodology.

A lot of the work of the project concerned the development of approaches to capture students' design performance digitally. Initially we used digital cameras, digital scratch-pads, digital pens, personal digital assistants (PDAs), digital recorders … all kinds of digital peripheral tools. Latterly we just used students' mobile phones. All students' performance is linked directly to a website – where their web-portfolios emerge directly and automatically as their project progresses.

It is worth noting that the approach enhances the ***validity*** of assessment. First it enables students to document their evolving work in many media. They can use drawing – writing – speaking (voice files) – video – photo and taken together everyone has a fair bash at making themselves (and their work) understood. This has always been one of the strengths of portfolio-based assessment, but it is enhanced when digital tools are available. The voice files in particular are really valuable to understand what students are doing/thinking and when aligned with photos of the work they are as valuable as gold-dust. We describe it as 'design-talk' and it is a form of data that has hitherto been unreachable for assessment.

It is important to recognise that the approach can be customised across a spectrum. At one extreme, the sequence of data-capture interventions is managed by the teacher and standardised by a 'script'. So after x hours of work the teacher will ask students to take a photo of their work (whatever it is) and record a sound file about the good points so far and the things that still need to be sorted out. Then normal work resumes until the next capture-point, when maybe the teacher asks them to explain (in bullet-point notes) how they expect their user to interact with the evolving product. This teacher-managed process obviously produces standardised portfolios where parallel data exists in all cases, regardless of the details of the task being undertaken.

This is a critical design feature of the e-scape system. The data-capture instructions by teachers are all ***procedural***. 'Whatever you are working on – take a photo of it' 'Whoever your user is – how would you expect them to react to your product'. In e-scape assessments we NEVER sought to *steer* students' ideas. Their ideas are their own – and should be valued as such. All we controlled was the data capture interventions – capturing whatever it was that they were doing at that point. Many teachers found this unsettling as they were used to taking a closer management role over students' evolving ideas.

In any event, our teacher-managed procedural interventions are good for national testing purposes – since they have the effect of standardising the *form* of the portfolios (there is always a voice file at this point – and a photo there – and a video there …). But the *content* was not standardised at all – since all the students' work was driven by their own ideas.

Despite the assessment benefit of the teacher-manages approach, it may be less useful for learning purposes – where teachers want to encourage students to take responsibility for their own decision-making in the portfolio. So at the other extreme, the system that we have developed can be seen as a toolkit that is available to students (and teachers) for developing their ideas and documenting that process. Students can choose whether to draw or write or speak or model and photo. And they can decide when those data capture points should occur –perhaps when a critical point is reached or a difficulty overcome. At this end of the spectrum, the resulting portfolios are much more individual and are therefore more difficult to use for national assessment purposes – but they are terrific for encouraging individualised performance.

At the culmination of this process in the e-scape project, we had portfolios from groups of students in 19 schools; 470 multi-media portfolios; 350 in d&t, 60 in science and 60 in geography. They were all of the teacher-managed variety and it is important to note that the *validity* of these data was repeatedly commented on by teachers, students and observers. The portfolios captured the authentic voice of the students as they tackled their tasks.

For full details of this work see the escape phase 3 final report (Kimbell et al 2009), available at www.gold.ac.uk/teru/projectinfo/projecttitle,5882,en.php

The 'pairs engine'

The portfolios in design & technology, in science, and in geography were then all assessed using a comparative judgement methodology, and to do this we developed a new software tool – the ***pairs engine***. The system is based on a theory initially developed by Thurstone (1927) concerning the reliability of comparative judgement. This theory was developed by Pollitt (2004) who used it for inter-board reliability studies for GCSE and other school-based examinations. Pairs judging in these cases was used to check the reliability of assessments that had already been made. In 2008 for e-scape phase 3 we developed the system further so that pairs judgement of the portfolios was the only form of assessment. We developed the pairs engine to run this as an automated process.

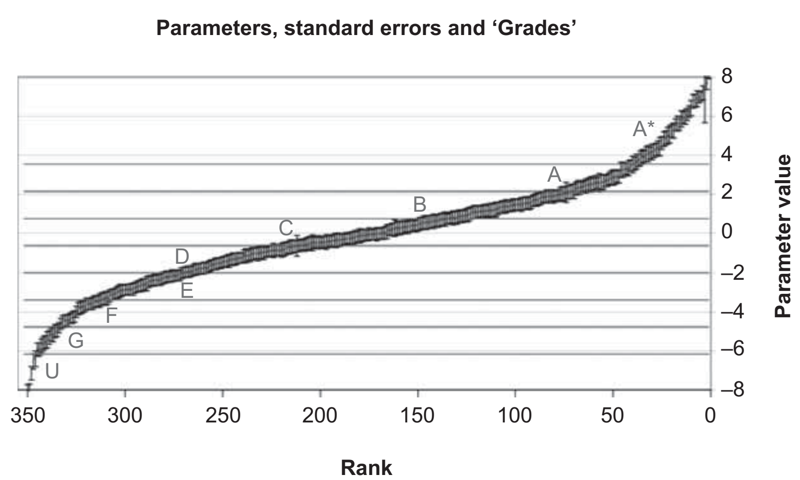
The engine presents a judge with a pair of portfolios and the judge has to scrutinise the work and make a holistic judgement about which of the portfolios represents the greater capability. For the design & technology sample we had 350 portfolios and 28 judges, each of whom made 130 paired comparisons. The geography and science samples were smaller and had judging teams of 6. Whilst training sessions for judges were conducted face-to-face in free-standing training days, the judging process itself subsequently took place remotely – typically in judges' homes. We had judges logged in from Ireland, Israel, and from across the UK.

The judgement process is based on criteria, but these are not scored directly – but rather are interpreted by the judge into a single holistic judgement. At the outset the engine assumes that all the portfolios are of equal quality, so judges might well be presented with two portfolios that are radically different in quality. These judgments are easy and quick (like walking through a house deciding which room is warmer or cooler). As the data begins to build however, the engine begins to estimate a rank order and thereby presents judges with portfolios that are closer in quality. These judgements are more difficult and require the judge to look deeper into the portfolios to identify discriminating features.

Eventually – when enough paired comparisons have been made – a complete rank order emerges and with very high inter-judge reliability. For each portfolio the engine generates a 'misfit' statistic – essentially reflecting the amount of disagreement between judges that it created. Moreover, for each judge the engine also generates a misfit statistic – reflecting the consensuality of that judge with the rest of the judging team. If either misfit statistic rises above an acceptable level, remedial actions are triggered. The remarkably high reliability of the judgement process (0.95) is explained by four factors:

- we are *comparing* (relative judgement) not scoring (on an absolute scale)
- as a result, judges' personal standards are eliminated as a variable. (Both 'hard' and 'soft' markers have to decide on a winner/loser)
- each portfolio is compared *many times* (with approx 20 other portfolios)
- the rank order emerges as the collective consensus of *many judges*.

The same levels of reliability were achieved with the science and the geography judging teams looking at their portfolios.



The out-turn data from the pairs engine is simply a rank-order (a VERY reliable rank order) and this can then be fed into Awarding Body systems for the subsequent awarding processes (eg deciding grade boundaries for A,.B,C)

We were very aware that a critical difference between e-scape judging and normal examination marking is the centrality of the **holistic judgement**. We were pleased that judges felt they could hold a sense of holistic capability in mind and use it to reward good performance. As one of our judging team put it …

> It gives more appropriate results than atomised approaches which can lead to inaccurate overall assessment especially when the overall attainment is more than the sum of the parts. This often happens when the various elements of a designing process come together in a successful outcome that outstrips the quality of work in any (or all) of the parts of the process. (DP)
>
> (in Kimbell et al 2009 p 110)

Assessment reliability

For the last four years of the e-scape project we worked in association with Pollitt who first introduced us to the notion of Thurstone pairs judgement, and the pairs engine is one of the outcomes of this collaboration.

In relation to the 2008 samples (350 in design & technology and 60 each in science and geography) Pollitt's analysis of the out-turn of the judging is both detailed and revealing. The paragraphs below are taken as direct quotations from his report to the e-scape team – and are produced in full in the final report.

Concerning quality control:

> "Because every single judgement made can be compared to the outcome predicted (with the benefit of hindsight) from the final rank ordering, very detailed monitoring is possible of the consistency of the judgements made by each judge, and of each portfolio.".

Concerning the 'fit' statistic for judges

> "Theory predicts that this statistic should average 1.00, and in these data it does exactly that. The calculation gives 1.64 as a criterion [for fit], and only one judge [out of 28] exceeds this. It may be significant that this judge made only 59 judgements, while the others averaged almost twice as many. [NB in fact the judge was reluctantly forced to withdraw from the process for personal reasons]. Overall the amount of misfit seems quite acceptable".

Concerning the 'fit' statistic for portfolios

> "16 [of 352] portfolios exceeded this level, [the acceptable 'fit' statistic] or 4.5%, which is satisfactory for a 5% significance test. [NB by highlighting

these misfit portfolios, the system allows them to be given separate special attention by moderators]".

Concerning Pollitt's summary of the process

"The portfolios were measured with an uncertainty that is very small compared to the scale as a whole … The value obtained was 0.95, which is very high in GCSE terms. Values of 0.9 or so are considered very strong evidence of validity for the test. It is worth noting that the average standard error of measurement for a portfolio was 0.668, which is just less than half the width of one of these "GCSE" grades. It is unlikely that many GCSE components – or any that are judged rather than scored quite objectively – could match this level of measurement accuracy".

[All quotations are taken from Pollitt's report to TERU published within the e-scape phase 3 final report (Kimbell et al 2009). All comments in square brackets are my additions for clarification]

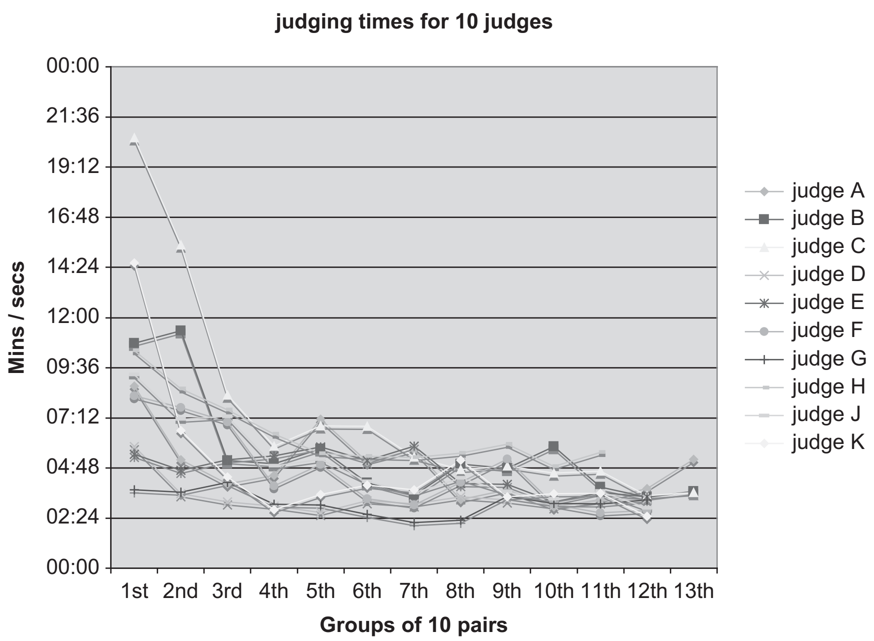
It is worth readers pausing a moment to acknowledge something that is quite profound in assessment terms. The e-scape portfolios were regularly judged to be very authentic accounts of students' designing activity. They were ***highly valid***. And now we can also show that the judgements made by teachers (concerning the quality of the portfolios) were ***highly reliable***. No longer are we forced to choose between validity and reliability.

The scalability of the process

It is a matter of some interest – not least for Examining Bodies – how long it takes to do this judging. We know it's easier to do (its comparative rather than absolute) – but there are lots of paired judgements to make. Is this really a process that could be scaled up to become part of a national system of assessment? The pairs engine automatically collects data on the judging process (eg the time taken for each judgement) and these timings – along with the comments of the judging team – are illuminating.

We monitored the time taken by judges to complete groups of 10 paired judgements. The first group of ten takes longest as the judge is coming to terms both with the portfolios and with the pairs engine interface. The 2nd group is typically quicker and the third quicker again. By the 3rd or 4th group, judges have typically reduced their judgement time to between 3 and 6 minutes, and by the 8th group they have reduced it further to between 2 and 5 minutes. The median time for making a paired judgement – across the whole of the 130 judgements and across the whole judging team – was 4 minutes 6 seconds.

This means that each judges' allocation of 130 paired judgements took them approx 8.5 hours. The scalability question is how this compares to the kinds of traditional coursework assessment that teachers are doing currently.



Asked to compare the judging process with his experience of conventional GCSE (16+) marking and moderation of project portfolios, one of our judges (an 'advanced skills' teacher and head of department) commented as follows:

> With conventional GCSE portfolios it has, in the past, been quite a "painful" experience doing the marking. Usually the first few can take up to an hour each for the larger (better??) ones and reducing down to about 20 or 25 minutes as I "tune in" to the marking criteria. I have also spent quite a time (an hour or two) pre-reading a few folios to get a feel for their overall standard and a rough rank order. Of course added to this can be a few hours (3–4) of internal cross moderation when there is more than one specialist option or more than one teacher marking work from the same exam board. A group of 20 folios including internal moderation and administration can therefore easily take 15+ hours... Ok, I am quite methodical, but I do have quite a lot of experience as well!
>
> As to which I prefer.... No contest! E-scape judgements win hands down. The time taken is dramatically reduced for the marking; there is no further administration to do or internal/external moderation. I would also have the added benefit of seeing what has been produced by other schools, something normally only available to examiners and moderators... a great bit of CPD!
>
> (Kimbell et al 2009 p 191)

This last observation is also worth a moment's pause and reflection. The challenge that I discussed earlier concerned the need to shift teachers' personal standards of quality and make them gradually more widely based so as eventually to reflect a national standard. But this is very difficult to manage in the current regime in which teachers only ever mark their own students' portfolios. Standards are ossified into schools, and only those who travel *between* schools can see the differences.

But with the e-scape pairs-engine, ALL portfolios go into a national pot. So teachers are not judging *their own* students' work, they are judging a selection from the national sample. So – for the first time – classroom teachers can get a direct view of the national standard of work. As the teacher noted above …

> I would also have the added benefit of seeing what has been produced by other schools, something normally only available to examiners and moderators... a great bit of CPD!

And a great step towards the development in teachers of genuinely national standards of judgement.

CONCLUDING THOUGHTS

There are three concluding thoughts that I would like to leave with readers, and the first relates to the issue I raised at the outset about four kinds of assessment – formative, summative, diagnostic and evaluative. As we saw, these four are undertaken for very different reasons and ought to involve different methods and instruments. My concluding thought though is more of an assertion. I believe that data derived from one of these four categories should NOT then be re-cycled to also serve a different purpose. Let me give a specific example. 16+ examinations are ***summative*** assessment and are for students, who use the resulting certificates as currency in pursuit of jobs or entry to further education. These data (in my opinion) should then NOT be re-used as ***evaluative*** data to judge schools. Similarly, formative data – resulting from all those informal interactions between teachers and students – should not be re-used for summative purposes. Each of the categories should be thought of as existing in watertight compartments; its *own* data generated in its *own* way and for its *own* purposes. The reason should be obvious – things work well for what they are designed to do – not something else. A house-brick does not make a good hammer, and if you start fiddling with the design to improve its hammer-ness, it will be less good as a brick. Whilst it seems easy and cheap to use student examination results as a measure of schools – the results are very damaging. Schools (if they can) resist a genuine intake of students (preferring to take only those who will do well in exams); there is then enormous pressure on schools to behave unethically (either by playing the D group game [see page 144] or by refusing to allow borderline students even to take the examination just in case they fail and damage the school statistic); and the data outweigh and distort all the other values to which the school should be paying at least equivalent attention. The school 'league-table' of GCSE passes – beloved of the tabloid press and thrusting parents – is an iniquitous, crude and damaging instrument that should be abolished. Interestingly the only schools in England that are entitled to deny these data to outside agencies, are our private, independent schools. And several that I know are now refusing to take part in the sordid beauty contest, preferring to demonstrate their excellence in more appropriate ways. Of course there must be some evaluation of schools, but we should do that through inspection and through a resurrected Assessment of Performance Unit, both of which can generate specific data for the purpose. Interestingly, in the USA there is an APU look-alike in the National Assessment of Educational Performance (NAEP).

My second concluding thought is more an observation on the issue of making judgements; about criteria & norms and about holistic & atomistic approaches. During the early days of the NC – with all the row about 150 Statements of Attainment – I spent a lot of time observing teachers making assessments. It was interesting to note how they did it. And how that differed from how they ***said*** they did it. Their classroom had lines of tables arranged in rows on which the three teacher spread out the portfolios they were assessing at the end of a project. First they laid out the portfolios along the rows, the best ones top left and gradually moving towards the weakest ones bottom right. Then they took different ones and gradually completed the long and exhausting assessment forms. At the end of a long evening, I asked them how they 'knew' the rank order ***before*** they had done the assessments. They were a bit sheepish about it but asserted that (having taught the students) they knew the work pretty well and had a good feel for whose was good, whose was better, and whose was best. But what about the assessment process with all the Statements, did that ever change their minds about the order? Did they shuffle this one up a bit and that one down a bit in the light of all that box-ticking? No they didn't. They did have initial disagreements and discrepancies – with a better one apparently missing out on some of the Statements – and a poorer one getting them. But that just forced them to go back and change their box-ticking for the 1st one. In short – the teachers trusted their judgement about the work MORE than they trusted the ticked boxes. The ticked boxes didn't *generate* the result (as was supposed to happen with NC assessment), rather the result – decided at the outset by holistic judgement – then informed the box-ticking. They were confident that the outcome was fair, and it seemed to me to be a pragmatic and effective twist on NC assessment procedures – in order to make an unworkable process more workable. The teachers used holistic judgement, and ranking – not unlike the pairs engine process (see page 16/17). I suspect that this process is being replicated in many classrooms all over the world, as teachers apply a bit of common sense to the out-of-control audit processes that have overtaken so much assessment. It makes sense to work from whole judgements of excellence and then to drill down into that judgement to tease out the detail of whether this or that quality is present.

My third concluding thought is about the consequences of more widespread use of the pairs-engine process. It is currently in use by assessment agencies (sometimes govt agencies and sometimes businesses) in 5 countries – but at the moment it is all in experimental or 'pilot' mode as the agencies test out its effectiveness for their purposes. But I believe that someone soon will use it on a national scale and it will completely revolutionise the assessment process to schools' advantage. Imagine a situation in which every teacher becomes a pairs-engine judge. And these teachers would not be assessing ***their own*** students – because all students taking that exam (from all over the country) would have their work in one big national pot (a website). The teachers (judges) would be from every school and would be making judgements about pairs of pieces from that national pot. Currently most assessment bodies operate a very hierarchical process, with examiners, moderators and chief examiners, but at a stroke the whole process is democratised – with every teacher empowered in the same way. In addition to bringing some seriously good reliability to the assessment process, it would also establish a genuinely *national* standard – and teachers could all partake in it, seeing the full national range of work.

In this chapter, I have argued that assessment has become increasingly pervasive in schools. What was once merely an occasional interruption in the normal flow of classroom activity has become a huge booming industry that dominates the educational agenda. This is an unstoppable force – and one that teachers must understand if they are to do their job professionally. Much of this understanding will revolve around technical issues (eg about reliability and validity), but underneath all that technical stuff lie deeper matters of morality and ethics. Teachers must of course develop the expertise to analyse and understand the significance of any assessments that they use (or are required by others to use). But equally they must develop the wisdom – and the courage – to challenge assessment practices that they judge to be inappropriate, ineffective or even damaging.

REFERENCES

Garmire, E. & Pearson, G. (Eds.) (2006). *Tech Tally: approaches to assessing technological Literacy.* Washington, DC: National Academies Press.

Gipps, C. (Ed.) (1992). *Developing assessment for the National Curriculum*. London: Kogan Page

Kimbell, R. (1986). *Craft Design & Technology A guide for teachers.* Milton Keynes: Open University Press for Secondary Examinations Council in collaboration with the Open University Press.

Kimbell, R. (1997). *Assessing Technology: International Trends in Curriculum and Assessment* Buckingham and Philadelphia: Open University Press.

Kimbell, R., Stables, K, Wheeler T, Wozniak A, & Kelly, V. (1991). *The Assessment of Performance in Design & Technology.* London School Examinations and Assessment Council / Central Office of Information

Kimbell, R., Wheeler, T., Stables, K., Sheppard, T., Martin, F., Davies, D., Pollitt, A. & Whitehouse, G. (2009). *e-scape portfolio assessment: phase 3 report*. Technology Education Research Unit, Goldsmiths University of London.

Laming, D. (2004). *Human Judgment: the eye of the beholder*. London: Thomson.

Pollitt, A. (2004). *Let's stop marking exams*. Paper given at the *IAEA Conference*, Philadelphia, September. Available at: http://www.cambridgeassessment.org.uk/research/confproceedingsetc/IAEA2004AP

Pollitt, A. & Crisp, V. (2004). *Could Comparative Judgements Of Script Quality Replace Traditional Marking And Improve The Validity Of Exam Questions*? A paper presented at the British Educational Research Association Annual Conference, UMIST, Manchester, September.

Pollitt, A. & Ahmed, A. (2009). *The importance of being valid*. A paper presented at the 10th Annual Conference of the Association for Educational Assessment – Europe. Cambridge Exam Research www.camexam.co.uk Malta, November.

Samuelson, F. (1987). Was early mental testing (a) racist inspired, (b) objective science, (c) a technology for democracy, (d) the origin of multiple choice exams, (e) none of the above?

Times Education Supplement 23/4/2010 http://www.tes.co.uk/article.aspx?storycode=6041784

Times 8th Feb. 2008. http://www.timesonline.co.uk/tol/news/uk/education/article3330575.ece

Sokal, M. *Mark the RIGHT answer*. Psychological Testing and American Society, 1890–1930. New Brunswick, NJ: Rutgers University Press.

Satterly, D. (1989). *Assessment in schools.* Oxford: Blackwell.

Thurstone, L. L. (1927). A law of Comparative judgement. *Psychological Review*, *34*, 273–286

US Government Accounting Office. (2005). http://www.rethinkingschools.org/special_reports/bushplan/test192.shtml

GARY O'SULLIVAN

8. TECHNOLOGY AND THE COMMUNITY

INTRODUCTION

The objective of this chapter is to discuss technology and the community by highlighting an innovation pedagogy model which is grounded in sociocultural theories of learning. There are a number of areas within the chapter where debate is possible and in fact desirable, the model discussed is just that…. a model. Internationally, a greater curriculum emphasis on traditional academic study may have brought about tensions and a disconnection between the subjects being taught and what pupils encounter when they leave school. There is a real danger that this increased emphasis on traditional academic achievement will undermine the provision of technology education as an essential part of schooling. However, there is growing research that suggests a disconnection can often lead to dissatisfaction from pupils with regard to the relevance of what and how they study at school.

> Unfortunately, evidence indicates that recent high school pupils in the US for example, who have completed more academic subjects than their predecessors, increasingly view academic schoolwork as less interesting, less meaningful, and less likely to be useful later in life (Wraga, 2009, p.88).

In this chapter a number of key interrelated components of a connected technology curriculum will be discussed, some theoretical underpinnings will be introduced and then some practical examples and guidelines for connecting technology with the community will be offered. This chapter advocates for an innovation pedagogical model which places technology education as the collector barrel of an educational technology curriculum injector (See Fig. 1). This is analogous to the hopper and barrel in a plastics injection moulder. Using the injector analogy, with technology education acting as the collector barrel, has the opportunity to help mix discrete components together, push them forward and produce outcomes which can be tangible and useful. Each component of the hopper will be discussed in depth and the role technology education and technology teachers could play will be identified. Technology education operating in this way may embody Dewey's principles and be utilized to connect the curriculum with the outside world via enterprising problem based activity. Dewey challenged us to think creatively about democracy and technology and about our responsibilities for technological change. One place for this thinking

P. J. Williams (Ed.), Technology Education for Teachers, 167–196.

to occur clearly resides within a connected technology curriculum which promotes education for enterprise and community partnerships. The technology curriculum injector presented in this chapter is both a visual aid and an analogy. It exemplifies bringing together the connected curriculum, education for enterprise and community partnerships. This mixture is fed into technology education resulting in enhanced connected and relevant outcomes.

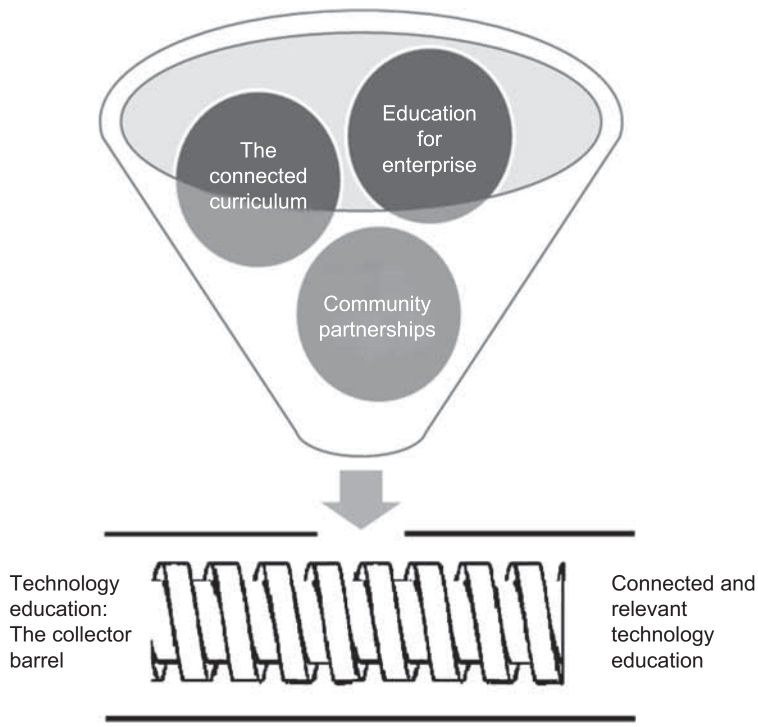


Figure 1. The technology curriculum injector (O'Sullivan, 2012).

COMPONENT ONE: THE CONNECTED CURRICULUM

John Dewey (1859–1952) was an early pioneer in suggesting that education should try and connect the interests of pupils with the intentions of the curriculum. Through his notions of productive pragmatism and his views on education and democracy, Dewey believed that there were multiple ways of looking at educational activity. Addressing these multiple viewpoints was the best way to overcome the problematic dualism of pupil and curriculum. Dewey wanted school learning to have the same emotional force as non-school learning and felt that connecting pupils' outside interests with the curriculum would increase motivation. Dewey's concern with experience, interaction and reflection is at the heart of most technology curriculum developments. It would be easy to assume Dewey was a promoter of child-centred learning. However, this is too simplistic. He was clearly disposed towards a connected curriculum. Dewey believed that knowing is relative as it involves connection to others. This position develops and extends an individual's knowledge by considering the viewpoints of others as they form communities of inquiry via problem solving activity.

Dewey argued that humans are constantly developing through interactions with their environment, society and technology. He saw successful technological development and change as a democratic process which was resolved through practice but led to no final absolute answer. Dewey describes in his seminal reading *Reconstruction in Philosophy* an epistemological conflict between tradition and practice, emotion and reason, doing and thinking, all of which underlie the assertions made in this chapter.

> When the school introduces and trains each child of society into membership within such a little community, saturating him with the spirit of service, and providing him with the instruments of effective self-direction, we shall have the deepest and best guaranty of a larger society which is worthy, lovely, and harmonious (Dewey, 1964, p. 311).

The purpose of the technology curriculum injector model is to enhance the position of technology education as an important component of general education and to ensure a stronger relationship between technology and the community. The injector manifests itself through national educational policies such as curricula, the personal beliefs of technology teachers and the classroom practicalities and realities that the learners face. These sometimes conflicting requirements are brought to bear on various technology curriculum offerings. The practicalities and realities of a connected curriculum is the start point of this model. In the model, this policy is built on community partnerships and involvement designed to encourage education for enterprise through technology education.

Technology education is often portrayed as the connector between curriculum on the one hand and employment on the other. This connection can be seen through industry involvement at a number of levels such as curriculum and assessment, development at a policy level, as well as a significant number of community based teaching resources for the classroom. However this chapter proposes that the connection to employment is only one facet of technology education's connectedness.

> Perhaps the most important contribution schools can make to the education of our youth is to give them a sense of coherence in their studies, a sense of purpose, meaning, and interconnectedness in what they learn (Postman, 1992, p. 185–186).

This employment connection can be based on quite narrow educational theoretical assumptions. These assumptions strongly rely on a causal connection between schooling and the world outside. Teachers of technology may unwittingly become facilitators and purveyors of these assumptions. For the purposes of this chapter an understanding of the work of Dewey, Watts, Saunders and others is a requirement. O'Sullivan, (2009 a) argues that the following four 'significant underlying or tacit theoretical assumptions' should be used to debate how the wider community links to education while maintaining a sound technology education. With any debate a clear understanding of the differing positions is essential to facilitate deeper understanding. It is important to position the technology and the community debate within a theoretical framework, and for the purpose of this debate the four theoretical assumptions are:

1. Structural functionalist perspective;
2. Structural Marxist perspective;
3. Liberal educators' perspective;
4. Progressive / emancipator perspective.

The first two are described as structural frameworks. Structural functionalism is a broad perspective which is incorporated as an underlying theory both in sociology and in anthropology. Structural functionalism spawns terms such as the 'nuclear family' and 'strong communities'. These communities are deemed to be held together by shared values, beliefs and intentions. Structural Marxism is a philosophical approach primarily associated with the work of the French philosophers in the 1960s and based on Marxism. A structuralist Marxist perspective would argue that the institutions of the state (including schools) function in the long-term interests of society. Both Functionalist and Marxist positions are based on modernist theories that look at operations from a macro or big picture perspective, invoking notions of the whole society. They imply strong causal frameworks and according to Saunders (2000) tend to be reductive, looking for explanations from meta-theories.

A liberal perspective is likely to approach learning from an empowerment standpoint focusing on the needs of individuals. Its intention is to prepare them to deal with complexity, diversity, and change. It provides pupils with a broader knowledge of the wider world (e.g. community and industry) as well as in-depth study in a specific curriculum area such as technology. A liberal education perspective would encourage pupils to develop a sense of social responsibility; this would be supported by transferable intellectual and practical skills such as communication and problem-solving. These skills would be demonstrated by the ability to apply knowledge and skills in real-world settings. From a progressive/emancipatory perspective, pupils need to learn how to critically reflect on their place in society in order to become active citizens. To become truly democratic an education system must facilitate the individual's understanding of the wider community and society, otherwise, they are unable to shape the future of the community with which they are interacting.

Understandings of these four perspectives are rarely considered from a single curricular perspective. However, they form the backbone of many assumptions made about technology education and its connections with the wider community.

Each perspective will be considered individually to facilitate understanding of their educational intentions. They all have some relationship with Dewey's assertion that learning is connected to society at every level.

1. STRUCTURAL FUNCTIONALIST PERSPECTIVE

The structural functionalist perspective views society as a whole, using the analogy of a living organism. Each aspect of society has responsibilities for the next and all are mutually interdependent. For schools, this has created an increasing pressure to respond to the needs of society. This perspective is supported by lobby groups who believe in education's responsibility to meet the economic imperative. Typically these lobby groups might come from professional technology practitioners and are associated with engineering and business professions. Countries such as England, USA and New Zealand have seen the development of their technology curricula influenced by the Engineering Council, the National Academy of Engineering (NAE) and the Institution of Professional Engineers New Zealand *(*IPENZ*)* respectively.

> Put crudely, if labour market requirements are not being met, we should be looking for policy which brings them in to line. Critically, this view presupposes that requirements can be 'known', that they are of a 'technical' nature and the 'norm is that they can be met through the choice of appropriate policies (Saunders, 2000, p. 686).

Saunders elaborates to say that in this perspective it is seen as logical that education should be part of a capital good and 'co-ordinate with the requirements of work because that is how societies function'. Watts (1983) identifies this notion as '*human capital'*. These bonds or '*functions'* are the ways in which education can service wider community needs. As part of a capital good rationale, education can be used to develop the human resources necessary for economic and social transformation. The focus on education as a capital good supports the notion of human capital, which emphasizes that the development of skills is an important factor in production activities. Practical vocational skills development has traditionally been associated with technology education. Developing these skills may be seen as a partial functional role of technology education but it is too narrow a perspective upon which to focus a curriculum with so much potential to help develop creativity and innovation in all school pupils.

HUMAN CAPITAL TREE: A NARROW VIEW OF HOW EDUCATION CAN SERVICE SOCIETY'S NEEDS

To understand how technology education may be helping to promote the structural functionalist perspective it is important to locate schooling within the human capital tree. In this analogy the tree's trunk is schooling which helps support the crown of the tree where the fruits and the major growth is supposed to occur. The roots of the

Human Capital Tree (see fig 2) are fed by the various processes, programmes and initiatives schools adopt to meet the functional requirements of the tree.

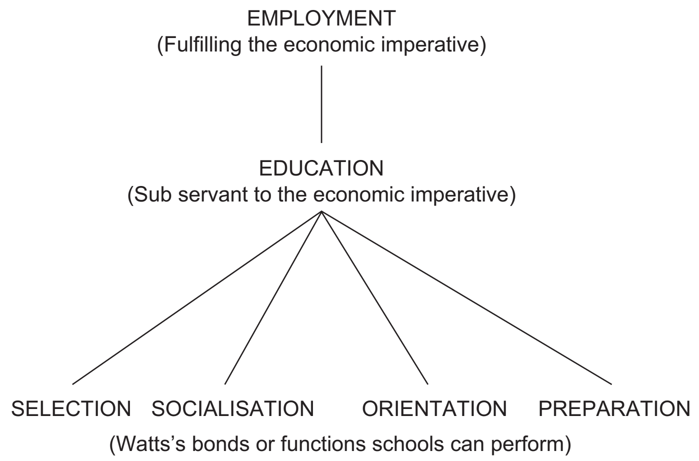


Figure 2. Human Capital Tree.

Building on the work of Schultz (1971), Sakamota and Powers (1995) and Psacharopoulos and Woodhall (1997) human capital theory is based on the assumption that formal education is connected and even responsible for the industrial production output and ultimately the prosperity of a nation thus helping to fulfil the structural functionalist perspective.

According to Babalola (2003), the rationality behind investment in human capital is based on three education related positions:

1. New generations must be given the appropriate parts of the knowledge which have already been accumulated by the previous generations;
2. New generations should be taught how existing knowledge is used to develop new products, to introduce new processes and production methods and social services;
3. New generations must be encouraged to develop entirely new ideas, products, processes and methods through creative approaches.

These positions are fundamental to many of the rationales developed for technology education curricula around the world.

The process of pupil selection matches closely the employment strategies of the industrial era thus fulfilling the first function. It relies heavily on industrial practices of the division of labour. Educational selection includes systems that regularly test pupils and separate them by the results. This separation normally includes splitting into academic and vocational type courses with those that fail being filtered off into lower level employment. This leads to misunderstandings from every party: pupil, employer and society in general. Internationally, historical accounts of technology education clearly reflect this separation model i.e. the operational use of a selection policy.

The second function identified in Fig.2 is the socialization process. This is embedded in the pupils' experience of schools. These experiences can involve explicit or implicit procedures, whereby the pupils begin to associate themselves with particular types of endeavours. This is often carried out in schools by reinforcing stereotypes (e.g. gender, class and racial associations with particular types of courses). Historical forms of technology education are often associated with this function (e.g. craft for boys and food for girls). In terms of school-community links, care should be taken to ensure that biased socialization does not occur so pupils can make decisions about future choices unhampered by previous biases.

The third function of orientation moves from the slightly more subtle socialization process to deliberate curricular intervention or channelling. Most notably this can be seen through career guidance, work experience or placement programmes. Additionally, one could readily associate school- community links with this function if they are carried out without a critical or questioning premise. Typically, the words 'enterprise' or 'entrepreneurial' are used in such orientation practices. The worry here is that a narrow representation of enterprise is promoted and models of technological practice explored may not reflect social good as well as economic gain.

The fourth of Watts's functions is that of preparation. This refers to the role of schools in preparing pupils with specific skills and knowledge required in the workforce. According to Watts, at the general level, this may mean numeracy and literacy. However, Saunders (2000) argues that it is this preparation aspect, which underpins '*new vocationalism'* and the introduction of education as training. It is also evident in many of the rationales for technology education throughout the world. Whereas many subjects offered at senior school levels are seen as pre-cursor to further educational study technology education is often over represented as pre cursor to work.

This functionalist perspective views people as 'human capital' and society is therefore making an investment in people; a term used in many education policy directives in recent times. According to Williams (2011):

> Spurred on by the global financial crisis, it is hoped that coordination and integration of STEM (Science, Technology, Engineering and Mathematics) activities will better equip a workforce for dealing with the contemporary nature of business and industry, and encourage more school leavers to seek further training and employment in areas of engineering and science (pp. 26–35).

Proponents of this perspective argue that investment in technology education will no doubt bring returns in the technological fields of both higher education and employment. According to Saunders, this human capital theory has proved to be incorrect, citing the English example of higher numbers of pupils going on to

University but studying in "esoteric courses" rather than science and technology (Saunders, 2000). The paradox accompanying this perspective is that despite the huge investment in education, there is little researched evidence that this connection has any real underlying impact on the prosperity of a society. Fagerlind and Saha (1997) assert that while nations may implement educational plans consistent with specific economic goals and strategies, there can be no guarantee of the outcomes. In fact they argue that the more political the goals of education, the more problematic the outcomes become.

2. STRUCTURAL MARXIST PERSPECTIVE

Structural Marxism is a perspective of economics which has developed from the writings of Karl Marx (1818–1883). Marxist perspectives would encourage the study of relationships that exist between people as they go about their endeavours and how that fits with their family life. Marx believed that human thought or consciousness was rooted in human activity; not the other way round. This viewpoint was opposed to many of the prevailing philosophies of the period. Marx had at the cornerstone of his thinking the concept of class struggles. The relationship between the classes was in his view extremely antagonistic. The ideologies a society adheres to and the educational policies they develop were all, according to Marx, determined to some extent by the economic structure of society. Structuralists view society and the state as a capitalist mode of production. Under capitalism, according to Marx, the productive powers of labour are shown as the creative economic power of human capital. He regarded labour power as the most important of the productive forces of human beings. This power is generated because the state reproduces the logic of a capitalist structure in its economic, legal, political and educational institutions.

Saunders (2000) argues that at present we are in a capitalist mode in which classes of people buy and sell labour but that this is not an equal relationship. The term outsourcing has become increasingly used by business and there are many cases where outsourcing could be replaced with the word exploitation. There are many cases of labour exploitation, and Saunders argues that Marxist perspectives are reflected in the existing education system. According to Saunders, education, from a Marxist perspective, maintains the status quo, thus enabling the capitalist mode of production to continue. This is achieved in education following much the same bonds as described earlier in the functionalist perspective. Functionalists identify socialization as a means of creating order whereas Marxists identify it as a means of maintaining social control. Functionalists identify selection as distributing recruits into a division of labour; Marxists view it as a means of sustaining inequalities both within the education system and in later life. These viewpoints are often found in work habits and attitudes and Saunders describes this as the "hidden curriculum".

Young (1998) refers to a divided system, which has a divided curriculum and divided qualifications and ultimately has a selective function. Technology education has a history of being at the centre of this selection process. This stems back to the selection of pupils into technical/vocational schools, programmes, courses and assessments. However, opponents of human capital would argue that rather than creating a plethora of good jobs which are unfilled because of a lack of necessary skills, the reality is precisely the opposite. In fact what we have is a workforce mismatched for the requirements of a modern knowledge economy.

3. LIBERAL EDUCATORS' PERSPECTIVE

The liberal perspective, through the delivery of liberal education, has come to signify the opposite view of education from the structural frameworks discussed above. The liberal perspective views education as important in its own right, rather than existing simply to fulfil some extrinsic factor such as employment or centralized economic objectives. Saunders (2000) contends that this view of education was historically associated with the aristocratic classes, but in the modern era is free from the divisive aspects of class. Technology education could be the ultimate liberal education offering if teachers of technology promote technology and the community in an appropriate more holistic way.

This liberal perspective would advocate that explicit vocational preparation is best undertaken either at work or just prior to beginning it. Instead of vocational education, advocates of this perspective believe the best preparation for life is a general education, which is broad, deep and informed by the whole culture; not just one aspect of it. This may include interactions with the world of work, not as direct preparation for a particular occupation but as a pedagogical process this is where the technology curriculum injector model proposed in this chapter could be advantageous. Effectiveness within this perspective should not be narrowly analysed by relating it to one particular employment or national economy.

> What is important for this perspective is the democratic imperative that no child should be denied access to these forms of knowledge and experience in the mistaken belief that they are not 'relevant' either to them or an extrinsic need like that of employers (Saunders, 2000, p. 692).

The liberal perspective advocates that this '*general education'* preparation is suitable for all aspects of future life, including work. Saunders describes the main problem for this perspective as finding ways for all pupils to get the opportunity and access to such an education. Generally, in education the knowledge is imparted and learned in disembodied chunks and then tested through examinations at a later stage where only those who have the cultural means to accommodate this method succeed. According to Bereiter (2002) liberal education gives learners access to a culture that transcends the particularities of their social and ethnic backgrounds. The liberal perspective can support technology education but it would be technology education as general rather than vocational.

4. PROGRESSIVE EMANCIPATOR PERSPECTIVE

This perspective is associated with individual growth and the learning styles which accommodate this growth. According to Saunders, this will lead to social goals of civic participation and democratic emancipation. Saunders identifies two sub-themes in this perspective. The first surrounds '*learner centeredness'* and personal growth, whereas the second is *'social reconstruction'* through empowerment. This perspective positions education centrally in social and personal reconstruction and is optimistic in nature. The technology curriculum injector model could help to facilitate this perspective by utilizing an innovative pedagogy designed to include greater understanding and connection of the various components being fed into the hopper.

Unlike functionalist and Marxist perspectives, the progressive perspective underplays the social and political context. It also under-emphasises the nature of knowledge and skill that the liberal perspectives see as the starting point. It emphasises the power of the educational process to allow the learner to transform both the context and the nature of knowledge and skill to re-orientate him or herself. According to the OECD there is robust evidence that knowledge and skills are an important determinant of economic growth and social development. Education and training systems play a crucial role in fostering the development of the human capital needed (Education Policy Analysis, 2001. Centre for Educational Research and Innovation OECD, Paris).

Developing civic participation and democratic emancipation by connecting school activity with out of school experience is not a new concept. It relies heavily on the work of Dewey and reflective thinking as explained by Marshall.

> This was not to make the schools an adjunct of industry and commerce and to acquiesce in the 'untransformed, unrationalised and unsocialised phases of our defective industrial regime', but of utilising the intellectual problem-solving potential inherent in modern technology; 'to make school life more active, more full of meaning, more connected with out of school experience' (Marshall, 1997, p. 309).

Young (1998), when talking about flexible specialisation and its relevance to education, introduced a notion of 'connective specialisation'. This contrasts with the insularity of the traditional subject specialists and ultimately with the divided curriculum which dominates the secondary sector. Divisive specialists see the curriculum from the point of view of their subjects, whereas connective specialists see their subjects from the point of view of the overall curriculum. Young argues for a shift from teacher centeredness which can be divisive to learner centeredness which should be connective. The technology curriculum injector model suggested here may allow for both teachers and students to be more connective in constructive ways.

A connective curriculum acknowledges that education takes place in communities of practice and that learning is purposive and a social process (Lave & Wengler, 1994 as cited in Young, 1998). It exposes the need to relate educational activities to developments in the wider society including but not exclusively linked to industry. So connectivity is more than just a curriculum model. It is the purpose of school itself!

Recent research has shown that aspects of self-understanding through construct developments play an important role in what students undertaking initial teacher education programmes learn (Massengill et al., 2005; Poulou 2005) and the way in which teachers ultimately teach (see Day et al., 2006; Boote 2006). The technology curriculum injector model construct proposed in this chapter is that technology education as a connected curriculum should help promote education for enterprise rather than technology education acting as human capital preparation.

COMPONENT TWO: EDUCATION FOR ENTERPRISE

Having discussed the connected curriculum component of the technology curriculum injector the next component for exploration is the notion of Education for Enterprise. Technology education should amongst other objectives be about developing enterprising attributes in our pupils. Despite a growing proliferation of enterprise education initiatives there is still considerable conceptual confusion as to what education for enterprise actually involves (Gibb and Cotton, 1998). This confusion is compounded by the integrated nature of enterprise activities in education. Enterprise education has been described in a variety of ways which are dependent on preconceptions. Some management literature has sought to define enterprise education as a distinct activity by identifying the boundaries between entrepreneurship studies and "traditional" management studies (Gibb, 1999; Solomon *et al*., 2002). From an education perspective enterprise education is often associated with a variety of concepts. These include work related learning (Dwerryhouse, 2001), action-learning (Revans, 1991; Jones-Evans et al., 2000; Smith, 2001), experiential learning (Kolb, 1984) and entrepreneurial learning (Gibb, 1999; Rae, 2000).

An article by Clark (2004) highlights the differing views about the word 'enterprise' when used in association with education. The article also highlights the issues surrounding interpretation particularly those associated with the economic imperative.

Education for enterprise has been defined in quite broad terms by a number of key stakeholders as:

> … a teaching and learning process directed towards developing in young people those skills, competencies, understandings, and attributes which equip them to be innovative, and to identify, create, initiate, and successfully manage personal, community, business, and work opportunities, including working for themselves … It is about how we teach across the curriculum and how we get our pupils to take ownership of their learning. Education for enterprise is not a discrete subject but provides learning experiences that encourage young

> people to be active participants in their learning (Ministry of Education, 2009, para.1)

These highlighted outcomes of enterprise education can be complex and unpredictable. Kearney (1996) suggested that the adoption of a broader approach to enterprise education (i.e. in alignment with the broad definition of enterprise education) may achieve the narrow outcomes, perhaps more effectively than the narrow approach itself. A viewpoint supported by Gibb (1993) identified that what occurs under the label of 'enterprise education' (rather than 'entrepreneurship education') focuses on developing what constitutes the broader definition of enterprise education that is, the development of personal attributes.

A simplistic approach to defining enterprise education is the teaching of business entrepreneurialism and the skills needed to start a business or enterprise (OECD, 1989). This has been described by some researchers as too narrow. Kearney (1996) argued that narrow definitions of enterprise education would reinforce the economic imperative stance and may make enterprise education unappealing to teachers, parents, community groups and pupils themselves. Schools who adopted this model of enterprise education were more likely to encounter resistance from staff and pupils (Kearney, 1996).

Caird (1989) felt that the rationale and history of the education 'for' enterprise movement was quite distinct from the movements to educate 'through' or 'about' enterprise. The former grew out of concern to develop small business and entrepreneurship following the economic imperative, whilst the latter were more related to criticisms of the education system and concerns with school leaver capability, which may have little to do with entrepreneurship. Filion (1994) argued that enterprise education is not about training pupils to become self-employed, rather

> It means training everyone to be able to take charge of themselves in today's world. It means training everyone to be autonomous and resourceful enough to get by on their own, in other words, to be enterprising people (Filion, 1994, p.71).

Jack and Anderson (1999) went as far as suggesting that the promotion of enterprise education can be politically expedient as it helps convey the 'friendly face of capitalism'.

Despite these concerns, in many countries there has been a shift in education policy away from liberal-humanist education towards a more vocationally focused curriculum. The change has come about partly as a response to economic targets and objectives set by national policy makers (Price, 1991). An example of this shift can be seen in the growing emphasis on making education more responsive to the needs of their communities. Included in a recent white paper published by the English Department for Education (2010) the foreword written by the Secretary of State identified that successful systems of education:

> have put in place comprehensive plans for school improvement which involve improving teacher quality, granting greater autonomy to the front

> line, modernising curricula, making schools more accountable to their communities… (Department for Education, 2010, p. 7)

The New Zealand Curriculum released in 2007 is a statement of official policy relating to teaching and learning. It describes a clear vision of education for enterprise by setting the direction for pupil learning. Included in this vision is a desire to develop young people:

> —who will be creative, energetic, and enterprising;
> —who will be confident, connected, actively involved, and lifelong learners.
> (Ministry of Education, 2007, p. 8)

They should be confident and this is reflected by them being:

> —enterprising and entrepreneurial.
> (Ministry of Education, 2007, p. 8)

Increasingly governments are looking towards incorporating STEM educational initiatives to help shape curriculum offerings to meet their objectives. The recent notion of STEM originated in the United States through collaboration between the Department of Labour and various National Academies. According to Kimbell (2011) the government in the UK wants to increase STEM skills to:

> —provide employers with the skills they need in their workforce;
> —help to maintain the UK's global competiveness;
> —make the UK a world-leader in science based research and development.
> (Kimbell, 2011, p. 7)

According to the STEM directory website in the United Kingdom:

> Enterprise activities promote a clearly structured and accessible approach to problem solving with Design and Technology (http://www.stemdirectories.org.uk/view_scheme.cfm?cit_id=383080).

In Western Australia the state government has taken this link even further by calling their subject Technology and Enterprise. They suggest that neither are:

> New concepts. They have been a way of life since civilisation and were developed from the core needs of humans for food, shelter and clothing. The Technology and Enterprise (T&E) learning area relates directly to the processes of applying knowledge, skills and resources to satisfy needs and wants, extending capabilities and realising opportunities.
>
> The Department of Education acknowledges that Technology and Enterprise plays an important role in the school curriculum by providing opportunities for children to become engaged in a range of learning experiences, set in

> relevant contexts with the ability to have meaning in their lives. These include:
>
> – Meeting the demands of a changing world by addressing the needs of individuals, families and societies.
> – Developing skills and experiencing systems and processes by bringing ideas from conception to fruition.
> – Being enterprising while actively pursuing opportunities.
> – Considering the social and environmental impact of solutions to achieve.
>
> (http://www.det.wa.edu.au/curriculumsupport/technologyandenterprise/detcms/navigation/about-t-and-e/?oid=MultiPartArticle-id-10971217)

This enterprising theme is developed further in the New Zealand curriculum when discussing key competencies which are described as capabilities for living and lifelong learning. Under the *Managing Self* competency it is suggested that pupils who manage themselves are enterprising. When describing the learning area of technology we are informed that technology will make enterprising use of knowledge and skills. Under the technological knowledge strand of the technology learning area, pupils are encouraged to develop knowledge particular to technological enterprises.

The process of technology education in the New Zealand curriculum 2007 is described as:

> Technology is intervention by design: the use of practical and intellectual resources to develop products and systems (technological outcomes) that expand human possibilities by addressing needs and realising opportunities (NZ Ministry of Education, 2007, p. 32).

It is clear that some policy makers see technology education as a key medium for delivering education for enterprise whilst involving the community. An understanding of the technology curriculum injector model proposed in this chapter could facilitate developing a connected curriculum which is more than just another attempt to meet the economic imperative. Education for enterprise as promoted here via the technology curriculum injector identifies that technology education should be an integral part of any education offering aimed at developing connectedness.

There is also a growing international consensus as to essential enterprising characteristics that should be developed as part of a programme designed to increase the enterprise performance of pupils. If a teacher is trying to develop an enterprising technology education offering, an awareness and promotion of these attributes is paramount. The ability to work with others in teams as well as independently is an important starting premise as this is how most technological activity occurs outside of the classroom. Skills such as negotiating and influencing take time to develop, these are equally as important as the practical skills which might be required.

A particular pedagogical approach is envisioned and promoted if teachers are going to encourage and develop enterprising pupil endeavours. Pupils must be taught to manage risk taking as well as how to generate and use creative ideas to ensure truly connected learning opportunities are tackled. This will require teachers and pupils to be flexible and look for ways to incorporate both the collector barrel and the injector to ensure successful outcomes.

Recent research (O'Sullivan, 2011) has identified some success criteria for the involvement of education for enterprise as an integral part of technology education. That involvement also adds to the connected nature of such undertakings when certain approaches are developed. The following section of the chapter aims to offer practical examples of how to facilitate a successful technology curriculum injector model.

Education for Enterprise Technology Teaching Approach

There is evidence (O'Sullivan, 2011) to support education for enterprise as part of technology education when the context for the activity is shared, authentic and real. This technological activity should be linked to practical undertakings and include developing tangible outcomes. To ensure connection with the pupils outside endeavours they should be given a controlling function within the project, i.e. some ownership of their individualized learning. Pupil engagement and contribution should be encouraged, mentored and acknowledged by the teacher who will be acting in a more facilitating role.

When using an education for enterprise approach pupils should be provided with and taught about flexible frameworks to facilitate project management. Schon (1991) identified that practitioners who receive real-time coaching and encouragement to think carefully (about what they do while they do it) learn in a more profound way. Therefore the teacher adopting this approach should encourage and value reflection from the pupils and acknowledge this by incorporating it into progression and assessment strategies. Both the teacher and the pupil should reflect on their practice from the beginning to ensure an enterprising approach is taken and facilitated.

Education for Enterprise Whole School Approach

Making the connections between technology education and the pupils' world outside of school may not be achieved by just one department; there must be support from the whole school. The technology curriculum injector model could be used to increase understanding throughout the school as to the nature of technology education and its place in the curriculum. To facilitate this support for participation and monitoring should come from the senior management team of the school. Teaching education for enterprise can be very demanding on the teachers, particularly in the early phases. To prevent individual teacher burn out staff should be encouraged to work in teams, thus ensuring the focus remains consistent even in the event of staff changes.

The understandings of education for enterprise should be shared amongst all staff not just those involved in particular projects. Education for enterprise should not be seen as another extra but it should be interwoven with key learning intentions from numeracy, literacy and the technology curriculum area. Timetable allocations must be flexible enough to allow for appropriate research to be undertaken and ensure enough time to see the projects through. All of this requires significant buy in across the school.

COMPONENT THREE: DEVELOPING COMMUNITY PARTNERSHIPS

Proverb: It Takes a Whole Village to Raise a Child

This chapter has highlighted a number of philosophical and theoretical approaches to the connective nature of technology education, it is clear that technology educators alone cannot help children prepare for successful adulthood. This brings us to the third component fed into our technology curriculum injector: developing community partnerships. It is evident that technology teachers, schools and their communities must work together to achieve this mutual goal. Firstly a technology teacher should reflect on why they are considering entering into any partnership. Additionally, they should be fully aware of the commitment, time and effort it takes to develop these endeavours and see them through. Successful partnerships are built and maintained by personal relationships which develop between the individual parties.

School Community Partnerships

According to (O'Sullivan, 2011) developing successful school community partnerships are dependent on numerous factors which need to be addressed. Firstly the community involvement should be sought at the planning stages of the activity. Partnership members need to be established these could include boards of trustees, parents as well as experts and mentors from the community. It is important to establish time expectations and commitments as early as possible. Teachers will need to develop key roles within the partnership. Establishing learning intentions and ensuring pupil participation and their control over decision making is kept central to the project. Try to establish community pride in the activities undertaken this can be maintained when reports and updates are provided to all parties regularly using a variety of media.

Partnerships are deemed successful when there are perceived mutual benefits for all parties involved. Below are two tables table 1 identifies some possible benefits for schools and the community enterprise. This should be considered to make sure the collaboration benefits both parties. The second table 2 is perhaps even more important because it establishes possible benefits for teaching and learning from a teacher and pupil perspective.

Table 1. Possible benefits of school community partnerships

School	*Community enterprise*
Increased personal motivation working in partnership with people outside the classroom.	Increased motivation for individuals and employees able to participate in a social good i.e. education.
Purposeful action working with others in the community and an increased awareness of the role enterprise plays.	Increased awareness for community enterprises of how schools work and a chance to develop some connectedness.
Improved individualised careers information.	Opportunities for employees to develop communication skills, liaising with a different social grouping.
Accurate up to date information about specific enterprises and industries.	Accurate information about school technology education programmes.
Access to experts in the community/ enterprise.	Access to experts e.g. language teachers.
Access to facilities beyond the scope of the school.	Access to educational facilities beyond the scope of the enterprise for training.
Possibilities for sponsorship to support the curriculum	Improved employer / employee relationships allowing staff to have contact with children in their community. Giving the employee personal satisfaction.
An increased understanding of the world outside the classroom including expectations of possible employers and how this relates to their personal growth.	An increased understanding of the world of education including the expectations of schools and individuals leaving school.
Increased understanding for teachers of how communities and enterprises work. Ultimately improving teaching and learning for individuals in their class.	Fulfilment of a possible personal altruistic desire to help improve the quality of teaching and learning.

Table 1 was generated after research (O'Sullivan, 2011) was carried out in schools looking at actual partnership case studies in various locations around New Zealand. What might this mean for the technology teacher and the pupils in the classroom?

Table 2. Possible benefits for pupils and teachers of school community partnerships

Pupils	*Teacher*
Increased motivation and a belief that what they are doing has a real world connection.	An opportunity to regenerate their own interest in what they teach.
Purposeful action an increased realization that the work they are undertaking in school has a place in their future lives.	To develop a sense of connectedness and an affirmation that what they teach is beyond what is required for assessment and qualifications.
An opportunity to get a taste of a possible profession enterprise or service.	Opportunities for teachers to perhaps look for career breaks and sabbaticals.
The opportunity to research through interviews and personal communication with experts in the field.	Access to new teaching materials and the latest resources.
Access to experts in the community with additional skill-sets that can complement the classroom teacher.	Access to experts e.g. to facilitate further understanding of their current practice.
Increased opportunity to access equipment beyond the scope of their technology classroom.	Opportunity to extend teaching and learning outside the classroom with easier access to community enterprises.
Opportunity for pupils to establish real clientele and stakeholders for their technological endeavours.	Giving the teacher a greater access to a wider source of guest speakers/experts to enhance their delivery.
An opportunity to make connections for work placements and even possible future employment.	An increased understanding of expectations of the local community through these shared exercises.
An opportunity for pupils to see in action both the vocational and academic aspects of technology education.	Opportunity to work with enthusiastic parents, community agencies and other enterprises. A chance to build technology based people networks.

Table 2 clearly identifies possible ways that the technology curriculum injector model could be utilized to enhance technology education provision. Before considering engaging into a partnership, the teacher must be clear about the learning goals for the partnership. This includes ensuring that the partnership and any outcomes are linked to the technology curriculum. One of the ways to achieve a successful outcome is to encourage partnerships as part of more extensive technology education units and not just one-off activities with little or no connection or relevance to the curriculum.

A teacher along with the senior management team of the school in consultation with any health and safety officer from the community partner must maintain a safe operating environment. It is important to ensure that both schools and the partnership have shared understandings of, and agreed targets for, the learning outcomes. To maintain integrity and continuity link pre-partnership learning activities with any site visits, and follow these up with post-visit activities. Discussions should occur about the partnership with pupils to ensure they appreciate that the enterprise people are giving up their expensive time. Pupils should be punctual, polite and prepared. Teachers can facilitate this by matching the partnership to the age and learning level of the pupils involved. Additionally they should appreciate that they are representing themselves, the school and the integrity of the partnership for future participants.

Partnership facilitators have an obligation to ensure that pupils are ready and able to take responsibility for their own learning and project management. This will require the explicit teaching of appropriate strategies such as those required for effective resource and time management. Maintaining commitment over the entirety of the partnership can be developed when participants see the relevance and importance of the partnership. It is important that participants are ready to make the most of positive connections that may arise (see table 2). Teachers and pupils should be encouraged to collate, analyse, critique and reflect upon the partnership and then utilize the experience to inform their practice and improve their assessments.

School and community partnerships can be beneficial to all parties concerned; however, the onus is on the teacher to ensure that the best interests of the pupils are kept at the forefront of any decisions made.

UTILIZING RESOURCES (PLANNING AND MANAGEMENT)

In addition to the components which are identified in the technology curriculum injector there are other issues such as how the community of practice i.e. technology teachers portray and promote their subject to the wider community. Which resources they select and use to enhance their teaching and learning offerings. Community resources available for the support and delivery of technology education are many and varied. The focus in this chapter thus far has been on the people involved in community partnerships. Here, the use of the word 'people' is in preference to 'human resources' which is associated too closely with the negative aspects of human capital theories. So how can technology teachers identify quality technology education resources? There are quality resources which have been developed the following criterion is adapted from Techlink http://www.techlink.org.nz/planning/Resources/resources.htm. Techlink is website dedicated to technology teachers, pupils and all those with an interest in technology education in New Zealand.

A quality technology education resource supports quality teaching and learning and extends best practice in technology education. The resources will follow government policy guidelines and meet the requirements of any current standards and codes that may apply. Quality technology education resource materials should be linked with a Technology Curriculum in a valid and correct manner. They should be technically accurate, culturally appropriate and show flexibility in approach. A good resource has balance in the content with regard to controversial topics. It should be user friendly, functional and correctly aligned with any assessment protocols where appropriate.

Quality technology education resources can help teachers to build positive learning and teaching environments which encourages diversity and enterprise. This can be achieved by highlighting exemplars which motivate pupils to engage in and complete manageable and meaningful technological activity. These exemplars should use combinations of teacher-directed groupings, co-operative groups, structured peer interaction and individual work to enhance learning cycles and encourage, scaffold and enable informed, managed learner-mentor dialogue.

Any selected resources should make learning processes in technology transparent and support pupils in setting specific learning goals. They should reinforce the use of inclusive technological language and practices that respect cultural and gender identity whilst building constructively on pupils' experience and knowledge. A good technology education resource will make explicit links between learning in technology from a broad variety of learning environments. They should help increase alignment between classroom technology programmes and accepted best practice in technology education.

A good resource will enhance pupil motivation by highlighting the need for clear information about the desired learning outcomes through effective, specific, timely, positive and responsive feedback. They should extend and improve the sustainability of school/community partnerships in technology education and promote self-regulation and reflection and the use of higher order critical thinking strategies by all pupils. When considering physical resources the classroom or technology teaching and learning space is of key importance. A careful selection of titles is required here because even the naming of a teaching and learning space for technology causes consternation and confusion for teachers and pupils in schools but also members of the wider community. Here is a list of some titles:

Table 3. Possible names for technology teaching and learning spaces

Workshops	*Laboratories*	*Studios*	*Suites*	*Rooms*
Woodwork	Robotics	Design	Technicraft	Home economics
Metal	Computer	3D	Craft	Textiles
Plastic	Food	Multimedia	Industrial	Practical
Engineering	Biotechnology	Fashion	Technology	Graphics
Hard materials	Digital	Soft material	Manufacturing	Life skills

These are all labels that have historically been placed above or next to teaching and learning spaces for technology education. Whatever the title, these are spaces in a school which are expected to reflect a connection between technology education and the world outside. If we follow Dewey's notion of intrinsic motivation these places should foster and encourage pupils to engage in practice, emotion and reason, doing and thinking. The change to modern technology education from the previous curriculum models has not always been reflected in the facilities made available for teaching the subject or the names we have given these facilities.

The technology curriculum injector model proposed in this chapter favours a connective active, participatory, experiential learning—the learning style that many young people exhibit in their personal lives. Dewey (as stated earlier in the chapter) advocated that school learning should have the emotional force of non-school learning and he felt that connecting pupils outside interests with the curriculum would increase their motivation. This is hard to achieve in a traditional technology education room which may represent a bygone past industrial era no longer relevant in a modern educational facility. A good starting point might be to visit modern community endeavours which reflect your particular technology offering. Old bolted down workshop benches or inflexible cooking classrooms may not aide your intention to connect with a changing world outside the classroom. Community visitors to your technology education teaching and learning space may well expect to see an environment which reflects sound aspects from modern technological practices.

It would be impossible to specify exactly what is required for technology teaching and learning spaces in this chapter. However, for the shift to the technology curriculum injector model highlighted there are general considerations for technology teaching and learning spaces that should be taken into account. Architects of educational spaces talk of a *built pedagogy* (the ability of space to define how one teaches). This is an important concept for the technology teacher looking to develop community partnerships. Technology teaching and learning spaces should be increasingly flexible and community connectable. There should be a combination of formal and non-formal learning environments which allow for both physical and virtual interactions. A visitor should be able to connect and relate to the technology teaching and learning space you have created.

First impressions count and in those early meetings between a teacher and the community partners your technology teaching and learning spaces should reflect your personal philosophy of what good technology education is about. Ideally all technology teaching and learning spaces should be in the same or at least within a workable close location to facilitate ease of access and transfer for both students and staff. Adequate room sizes and flexibility of the technology teaching and learning spaces should be specified. Spatial needs mean more than just the classroom's health and safety requirements. The room should have an emotional dimension in terms of personal space as well. There should be sufficient good quality natural and artificial controllable combination lighting including black-out facilities for video conferencing, presentations and virtual exchanges with community partners. All of this you might expect to find in a modern technological environment outside of school.

A technology classroom needs good ventilation and airflow including different types of extraction for odours, dust etc. The ability to maintain a comfortable and adjustable working temperature is important. A technology classroom should also have specifically designed sound reducing internal acoustics and minimisation of noise transfer. Sufficient and flexible power outlets including whole room shut down are required for health and safety reasons. Energy efficiency; (which is an important factor when considering on-going costs for schools) should also be factored in. Adequate consideration must be given to digital technologies both hardwired and wireless. Sufficient wet areas, clean areas, dust free areas combined with appropriate safety flooring and flexible wall coverings are necessary to ensure flexibility of the teaching space. Particular to technology education is the need for adequate access for the maintenance and storage of larger machinery and materials. Adequate preparation areas for both teacher and materials are required this could be combined with adequate storage for materials and pupil work. To encourage enterprising undertaking and outcomes, consideration should also be given to free space for creative thinking and play. Access to media rich resource areas for the stimulation of enterprising thinking should also be encouraged.

Beyond the immediate technology teaching and learning spaces, other considerations of high importance are accessible and well maintained disabled and single sex toilets. A work presentation/display and socialisation spaces for pupils and a communication centre/interview room to work with community partnerships.

This section may seem a bit pedantic however in my technology education career I have been responsible for redesigning enterprising technology spaces no fewer than five times. It is important that all parties are involved in the change of existing or establishment of new facilities. As a minimum this should include designers/architects, senior management, teachers, pupils, parents and community partners. See (tables 1 and 2 above) to facilitate the types of teaching activities that might occur in these technology teaching and learning spaces.

ENHANCEMENT OF TECHNOLOGY PROVISION

If we are truly to enhance our provision and facilitate a technology curriculum injector model, teachers must consider how pupils are to connect with the community partnerships we are trying to promote. Pupils are increasingly socially connected by some of the technologies they use. The way they do this is anything but traditional; mobile technologies combined with virtual social media have revolutionized the way we connect. Technology teachers should find new ways of incorporating these and future technologies into how they teach.

If technology education is to be seen as a modern subject teachers should consider utilizing modern smart materials such as thermo chromic inks which change or reveal images when hot can be used to promote community enterprises. Whilst photochromic inks respond to changes in light conditions and can be used on clothing to promote safety at night, smart materials are developed to respond to environmental stimuli with particular changes in external or internal variables. These smart materials are also referred to as responsive materials. Depending on changes in their conditions, smart materials change either their properties (mechanical, electrical, appearance), their structure or composition, or their functions. Mostly, smart materials are used where their inherent properties can be favourably adapted to meet performance needs. Sports, fashion and music all incorporate smart materials into their production activities. All three of these areas are highly motivational and relational to the pupils in technology classrooms.

Amabile et al. (1994) highlights an *intrinsic motivation principle of creativity.* This is where people are most creative when they feel motivated primarily by the interest, enjoyment, satisfaction, and personal challenge of the work itself—not by external pressures such as those given by the teacher. Mumford et al. (1997) noted that having appropriate resources influences those trying to be creative and indicates that their endeavours are worthwhile. Traditional materials and teaching methods are not redundant but they should be complemented by the incorporation of new smart materials and modern practices. If teachers are trying to enhance their technology provision they should consider the technology curriculum injector model as a positive way forward.

> Dewey argued that schools should strive to emphasize moral goals based upon democratic civic and social experience, vocational and practical usefulness, and individual development in light of the rapid modernizing changes that were taking place in Western civilization (Butts, 1973, p. 471).

In New Zealand for example many technology education activities have moved towards authentic real world learning opportunities. However, some lack that community connectedness that would ensure recognition of fundamental changes that are going on in society. The current offerings can be piecemeal in approach and lack cohesion. There is scope and opportunity to enhance the delivery of technology education by incorporating innovative pedagogical strategies like the technology curriculum injector model when planning for a connected curriculum offering. Connecting theory to practice is one of the greatest challenges facing technology education. One challenge is to foster pupils' abilities to integrate their learning over a period of time employing metacognitive strategies in order to meet those challenges in the 21st century technology teaching and learning space (Brears et al., 2011).

Learning that assists in developing integrative and metacognitive capabilities is considered important because it assists in developing habits of mind thus preparing pupils to make informed choices relating to complexities in conducting personal, professional and civic life (Huber & Hutchings, 2008).

RAISING THE PROFILE OF TECHNOLOGY

The establishment of a connected relevant technology education programme by utilizing the technology curriculum injector model and designing/adapting suitable teaching and learning spaces with modern facilities and materials would be a reasonable start point. Technology teachers should look for opportunities to increase the approbation of their programme both within the school itself and to outside communities to ensure the provision of technology education as an essential part of schooling. Technology education is still perceived as a lower level activity by many.

Technology education should be seen to be a strong high profile modern connected curriculum area.

How technology is taught in this technology curriculum injector model should reflect certain principles. The following diagram has been used as a discussion point with pre-service technology teachers to broaden their personal constructs of technological activity and to highlight the connected nature of enterprising teaching and learning in a technology education environment.

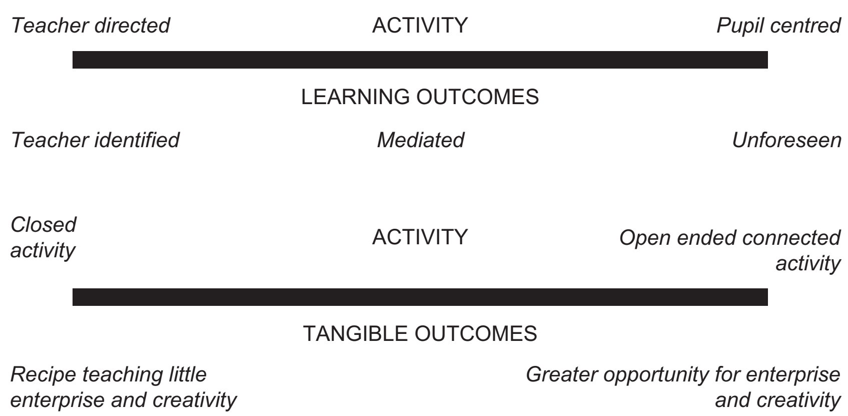


Figure 3. Technology curriculum injector teaching and learning approach.

The top layer of fig. 3 above the left hand side shows a traditional model for the teaching of technology. The right hand side reflects the technology curriculum injector model. It is not a case of either/or; it is about striking a balance between the two models. There are times when a teacher directed activity is appropriate. The introduction to safe use of particular technological equipment is a good example. Using that knowledge to change a way of doing something for the better might be an example of an enterprising pupil centred response. In the first scenario the learning outcomes or intentions are clearly defined by the teacher. In the second scenario they might be mediated or agreed between the teacher and the pupil or in a unique response unexpected by either party!

In the bottom layer of fig. 3 the activity on the left is closed and probably contrived by the teacher alone. It offers little scope for enterprise and creativity and follows a recipe approach which is drip fed by the teacher. The outcome is predictable with little variation form one pupil to another. The right hand side is more open giving the pupils scope to work with clients from the community with real needs, wants or opportunities. There is a far greater opportunity for enterprise and creativity. The outcomes from this side will show increased freedom with much more variation in response. Again it is not a case of either/or but a combination of both which should follow the technology curriculum injector model.

Teachers who are unsure of the approach promoted in this chapter are often most perplexed by how students move from the identified issue or problem to the concept development stage. This area which seems to challenge technology teachers and pupils alike is called the fuzzy front end. The '*fuzzy front end*' is a borrowed term from New Product Development (NPD) research. To be connected to their communities teachers should be willing to consider technology practices from outside of the classroom. Product development processes that occur in industry and design studios are similar in many ways to longer projects carried out in technology education. Obviously in one chapter it would be impossible to reflect all these processes therefore one specific area will be highlighted. New Product Development includes developmental work around four foundational elements:

1. Opportunity Identification
2. Opportunity Analysis
3. Idea Genesis
4. Idea Selection
5. Concept and Technology Development

(Koen et al., 2001, pp. 50–51)

The fuzzy front end is the messy "getting started" period of trying to meet a need, issue or opportunity. Although the Fuzzy Front End may not be an expensive part of solution development, it can consume 50% of development time (Smith & Reinertsen, 1998). *Opportunity Identification* is the element in technology education where the pupil is looking to take a chance on an idea. Teachers striving for a connected and relevant technology education should encourage enterprising but safe risk taking so this facet needs to be handled carefully.

Opportunity Analysis is the element where teachers want the pupils to translate the identified opportunities into a specific context. Here, pupils can look forward and see possibilities for positive outcome development. Extensive efforts may be made to align ideas to stakeholders and do market studies and/or trials and research. Strong collaboration between the connected parties improves the chances of success. The third element is the idea genesis, which can be described as an evolutionary and iterative process progressing from birth to maturation of the opportunity into a tangible idea. The process of the idea genesis can be made internally or come from outside impulses, e.g. a pupil being exposed to a new material such as a smart material or a client/stakeholder with an unusual request.

The fourth element is the idea selection. Its purpose is to choose whether or not to pursue an idea by analysing its potential value. There needs to be careful questioning provided by the teacher to ensure the pupils entertain ideas which are in fact viable. This needs to be handled carefully. Too much intervention and we can stifle creativity and innovation. Too much hands off might mean frustration and ultimately failure for the learner the teacher has to decide on an individual basis how much freedom to give. Some learners may learn something new from failure but others may be switched off.

Once a programme like this has been established an additional set of challenges may be faced. Will the other teachers in your department, syndicate or faculty be receptive to this approach? Will parents be happy if pupils do not bring home the obligatory salad tongs, spatula, swimming clothes bag or scones? Will the pupils lining up outside the workshop or textiles room expect to be let loose on equipment and material? Will they appreciate spending time doing interviews with prospective clients? The answer to all these might be no! If technology teachers are to pursue innovative, creative, enterprising programmes reflective of what goes on outside the classroom they will have to take risks too.

The suggestion is to start small i.e. don't change a whole programme overnight. A mixture of traditional units and the technology curriculum injector model will need to be established and promoted. Technology teachers are going to have to change the perception and understandings of all the community parties involved. The technology curriculum injector teaching and learning approach discussed above will need to be demonstrated and explained to fellow technology staff as well as the pupils. Consideration should also be given to creating awareness in other teachers in the school, the senior management team, the parents and any community partners.

Initially concentrate on one unit. Look for opportunities to promote the successes. There are a number of ways to increase the approbation of technology education and awareness of the curriculum injector model.

Media rich technology education displays combined with screened promotions running in the classroom showing pupils endeavours and outcomes. Encourage pupils to generate you-tube clips which highlight successes from their endeavours.

Open days are a great opportunity to show how the subject has changed and is meeting the needs of today's students in a connected way. Enter national and international technology education competitions. Do presentations on teacher only days to other staff utilize professional development time to create buy in to the changes you are promoting. Develop presentations to senior management teams and governing school boards or boards of trustees utilize inter active displays for parents' evenings. These are possible sources for future partnership arrangement contacts and it is important that they understand the technology curriculum injector model.

Within the school itself technology awards should be given out regularly during assemblies. Technology teachers should be encouraged to run and promote after school technology clubs. Community technology education open days are opportunities to invite in local partnership potentials to view the work undertaken by pupils. Create (where appropriate) a database of parents who may offer potential support or partnership opportunities. Conduct media releases to show off the pupils' work and create regular displays at school events.

Have a rolling display in the staffroom and undertake appropriate education outside the classroom activities (EOTC) which enhance and highlight the programme intentions. Invite interesting and enterprising guest speakers to create motivation and interest. Become an interesting and enterprising guest speaker and visit local community groups to promote what you are doing. Look for funding opportunities to enhance your facilities and resources. Engage with careers advisors to make sure they know what technology education is trying to achieve. Look for enterprising opportunities to work with both contributing associate schools and higher and further education providers.

CONCLUSION

Technology education in its current form is a comparatively new subject; it has developed and changed from a number of traditional subject offerings. A host of rationales have been offered elsewhere as to why this change was necessary. The establishment of a new subject in an already overcrowded curriculum is no easy feat. This chapter has highlighted an increasing disconnect which is occurring in education and offered a way forward. A prime motivation for sustaining technology education in the curriculum is for students to understand and appreciate that technology plays such a major role in our communities and society. The technology education curriculum injector model proposed here brings together a number of components under the umbrella of technology and the community. These components may have some merit independently but together they offer a stronger rationale for keeping technology as a core subject within the curriculum. An attempt has been made to propose a way forward and some examples of how to achieve this have been discussed. Ultimately the success of the subject will be judged on the performance of the pupils within it and this is clearly the responsibility of the teacher. However, engagement and motivation increasingly will play a big part in how the subject is perceived and accommodated. Involving the community in positive ways and increasing their understanding can only help that accommodation.

REFERENCES

Amabile, T. M., Hill, K. G., Hennessey, B. A., & Tighe, E. (1994). The Work Preference Inventory: Assessing intrinsic and extrinsic motivational orientations. *Journal of Personality and Social Psychology, 66*, 950–967.

Babalola, J. B. (2003). Budget Preparation and Expenditure Control in Education. In Babalola J.B. (Ed.) *Basic Text in Educational Planning*. Ibadan Awemark Industrial Printers.

Bereiter, C. (2002). Liberal education in a knowledge society B. Smith (Ed.). Illinois: Open Court Publishing.

Boote, D. N. (2006). Teachers' professional discretion and the curricula. *Teachers and Teaching: Theory and Practice*, *12*(4), 461–478.

Brears, L., MacIntyre, W., & O'Sullivan, G. (2011). Preparing teachers for the 21st century using PBL as an integrating strategy in science and technology education. *Design and Technology Education: An International Journal*, *16*(1), 36–46.

Butts, R. F. (1973). *The education of the west: A formative chapter in the history of civilization.* New York: McGraw-Hill.

Caird, S. (1989). Enterprise education: the need for differentiation. *British Journal of Education and Work*, *4*(1), 47–57.

Clark, J. (2004). Enterprise Education or Indoctrination? *New Zealand Journal of Educational Studies, 39*(2), 321–332.

Day, C., Kington, A., Stobart, G. and Sammons, P. (2006). The personal and professional selves of teachers: stable and unstable identities. *British Educational Research Journal*, *32*(4), 601–616.

Department for Education (2010). *The Importance of Teaching: Schools White Paper.* Retrieved from https://www.education.gov.uk/publications/eOrderingDownload/CM-7980.pdf.

Dewey, J. (1933). *How We Think. A restatement of the relation of reflective thinking to the educative process* (Rev. Ed.). Boston: D. C. Heath.

Dewey, J. (1964). *John Dewey on education: Selected works.* R. D. Archambault (Ed.). New York: Random House.

Dwerryhouse, R. (2001). Real work in the 16–19 curriculum: AVCE Business and Young Enterprise. *Education + Training*, *43*(3), 153–61.

Fagerlind, A. & Saha, L.J. (1997). *Education and National Developments*. New Delhi: Reed Educational and Professional Publishing Ltd.

Filion, L. J. (1994). Ten steps to entrepreneurial teaching. *Journal of Small Business and Entrepreneurship*, *11*, 68–78.

Gibb, A. (1993). "The enterprise culture and education: understanding enterprise education and its links with small business, entrepreneurship, and wider educational goals". *International Small Business Journal*, *11*(3), 11–34.

Gibb, A., & Cotton, J. (1998). "Work futures and the role of entrepreneurship and enterprise in schools and further education", background paper to the conference held at the Department of Trade and Industry, 8 December, Enterprise and Industry Education Unit, Durham University Business School, Durham.

Gibb, A. (1999). Can we build effective entrepreneurship through management development? *Journal of General Management*, *24*(4), 1–21.

Huber, M. T. & Hutchings, P. (2008). *Integrative learning: Mapping the terrain*. The Carnegie Foundation for the Advancement of Teaching and Association of American Colleges and Universities (AAC&U). Retrieved from http://www.techlink.org.nz/planning/Resources/resources. htm.

Jack, S. L., Anderson, A. R. (1999). Entrepreneurship education within the enterprise culture: producing reflective practitioners. *International Journal of Entrepreneurial Behaviour & Research*, *5*(3), 110–25.

Jones-Evans, D., Williams, W., & Deacon, J. (2000). Developing entrepreneurial graduates: an action-learning approach. *Education + Training*, *42*(4–5), 282–288.

Karl Marx, Das Kapital, Volume 1.

Kearney, P. (1996). *The Relationship between Developing of the Key Competencies in Students and Developing of the Enterprising Student*. Australia: DEETYA.

Kimbell, R. (2011). Handle with care… *Design and Technology Education: An International Journal*, *16*(1), 7–8

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development.* Englewood Cliffs, NJ: Prentice-Hall.

Koen et al. (2001). Providing clarity and a common language to the 'fuzzy front end'. *Research Technology Management, 44*(2), 46–55.

Lee, G. & Hill, D. (1996). Curriculum Reform in New Zealand: Outlining the New or Restating the Familiar? *Delta, 48*(1), 19–32.

Marshall, J. D. (1997). The new vocationalism. In M. Olsen & K. M. Matthews (Eds.), *Education policy in New Zealand: The 1990s and beyond*. Palmerston North, New Zealand: Dunmore Press.

Massengill, D., Mahlios, M. & Barry, A. (2005). Metaphors and sense of teaching: How these constructs influence novice teachers. *Teaching Education, 16*(3): 213–229.

Ministry of Education. (2007). *The New Zealand Curriculum*. Wellington: Learning Media.

Ministry of Education. (2009). *Te Kete Ipurangi*. Retrieved from http://education-for-enterprise.tki. org. nz/About-E4E/Why-focus-on-E4E/Defining-E4E.

OECD (Organization for Economic Co-operation and Development). (1989). *Towards an Enterprising Culture. A Challenge for Education and Training*. Paris.

OECD (Organization for Economic Co-operation and Development) (2001). *Cities and Regions in the New Learning Economy*. A study carried out and published by the OECD Centre for Educational Research and Innovation (CERI). (Charles Edquist, Gareth Rees, Mark Lorenzen, and Stéphane Vincent-Lancrin drafted the report, co-ordinated by Kurt Larsen of the OECD/CERI Secretariat.)

O'Sullivan, G. C. (2009). Technology education in New Zealand: The connected curriculum. *Design and Technology Education: An International Journal*, *15*(1), 31–39.

O'Sullivan, G. C. (2009a). Technology education: Making the difference education for enterprise. In C. Benson, P. Bailey, S. Lawson, J. Lunt, & W. Till (Eds.), *Seventh International Primary Design and Technology Conference* (pp. 3–8). Birmingham, England: Centre for Research in Primary Technology at Birmingham City University.

O'Sullivan, G. C. (2011). Technology Education and Education for Enterprise (E4E). In C. Benson, & J. Lunt (Eds.), *International Handbook of Primary Technology Education*. Rotterdam: Sense Publishers.

O'Sullivan, G. C. (2012). *Technology Education; Education for Enterprise (E4E)*. Unpublished doctoral dissertation, Curtin University of Technology, Perth, Australia.

Postman, N. (1992). *Technopoly*. New York: Vintage.

Poulou, M. (2005). Educational psychology within teacher education. *Teachers and Teaching: theory and practice 11*(6), 555–575.

Price B. (1991). *School industry links the consequences of minding other people's business*. Australia: ACER.

Psacharopoulos, G and Woodhall, M. (1997). *Education for Development: An Analysis of Investment Choice*. New York: Oxford University Press.

Rae, D. (2000). Understanding entrepreneurial learning: a question of how? *International Journal of Entrepreneurial Behaviour & Research*, *6*(3), 145–59.

Revans, R. W. (1991). Action learning – its origins and practice. In Pedler, M. (Eds), *Action Learning in Practice* (2nd ed.), pp. 3–15. Aldershot: Gower.

Saunders, M. (2000). Understanding Education and Work; Themes and Issues in the Routledge International Companion to Education. London: Routledge.

Sakamota, A. and Powers, P.A. (1995). Education and the dual labour market for Japanese men. *American Sociological Review, 60*(2), 222–246.

Schon, D. (1991). *The reflective practitioner: how professionals think in action.* Aldershot: Ashgate.

Schultz, T. W. (1971). *Investment in human capital*. New York: The Free Press.

Smith, P. G. and Reinertsen, D. G. (1998). *Developing products in half the time* (2nd ed.). New York: John Wiley & Sons.

Solomon, G. T., Duffy, S., Tarabishy, A. (2002). The state of entrepreneurship education in the United States: a nationwide survey and analysis. *International Journal of Entrepreneurship Education*, *1*(1), 65–86.

Watts, A. (1983). *Education, employment and the future of work*. Open University Press.

Williams, P. J. (2011). STEM Education: Proceed with caution. *Design and Technology Education: an International Journal, 16*(1), 26–35.

Wraga, W. G. (2009). Toward a Connected Core Curriculum. *Educational Horizons, 87*(2), 88–96.

Young, M. F. D. (1998). *The Curriculum of the Future*. London: Falmer Press.

AFFILIATION

Gary O'Sullivan
College of Education,
Massey University

DAVID BARLEX

9. CURRICULUM DEVELOPMENT

INTRODUCTION

This chapter is in three main sections: Curriculum considerations, Curriculum innovation and Detailing the curriculum plus a short conclusion. Curriculum considerations discusses fives important areas that effect the technology curriculum: stakeholders and their influences, statutory requirements, examination board specifications, resource implications and approaches to implementation. Curriculum innovation discusses the contribution of individual teachers to curriculum development, the importance of collaboration to creative curriculum development and interdisciplinary approaches to technology curriculum development. Detailing the curriculum discusses six important aspects that need to be taken into account when developing a technology curriculum: achieving breadth and balance; providing progression; enabling differentiation; designing units of work; implementation and evaluation and revision. The conclusion will summarise the role of curriculum developers in technology education and indicate their centrality in the continuing development of the subject.

CURRICULUM CONSIDERATIONS

The technology curriculum is highly contested. The curriculum experienced by pupils in school will be the result of power struggles between vested interests. It will be influenced by the views of stakeholders, the interpretation of statutory requirements, the requirements of examinations, the availability of resources and the methods by which it is taught. This section considers the way these various effects might play out.

Stakeholders and influences

Consider the curriculum journey in technology education of pupils as they move through lower secondary school, in most developed countries a three-year journey for pupils aged 11–14 years. The pupils are clearly consumers of the technology curriculum. Through it they can expect to acquire a range of knowledge, skill and understanding that provides personal satisfaction and develops self esteem and may, if they so choose, lead to courses of further study that sets them upon a trajectory leading to a technical career. They are definitely stakeholders but it is likely that

P. J. Williams (Ed.), Technology Education for Teachers, 197–230.

they have only very limited influence on the nature of their curriculum experience. In most schools teachers are the gatekeepers of the curriculum experience and do not enter into negotiations with pupils as to what the pupils should learn or how they might learn it. This need not be the case. Recently the Design & Technology Association in England posted on their website a set of open starting points (Design & Technology Association 2010) for designing and making electronic products. These starting points are available as visual brainstorms which the teacher can use with the class to explore the context and identify many different sorts of electronic product that could be designed and made in response. These open starting points provide the opportunity to give pupils a voice as to what sort of product they want to design and make. The exact nature of the products designed and made will depend on the age and previous experience of the pupils and the resources available in the school, but giving the pupils a voice will increase their influence on the curriculum and provide some ownership which is likely to increase their motivation. The parents and carers of the pupils are also stakeholders in that they will have an interest in what their children are doing in schools, whether they find this enjoyable and rewarding and to what extent it provides them with useful qualifications. Whilst parents may not have influence on the nature of the technology curriculum they will almost certainly have influence on the extent to which it is valued by their children. This influence can manifest itself at option time when pupils choose courses of study linked to their career aspirations. In England state schools have to provide the opportunity for pupils to study technology after age 14, but pupils are not required to study the subject. So to this extent technology becomes an optional subject. Some schools take the position that all pupils should study technology until the age of 16, giving the subject high status. At schools where technology has a low status it is possible for young people to be advised by their parents, amongst others, against further study of technology in preference for other subjects with a longer tradition in the school curriculum.

Technology teachers are also stakeholders and in some circumstances can have considerable influence on the curriculum. In countries where the only guidelines are broad statements of achievement, teachers are free to do as they like provided students are given the opportunity to achieve. In some countries government departments decide on the content of textbooks to be used by teachers e.g. India and France and in other countries e.g. England and Scotland they provide schemes of work which teachers may choose to follow. The extent to which teachers deviate from an externally imposed orthodoxy will vary. For schools where success in external examinations is important in maintaining the position of the school in performance league tables, teachers may be reluctant to use their influence and experiment with their curriculum. In a subject like technology which by its very nature is subject to change, this can lead to a curriculum offering which becomes out of date very quickly. The use of electronics in the technology curriculum provides a good example of this. Most manufactured electronic products now have embedded intelligence in that they contain integrated circuits that have been programmed to behave in a particular way.

They also usually use surface mounted components. This has been the case for over 30 years. Yet most schools still use limited, hardwired, through-hole, out of date electronic components as part of their technology curricula.

The technology curriculum in a school can to some extent be influenced by local employment opportunities and the views of local employers. If, for example, local industry is hi-tech then the technology curriculum might not only reflect this but also take advantage of the situation and invite local industrialists to contribute to the curriculum. In some countries there are national systems designed to help employers make this contribution. The STEM ambassador scheme in England is an example (STEMNET 2010) and in the USA the Institute of Electrical and Electronic Engineers (IEEE) supports a range of activities through which professional engineers can contribute to school technology programmes (IEEE 2012).

Professional bodies representing those employed in technology-based industries are stakeholders. Pupils studying technology at school may become interested in technical careers and may eventually find employment in such professions. To this extent the technology curriculum represents a pipeline of future employees and it is in the interest of the professional bodies to support and influence the technology curricula. The IEEE in the USA and the Royal Academy of Engineering in England have both been active in influencing the technology curricula in their respective countries at the national level.

The professional associations of technology teachers are significant stakeholders. For example in New Zealand, TENZ (Technology Education New Zealand) provides a professional network to promote and support Technology Education through:

- Developing and maintaining national and international links between those working in Technology Education and with the wider technological community,
- Supporting professional, curriculum, and resource development in Technology Education,
- Encouraging research in Technology Education,
- Organising a national Technology Education conference every two years (TENZ, 2011).

In the USA the ITEEA (International Technology and Engineering Educators Association) performs a similar function having as part of its mission statement ‘to promote technological literacy for all by supporting the teaching of technology and promoting the professionalism of those engaged in these pursuits. ITEEA strengthens the profession through leadership, professional development, membership services, publications, and classroom activities.’

(Taken from the ITEEA website May 2011)

Government requirements

In recent times there has been a global trend for governments to define national curricula. Technology has proved particularly challenging for several reasons.

First it is a relatively new subject and as such has to establish the range of knowledge, skills and understanding it wishes to embrace. As a new subject during the time immediately after its introduction, it had to rely on those who have taught other subjects to become the teachers of this new subject. A corollary to this is that the subject must 'grow' from subjects that have previously been taught in the curriculum. In the case of technology in the USA the predecessors were subjects under the industrial arts 'umbrella' which featured fabrication of objects in wood and/or metal using a variety of hand, power, or machine tools. Technology is clearly much wider in scope and one of the challenges facing those developing the technology curriculum in the USA was to establish the organizing principles by which such a curriculum could be described. The result was an extensive description of technology (International Technology Education Association 2007), comprising over 250 pages, which described the content for the study of technology in five categories:

- The Nature of Technology
- Technology and Society
- Design
- Abilities for a Technological World
- The Designed World

The designed world was divided into seven 'technologies':

- Medical technologies
- Agricultural and related biotechnologies
- Energy and power technologies
- Information and communication technologies
- Transportation technologies
- Manufacturing technologies
- Construction technologies

The document is impressive in both its breadth and depth but does lead to the question: how can such a curriculum description be translated into classroom teaching? These Standards for Technological Literacy are not binding and are open to adoption and interpretation by individual states in the USA. Compare this to the situation in England (Qualifications and Curriculum Authority 2007) in which the description for technology (called design & technology) is statutorily binding (state schools are required to teach the subject from to all pupils aged 5–14 years) and comprises just 9 pages organised into six sections including criteria for assessment.

- An importance statement
- Key Concepts
- Key Processes
- Range and content

- Curriculum Opportunities
- Attainment Targets

Here we have two quite different interpretations of 'curriculum content' for technology. Inspection of the attainment targets reveals that the emphasis in England is focused on designer maker competence and the evaluation of products that the pupils themselves have designed and made. There is little if any assessment on technological knowledge as such, although of course to design and make effectively pupils have to draw on their store of technological knowledge. In England technological knowledge is conceived in very broad terms as concerned with designing and making with resistant materials, food, textiles and technical components within systems and control. This is in stark contrast to the extensive and detailed description in the USA. Note however that at the time of writing the situation in England is subject to change as the recently elected government has instigated a curriculum review.

Examination Boards

In many countries school pupils take nationally recognized examinations which are used to provide entry qualifications for further study or employment and in some cases to gauge the performance of the schools they are attending. It is noteworthy that not all subjects are valued in this way. In the USA the situation is complex in that every state has its own policies relative to assessments. There are national standards in most disciplines, but assessments are developed and administered at the state level. In the case of New York State, which is not untypical, there are no required state exams for Technology Education (Office of Assessment Policy, Development and Administration (APDA) 2011). The situation in England is quite different. There are three non-government awarding bodies which provide specifications of what must be learned and assessment tools against which the learning is assessed. The specifications must meet the requirements laid down by the government. At the time of writing this is under review with the recently elected government announcing its intention to involve universities in deciding the content of specifications. The assessment is high stakes in that the government uses the performance of pupils to determine the position of the school in the examination performance league tables. At the moment design & technology is the most popular option subject and schools cannot afford for such a popular subject to under-perform. This situation tends to make both teachers and awarding bodies conservative and resistant to change and there has been some criticism of the awarding bodies for retaining outdated technologies in their specifications, particularly with regard to modern electronics as mentioned earlier. However innovation in assessment methods have occurred using Adaptive Comparative Judgement (Kimbell, 2007). In New Zealand the situation is slightly different (New Zealand Qualifications Authority 2011) with technology being a subject that is included in the New Zealand Certificate of Educational Achievement for pupils aged 16. Evidence of technology achievement is presented via a portfolio and assessment is carried out via teacher assessment and moderated by a national external moderator. No private companies are involved. Hence examination boards can have a wide range of influence on technology education depending on local circumstances. This may be:

a. no influence in the situation where there is no recognized award,
b. a reactionary influence which mitigates against change in recognized awards where change is seen as likely to put at risk performance in high stakes testing,
c. a progressive influence in developing new forms of assessment and
d. an influence which put a premium on teacher assessment.

Resource implications

Technology lessons will be dependent on the resources available to teachers. These can be divided into two broad categories – physical resources and intellectual resources. Physical resources include appropriate workspaces, suitable tools and equipment and necessary materials, ingredients and components. Attempts to modernize technology curricula so that they reflect the industrial use of computer controlled devices has led to schools acquiring computer assisted manufacturing (CAM) facilities – CNC lathes and mills, laser cutters and most recently rapid prototyping machines (3D printers). These facilities are of course little use without the appropriate computer assisted design (CAD) software. Such CAD software can be used to model the appearance and structure of products in resistant materials and textiles plus the function of mechanical and electronic systems within the products. With students aged 16+ years such software can be used for finite element analysis and modeling fluid dynamics. Hence, in addition to the initial capital investment required to set up a technology department, schools will need to budget for regular updating of equipment and software. Intellectual resources embrace a wide range of media which enable teachers to use the physical resources in an effective and efficient way. This depends on the teachers having appropriate knowledge, skills and understanding of CADCAM software and hardware. This requires initial teacher education to keep up to date in these areas and teachers in post being able to access appropriate professional development. Clearly both physical and intellectual resources are essential if pupils are to enjoy a modern technology course of study and their provision is not inexpensive, requiring both initial expenditure and then a commitment to further on going and recurrent financial support.

Approaches to implementation

In England the Design & Technology Association has articulated four important and complimentary approaches to teaching technology (Barlex, 2011a). These are: ‘making without designing’, ‘designing without making’, ‘designing and making’ and 'exploring the technology and society relationship'. Consider the activity in which pupils working collaboratively make a small scooter, using plans provided by the teacher and a set of part prepared materials and components. Each team of pupils perhaps four in number produced a finished scooter which they can ride individually. They have the opportunity to develop skills and tricks within their team and, through practice and observation, identify the teams 'best scooter' and these 'best scooters' compete against each other to be awarded the class 'best scooter' award. Most pupils aged 11–12 years would thoroughly enjoy this activity and in the process acquire a wide range of making, assembly, maintenance and repair skills. Hence it is not difficult to justify this sort of activity as one that is worthwhile within a technology education programme. However, if all the experience were of this type, making without designing, however attractive and appealing, there would be significant omissions with regard to a balanced technology education.

Consider the activity in which pupils deign without making. This was the premise for the Young Foresight project (Young Foresight 2000) in which pupils were required to work collaboratively in designing but NOT making products and services which used new and emerging technologies. One such technology was a material called QTC which could act as a stress dependent conductor. In a relaxed state it had a very high resistance. Stressing the material caused the resistance to decrease, the greater the stress the less the resistance and the greater the conductivity. One group of pupils, aged 13 years, used this idea as the basis for an epilepsy attack alarm system. One of the pupils knew from personal experience that the onset of an attack was accompanied by rapid movements in the jaw just below the ear. The group reasoned that such movement could apply pressure to a piece of QTC, worn in a discrete earpiece, and the resultant change in conductivity could be used to trigger a system that used GPS technology to alert paramedics that an attack had happened and the location of the person experiencing the attack. This 'design without making' activity enabled the pupils to identify a design task that they thought worthwhile, to consider the application of new technology and integrate this application into a systems view of modern communication technology. Had the pupils been required to make their ideas for using QTC, it is extremely unlikely that they would have considered such a design proposal and, if they had, they would almost certainly have abandoned it as beyond their making capabilities and the resources available in their school. As with 'making without designing' it is not difficult to justify the educational value of such designing without making in a school technology programme. However, a programme that consisted solely of such exercises would not provide a balanced approach to technology.

Consider the activity in which pupils design what they are going to make and then make what they have designed. This is often seen as the heartland of technology education, although it does not reflect the reality of technological activity in the world outside school, where those who design artefacts are usually not those who manufacture them. The decision making that pupils have to undertake when they are designing and making has been described as involving five key areas of interdependent design decision (Barlex 2007a): conceptual (overall purpose of the design, the sort of product that it will be), technical (how the design will work), aesthetic (what the design will look like), constructional (how the design will be put together) and marketing (who the design is for, where it will be used, how it will be sold). This approach can be represented visually as a pentagon diagram shown in Figure 1. This interdependence of the areas is an important feature of design decisions; hence the lines connect each vertex of the pentagon to all the other vertices. A change of decision within one area will affect some if not all of design decisions that are made within the others. Although the teacher usually identifies the sort of product the pupils will be designing and making, which makes it very difficult for pupils to engage in conceptual design, there are still many opportunities for making design decisions in the other areas. It is the juggling of these various decisions to arrive at a coherent design proposal that can then be realised to the point of fully working prototype that provides the act of designing and making with such intellectual rigour and educational worth and an essential part of technology education.

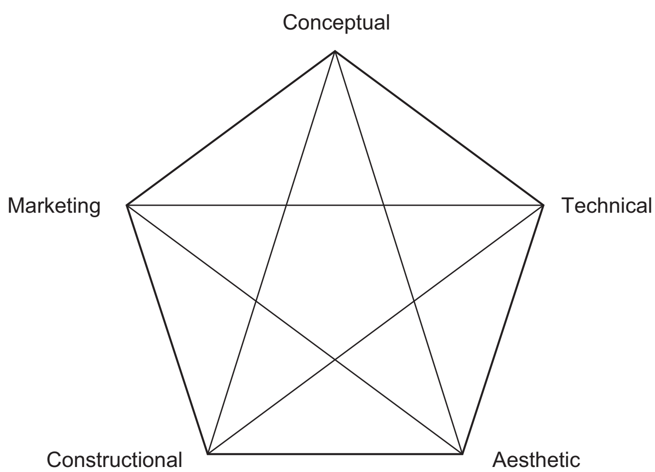


Figure 1. The design decision pentagon

It is possible that pupils can, as part of a technology course of instruction, carry out 'making without designing', 'designing without making' and 'designing and making' and not have the opportunity to explore the relationship between technology and society and through this develop an understanding of the nature of technology. The USA and New Zealand curricula include specific reference to the nature of technology, whereas the curriculum for England does not although it does engage pupils with impact beyond intended benefit and unintended consequences. David Layton (Layton 1995) has argued that developing critique competence in young people with regard to technology is a very important facet of technology education. Brian Arthur (2009) describes our relationship with technology as being almost bipolar in terms of our trust for the natural compared to our suspicion of the artificial.

> These two views, that technology is a thing directing our lives, and simultaneously a thing blessedly serving our lives are simultaneously valid. But together they cause unease, an ongoing tension, that plays out in our attitudes to technology and in the politics that surrounds it (p. 214).
>
> … we trust nature, not technology. And yet we look to technology to take care of our future – we hope in technology. So we hope in something we do not quite trust (p. 215).

A school technology programme that did not engage pupils with exploring our ambivalent relationship with technology would seem to be missing an essential ingredient.

Hence any 'grand plan' for a technology curriculum will need to give each of these four activities appropriate significance. Depending on the overall purpose of any one technology curriculum the relative significance of these components may vary, but it would seems that each should be present to some degree.

CURRICULUM INNOVATION

Innovation in the curriculum can be achieved by individual teachers inspired by their personal vision for their subject, providing their room for manouvre is not curtailed by an over prescriptive national curriculum. Teachers and others engaged in curriculum development can achieve significant innovation if they deliberately involve others so that the endeavour becomes collaborative. Interdisciplinary activity is also a powerful means of curriculum innovation. This section will discuss examples of all three activities with regard to the school technology curriculum.

Teachers and their visions

Teachers working in schools can make a significant contribution to curriculum development. Here are three examples from England. The first example concerns the work of Philip Holton a head of faculty at a high school (pupils aged 11–19 years) in South East England. Philip has adopted the unusual approach of asking pupils to consider a phenomenon and develop from it products that utilise that phenomena. Hence he has designed a unit of work in which pupils are introduced to the phenomenon of the Peltier effect enshrined in a solid-state device that when activated transfers heat from one side of the device to the other side against the temperature gradient. He believes that pupils will find the 'cold on one side hot on the other side' sensation highly intriguing. Using this intrigue to engage the pupils they can then investigate how to maximise the effect for cooling purposes.

Once they have an understanding of this they are in a position to design and make a variety of cooling devices for different purposes that they consider worthwhile – everything from a drink cooler to maintaining an organ for transplant at the correct temperature during transportation. This curriculum innovation, if successful, could be the starting point for a set of phenomenon based starting points for designing and making activities in technology education.

The second example concerns Ilsa Parry an innovative young designer and Jim Smith a young head of department in a secondary school in Derbyshire. They have had the idea that a useful activity to prepare pupils to be able to make what they themselves have designed, would be to make what someone else has designed. But they wanted to do more than simply provide the pupils with working drawings. They plan to make available examples of lighting products Ilsa has designed and challenge pupils to redesign these artefacts so that they can be manufactured with the tools, equipment and materials available in the school workshop. Such an activity would require pupils to analyse the design decisions of the original designer, and consider how these need to be adjusted to meet the school situation. In the process it would be important not to compromise the integrity of the product. This is a challenging activity that will immerse pupils in designerly thinking. If successful this innovation could provide the first example in a series of generic 'making from existing product idea' suite of activities.

The third example concerns two young heads of faculty Manjinder Sangha and Steven Parkinson. They have designed an interactive curriculum development matrix (ICDM) tool. In this tool teachers use a series of cards, that define teaching and learning activities, to describe a school technology scheme of work over a three year period on a week by week basis. This activity can be carried out by a whole department with each card being discussed before it is given a place in the scheme. The cards are colour and shape coded so patterns of learning and, importantly, omissions can be discerned at a glance. Significantly the result is the work of collaborative effort and open to public scrutiny. It is, as one teacher put it, 'not locked in the head of department's laptop!' (Mitchell 2009). Interestingly the ICDM tool provides the opportunity to describe an exiting curriculum and identify weaknesses and plan for the implementation through gradual improvement. This is a particularly interesting piece of curriculum development because it is, in a sense, a meta-tool allowing teachers to see the inadequacies of their current offering and then carryout small highly focused development to overcome the inadequacies.

Creative collaboration

In the three examples discussed here those with the responsibility for the curriculum development deliberately involved others so that the effort became collaborative. Vera John Steiner (John Steiner 2000) has argued that collaboration between individuals who share a common vision can lead to highly creative outcomes, which in many cases far outstrips what could be achieved by those individuals working in isolation.

When design & technology was introduced into the National Curriculum in England there was little if any preparatory professional development for those who would have to teach this new subject. The teachers required to do the teaching were from diverse backgrounds. Some had been teachers of home economics with experience mainly in teaching pupils to cook meals for the family, others had been teachers of CDT (craft, design & technology) with experience primarily in teaching pupils to make things in wood and metal, others had been teachers of art and design, others had specialized in teaching technical drawing. The teachers of these previously taught disciplines clearly had something to contribute to the new subject but a major difficulty was that individual teachers only had access to their particular contribution, so a challenge was to develop a picture of these contributions that could be shared by teachers from across the different subjects. The Nuffield Design & Technology Project responded to this challenge by deliberately interviewing teachers from across these subjects to find out what it was that they 'brought to the party'. It transpired that the sum of these individual contributions made a significant contribution to the set of design strategies that pupils might use.

The home economics teachers supplied the PIES approach to identifying needs. PIES is an acronym for physical, intellectual, emotional and social. By considering needs across this spectrum pupils were able to look at situations and identify the likely needs of those in such situations and consider what might be designed and made to address those needs. Also pupils could scrutinize existing products through the PIES lens to explore just what needs the product met and how it might be improved. The art and design teachers supplied using metamorphosis (changing one shape into another through gradual modifications) and observational drawing of natural form as powerful strategies to explore shape and form, and move pupils away from mundane and stereotypical responses. The art and design teachers also provided the idea of using mood and image boards to help pupils appreciate how the appearance of a product might be related to the life style of a user. The technical drawing teachers gave insight into the use of surface developments (or nets as they are called in mathematics) to help pupils achieve 3D form from 2D materials. Some of the CDT teachers with an engineering background suggested the use of attribute analysis as a means of discovering the defining features of a product, and, more importantly, changing these to develop ideas for new products. These and other design strategies were collected into a chapter in a Student Book. Each strategy was supported by a short focused task which gave pupils the opportunity to practice the strategy so that they could gain some fluency in its use before using it in a full blown designing and making assignment (Barlex 1995). Collecting the strategies into a single chapter in the book that pupils took to all their technology lessons gave each teacher, whatever his or her previous discipline, access to the collective wisdom of all those teaching the subject. This collaborative endeavour helped the subject define itself in terms of the knowledge of those teaching it, despite the fact that this knowledge was not in any sense evenly distributed across the community of practice.

The report ‘All our futures: Creativity, culture & education’ (Robinson 1999) argued strongly for teaching pupils to be creative, and one of the oft quoted benefits of technology education is that it can enhance pupil creativity (Rutland and Spendlove 2007, Nicholl et al 2008). However there has been concern that prevailing practice in design & technology did not live up to these expectations (Parker 2003). Hence a challenge to design & technology in England was to develop a curriculum that enhanced pupil creativity. One response to this challenge was the Young Foresight project which required pupils to work collaboratively in designing, but not making, products and services for the future. In this task the pupils were supported by mentors from industry. The evaluation of the project (Murphy 2003) revealed that pupils saw the value of working together and fully acknowledged that they were able to be more creative in their responses than if working as individuals. The project took this collaborative approach further in deliberately involving the industrial mentors in contributing to the refinement of the curriculum materials being developed by the project. The mentors talked at length with the evaluators concerning the strengths and weaknesses of the materials as they saw them from their industrial perspective. The evaluator reported these as as they saw them, from their industrial perspective. The evaluator reported these comments in full to the project with the result that some materials were discarded, others adapted considerably and some completely new materials were developed (Barlex 2011b). Without collaboration between the industrial mentors and those writing the materials this refinement would not have been possible and the authenticity of the activities acquired through this collaboration would have been lost. The collaboration required the mentors to feel that their comments would be listened to and for the project to value the contribution of the mentors to the curriculum development process. Without this mutual trust this collaboration would have floundered.

Mihaly Csikszentmihalyi (1999) an acknowledged expert on creativity, makes a strong case for building communities that nurture creative genius as opposed to developing highly gifted individuals.

> ... the occurrence of creativity is not simply a function of how many gifted individuals there are, but also how accessible the various symbolic systems are and how responsive the social system is to novel ideas. Instead of focusing exclusively on individuals, it will make more sense to focus on communities that may or may not nurture genius. In the last analysis, it is the community and not the individual who makes creativity manifest. (p. 333).

The work of the Design & Technology Association in setting up the Digital Design & Technology Support Centres reflects this approach. Each support centre is required to work with teachers in its locality, to enable them to introduce digital technologies into their design & technology curricula, so that pupils can use these technologies in their designing and making. The setting up of these centres required collaboration between two groups of professional development providers; those with expertise in the use of product modelling software such as ProDesktop, ProEngineer, Creo, Artcam and Speedstep and those with expertise in the use of programmable interface controllers, circuit board design and manufacture. 36 centers have been set up and over a five-year period individual centers have moved from a position of providing support in either product modelling or modern electronics to providing in service in both arenas. This has required collaboration between members of the two communities and in several cases has resulted in significant curriculum development. Three instances are noteworthy. Collaboration between textiles teachers and electronics teachers has enabled pupils to design and make ‘wearable electronics’. The combined use of CADCAM to model and produce functioning modern electronic products. The introduction of surface mount technology as a cost effective and simpler method of circuit production. Although this example concentrates on supporting teachers in the use of digital technologies, the principal of developing creative communities as a means of curriculum development can apply to the introduction of any level of technology and appropriate pedagogy.

Developing interdisciplinary approaches

Richard Kimbell and David Perry (2001) make a persuasive case for technology education to use interdisciplinary approaches as a means of curriculum innovation, asserting that (design &) technology “has an awkward insistence on being neither a specialist art nor a specialist science. It is deliberately and actively interdisciplinary. It is creative, restive, itinerant, non-discipline” (p.6). This section discusses three examples of interdisciplinary activity involving technology education. The first example concerns the work of David Burghardt and Michael Hacker (2010), who have developed a ‘mathematics infusion’ approach to technology education. They and their co-workers developed a 20 day middle school curriculum unit requiring pupils to plan, design, and physically model a “bedroom” that must meet specific cost and building requirements (e.g., the window area must be at least 20% of the floor area, the minimum room size is 120 square feet, the minimum closet size is 8 square feet, etc). The approach adopted used ‘informed design’ which encourages pupils to increase their content knowledge before they suggest a solution to a problem, in order to be informed by prior knowledge, instead of trial and error (Burdhardt & Hacker, 2004). In an informed design activity, pupils expand their knowledge and skill base by completing a series of short, focused tasks called *Knowledge and Skill Builders* (KSBs). The mathematical KSBs were the crucial Bedroom Design tasks that infused grade-related mathematics, enabling the teachers to reinforce mathematics within the technological context. There were a total of seven KSBs in the Bedroom Design curriculum. These included: geometric shapes, factoring, percentages, mathematics of scale, mathematical nets, aesthetics, and spreadsheets/pricing information. The evaluation of this project indicated that there was a considerable change in mathematical ability, as measured through pre and post infusion tests, for pupils of low ability. Here we have an interesting example of an interdisciplinary approach which leads to enhanced learning of mathematics through technology lessons.

The second example concerns the Nuffield Key Stage 3 STEM Futures Project (Nuffield Foundation 2010). In this curriculum pupils are challenged to work collaboratively in using skills, knowledge and understanding about closed loop systems to identify a problem or question relating to sustainable futures. They then research, design and present a closed loop solution. The pupils undertake relevant preliminary learning concerning waste, transport and climate change. Teachers of mathematics, science and technology are involved in teaching this preliminary learning. In the teachers guide there are example questions that pupils might tackle under the following broad question categories:

- How can we bring transport in our area into a closed loop system?
- How can we redesign familiar household products using cradle to cradle thinking?
- How do we redesign clothing to be within a closed loop system?
- How can we use alternative energy sources to bring energy into a closed loop system?
- How might waste management systems be brought into a closed loop?
- How can geo-engineering help human activities be part of a closed loop system?
- How can we develop ways of providing food that incorporate closed loop thinking?

The task of the teacher is to help pupils move from such broad questions to a more focused question that they can tackle with some confidence. Hence in considering redesign of familiar household products a more focused question would be, 'which is more sustainable, a towel or an electric powered hair drier? Design a cradle to cradle hair drier.' In considering waste management a more focused question would be, 'How does the local authority manage waste disposal? How might cradle to cradle thinking bring waste systems into a closed loop?'

The most basic outcome is a display over two A2 boards, but there are different options depending on the confidence of the pupils and the expertise and numbers of staff involved. The following are all possible:

- Electronic presentation, e.g. slide shows, animations, games
- Flat presentation work, e.g. posters, leaflets, brochures
- Static 3D models, e.g. scale models
- Active 3D models, e.g. working models
- Interactive media, e.g. debates, radio shows, interviews
- Performance, e.g. plays, poetry, song.

The evidence from the piloting of the Futures Project indicated that managing pupils so that they have choice about the question they tackle, and some autonomy in how they develop and present the answers to the question, is challenging for many teachers. It requires a pedagogy far removed from the familiar instruction that dominates the teaching of many school subjects. Technology teachers who are used to supporting pupils through relatively open-ended project work are in a strong position to support colleagues from other disciplines who may not have this experience.

The third example concerns the work of Learning and Teaching Scotland (LTS). In developing teaching resources for the new 'curriculum for excellence' LTS has developed as part of a STEM initiative an interdisciplinary unit of work concerned with renewable energy (Education Scotland 2011). The study of renewable energy is introduced by a short video in which a prominent populariser of science and technology interviews young professional engineers who are working in the renewable energy industry in Scotland. Pupils undergo four learning journeys. The first 'From fossil fuels to wind' meets some of the science requirements of the new curriculum. The second 'Wind, wave and tidal' meets some of the technology requirements of the new curriculum. The third 'Calculating the wind' meets some of the mathematics requirements of the new curriculum. In the fourth learning journey 'This island is going renewable' pupils are challenged with making the case for the use of renewable energy on a small island community. In this challenge the pupils will need to use their learning from the first three learning journeys, and also develop skills in using maps and geographical information systems to gather, interpret and present data relating to location of renewable technologies. This large challenge is divided into three smaller challenges.

Challenge 1 reads:
An important part of any energy plan for a community would include consideration of energy consumption and ways to reduce this. Advise one of the following user groups about the use of energy to support their lifestyle/business:

- an elderly couple who are retired and live in a small cottage
- a family consisting of a mother, father and two teenage children, living in a three bedroom detached house. The father works at the local school, the mother works at the slate mine and the children attend the local school
- a family consisting of a mother and father and a baby aged 6 months, the mother is a full-time mum, and the father works in the timber mill
- the local post office/community shop
- the head teacher of the island school, which has 250 pupils

Challenge 2 reads:
Based on your findings from Challenge 1 on individual user groups, work out an approximate energy usage for the whole island.

- Could all the energy needs of the island be provided by wind, tides or waves?
- Decide as a team the kind of information you will need to know about renewable technologies to help you answer this question**.**
- How will you analyse this information?
- What criteria will you use for comparing the different possible renewable technologies?
- Which other factors will you need to consider?

Challenge 3 reads:
Create an exhibition stand displaying the findings of your investigations into the feasibility of using renewable energy on the island to help inform the islanders about the issues around energy such as:

- energy usage and consumption
- options for generating energy from renewable sources
- best locations for particular technologies
- a scaled model of the island to demonstrate the potential impact that the technologies could have on the landscape

You could include examples or photographs of the working models you have been making in class, charts, diagrams, written explanations, PowerPoint presentations, leaflets, annotated maps, etc.

The approach to interdisciplinary work here is not dissimilar to that of the Nuffield Key Stage 3 STEM Futures project, but there are significant differences. The challenge is set by the teacher rather than being negotiated with the class, the pupils' response to the challenge is clearly structured and there is not the explicit focus on developing closed loop solutions, although to some extent this is implicit in the challenge.

DETAILING THE CURRICULUM

Developing the detail of a curriculum unit, even a small one, is a considerable challenge. This section will discuss the wide range of features that teachers need to consider if they are to develop units of work that can contribute to a broad and balanced curriculum, achieve progression and enable differentiation. The section will also describe in detail how units of work can be designed to include different pedagogical approaches appropriate for technology education, and consider factors that influence implementation. The section will conclude with a discussion of evaluation and revision.

Achieving breadth and balance

Most curricula require the pupil experience to be broad and balanced. This will always be a challenge for technology curricula, as technology is by its very nature very broad. This challenge can be made more demanding by the extent to which a particular curriculum attempts to embrace this breadth. In the USA the Standards for Technological Literacy (International Technology Education Association 2007) are extremely broad and detailed, describing seven different technologies and the learning associated with each from ages 5–17 years across some 60 pages. Achieving complete breadth here seems almost impossible and teachers within a school will almost certainly opt for a limited number of technologies according to their expertise. So, in reality, the resulting curriculum will almost certainly not be that broad. However, this still leaves the problem of balance, in that the learning experience across the chosen technologies must be organized to give each 'technology' similar significance in the timetable. The situation in England is different in that the content is organized according to the medium of designing and making – resistant materials, food, textiles and technical components, hence there appears to be much less breadth than is required by the USA curriculum. However, even this more limited approach gives problems. A common approach to organizing a broad and balanced approach is a rotational circus. At each stage of the circus pupils are taught technology with regard to a particular medium of designing and making and then move on to the next stage where they receive instruction in a different medium. The result is that pupils can experience being taught by four different teachers within a single year. The main argument for this approach is that teachers expert in a particular medium are responsible for the instruction in that medium. The main argument against this model is that continuity and progression are much more difficult to achieve (Davies and Steeg 2005).

One of the difficulties encountered with a broad and balanced approach is that depth in a particular area is sacrificed for breadth across several areas. One approach to dealing with this is to combine traditionally separate areas of teaching. Hence in England at the time of writing there is much interest in the combination of textiles and electronics such that pupils design and make relatively simple wearable items into which simple functional electronic circuits are embedded. Initially these have been simple 'light up with a switch devices' but, as teachers gain more experience, such items are likely to contain embedded intelligence through the inclusion of PICs (programmeable interface controllers) (Gardener and Ambrose Brown 2011). In New South Wales, Australia, the problem of breadth is elegantly solved in the stage 6 syllabus by concentrating on designing and producing without specifying particular materials plus the consideration of new and emerging technologies. The objectives are shown in Table 1. This approach does of course put the decisions about choosing and using materials as a feature of breadth in the hands of the teachers.

Table 1. Objectives for Design and Technology Stage 6 Syllabus New South Wales Australia

Students will develop:
1. knowledge and understanding about design theory and design processes in a range of contexts;
2. knowledge, understanding and appreciation of the interrelationship of design, technology, society and the environment;
3. creativity and an understanding of innovation and entrepreneurial activity in a range of contexts;
4. skills in the application of design processes to design, produce and evaluate quality design projects that satisfy identified needs and opportunities;
5. skills in research, communication and management in design and production;
6. knowledge and understanding about current and emerging technologies in a variety of settings.

Taken from http://www.boardofstudies.nsw.edu.au/syllabus_hsc/pdf_doc/design-technology-st6-syl-from2010.pdf April 2012

Achieving progression

As pupils make progress in their learning of technology, they acquire and can use a wider knowledge base, understand and apply more demanding concepts and are able to use more sophisticated making and manufacturing techniques. It is important that the teacher has ways to enable and reveal this intellectual and psychomotor growth.

In the case of 'designing without making' the Young Foresight project developed a four point conceptual framework to support this sort of activity. In developing and justifying their design proposal pupils were required to take into account four factors:

1. The technology that is available for use. This should be a new and/or emerging technology and be concerned primarily with how the new product or service will work. Pupils should not concern themselves with manufacture.
2. The society in which the technology will be used. This will be concerned with the prevailing values of the society, what is thought to be important and worthwhile. This will govern whether a particular application of technology will be welcomed and supported.
3. The needs and wants of the people who might use the product or service. If the product does not meet the needs and wants of a sufficiently large number of people then it will not be successful.
4. The market they might exist or could be created for the products or services. Ideally, the market should one with the potential to grow, one that will last, and one that adapts to engage with developments in technology and changes in society.

Clearly, these factors interact with one another and influence the sorts of products and services that can be developed and will be successful. Each of these four factors can be a feature of progression. The technology being considered can vary from simple to complex, and the level of knowledge and understanding required to indicate the feasibility of the proposal will vary accordingly. The view of the prevailing societal values can vary from naïve to sophisticated, and the way in which these values are identified and portrayed can vary accordingly, requiring pupils to use trend data at high levels of performance. The consideration of needs and wants can be based on simple anecdotal considerations or involve a PIES analysis (see page xx), which in itself can be carried out at different degrees of sophistication. The consideration of the market can range from simply identifying a particular market to considering the sorts of business model that might be appropriate for that market and/or sectors within that market, and even consider the sorts of return that investors might expect from the size of the market and the extent of market penetration. Hence a teacher can, as pupils move through a sequence of designing without making tasks, require a class or individuals within a class to engage with each of the four features in ways that become more demanding and hence achieve progression.

As pupils move through a sequence of 'making without designing' tasks in resistant materials progression can be seen as starting with hand tools, progressing to machine tools and finishing with computer controlled machine tools. This is not as straightforward as it seems. The use of a coping saw to cut a complicated curved shape accurately, such that several attempts lead to identical shapes, requires a high level of skill and considerable practice. It is probably easier to use a vibro saw for this task and this requires less skill and less practice. Drilling a perpendicular hole with a hand held drill be it a hand operated or a hand held power tool is more difficult than achieving a perpendicular hole with a pillar drill. Pupils with few, if any, traditional making skills can be quickly taught to use a CAD file to operate a laser cutter and achieve results far beyond their manual dexterity. A case can be made for starting with hi tech making and a very limited use of a simple hand tools e.g. cutting to length, and simple machine tools e.g. drilling holes and then moving on to more demanding hand and power tools. Overlaid on this progression there has to be a development of measuring and marking out skills and also finishing techniques. An interesting example of introducing young pupils to hi tech making is provided by the Techlink project (www.techlinkinschool.com) in South West England. Here pupils as young as 7 years old are introduced to 2D design software and learn how to cut out their designs using a simple 2D flat bed cutter (Barlex and Miles Pearson 2008). The manipulation of ingredients in food technology lessons probably follows the conventional move from hand tools (cutting, chopping, slicing, mixing, whisking) to the use of food processors. In working with textiles cutting out and sewing pieces together usually starts with hand techniques before pupils move on to using sewing machines but even here the influence of CADCAM is beginning to make an impact. It is relatively easy to learn how to produce designs for embroidery on screen and then have a computer controlled sewing machine carry out the embroidery. The application of surface decoration, through a combination of CAD and computer controlled dye sublimation is now through a combination of CAD and computer controlled dye sublimation, is now becoming standard practice in many textile technology courses in the UK (Ambrose Brown 2011).

As pupils move through a sequence of designing and making assignments progression can be achieved by increasing the level of challenge within the assignments over time. This progression in challenge has been achieved through the manipulation of the following features.

- The way the product works
  The greater the complexity of technical working required, the more challenging the task. The more difficult the product is to make, the more challenging the task.
- The materials, components, tools and equipment
  The wider the range of materials and components available, the more challenging the task. The wider the range of tools and equipment to be used, the more challenging the task. These ranges should get wider as pupils become older.
- The time available
  This is usually decided by the teacher, although time management within the task is a feature over which pupils have some control and where decisions can affect

success. Long periods of self-direction are very demanding in terms of planning and sustaining motivation.

- The type of working required
  The range of scenarios here includes: working solo; working as part of a group all dealing with a single medium of outcome; working as part of a group with different members dealing with different media of outcome. The more lines of communication, the more challenging the task becomes.
- Presentation and reports
  Presenting and reporting design proposals and/or methods used for tackling the task add to the demands of the task.
- The level of autonomy
  The extent to which pupils are required to self manage their progress through a task is an important feature of progression. If developing autonomy is seen as important then it might be necessary on occasions to reduce some of the other demands of the task.
- The range of conflicting requirements inherent in the task
  Resolving conflicting requirements is one of the most challenging aspects of design. Varying the number of stakeholders whose needs have to be considered is one way of manipulating the range of conflicting requirements. For example, in designing and making a toy pupils might consider just the child who will play with the toy, but they might also consider the parents and carers, the affordability of the toy, and the place of the toy in the market of similar toys.

Teachers can manipulate these features to make a designing and making assignment more or less challenging. The teacher may want to do this for the class as a whole in response to the timing of the task. A task devised for 11/12 year olds can easily be made suitable for 12/13 year olds by changing the challenge. Or the teacher can do this on an individual basis through negotiation with a pupil, so that the pupil has to meet requirements that are more or less stringent than those for others in the class.

Progression in the exploration of the relationship between technology and society has been described in the New Zealand Technology curriculum as a set of achievement objective statements concerning the characteristics of technology. These are shown in Table 2.

This set of statements provides an interesting starting point for considering such progression but does not yet represent an agreed orthodoxy. Level 3 for example is concerned with the nature of technological knowledge as validated by successful function in implicit contrast to the nature of scientific knowledge which is validated by successful explanation. This can be simplified as "if it works then the technological knowledge must be sound" but even at this level it requires an almost philosophical stance on the part of the learner. In contrast the idea of unintended consequences appears at Level 8 and a simple costs benefits analysis of the motorcar enables quite young pupils to appreciate this idea.

Table 2. Characteristics of Technology from the New Zealand Technology Curriculum (2007)

Nature of Technology	*Characteristics of technology*
Level 1	Understand that technology is purposeful intervention through design
Level 2	Understand that technology both reflects and changes society and the environment and increases people's capability.
Level 3	Understand how society and environments impact on and are influenced by technology in historical and contemporary contexts and that technological knowledge is validated by successful function.
Level 4	Understand how technological development expands human possibilities and how technology draws on knowledge from a wide range of disciplines.
Level 5	Understand how people's perceptions and acceptance of technology impact on technological developments and how and why technological knowledge becomes codified.
Level 6	Understand the interdisciplinary nature of technology and the implications of this for maximising possibilities through collaborative practice.
Level 7	Understand the implications of ongoing contestation and competing priorities for complex and innovative decision making in technological development.
Level 8	Understand the implications of technology as intervention by design and how interventions have consequences, known and unknown, intended and unintended.

As at 18 September 2007

Enabling differentiation

When pupils are tackling 'designing and making' assignments it is important that that each pupil can tackle the assignment with the expectation of success and through this reveal his or her level of achievement. One way to achieve this is for the teacher to deliberately set different assignments of different demand to different pupils in the same class. This is not always easy and can lead to resentment from pupils e.g. "Why's she doing that when I'm doing this?" If the different assignments require very different tools, materials and equipment then the lessons can become difficult to manage. Another way is to set all pupils the identical assignment, and provide appropriate support to each pupil as he or she tackles the assignment, and achieve differentiation through the differing sophistication of the outcomes that each pupil produces. This is much more manageable but relies to a large extent on the initiative of the pupils. A middle way is to set a class the same general design brief for the designing and making assignment, but negotiate on an individual basis the specification that the final product should meet. In this way the pupil is involved in the decisions informing the demand of the assignment they will tackle, and the teacher has the opportunity to ensure, as far as is possible, that each pupil is operating at the limit of their ability, and will be able to reveal their level of achievement. This approach should ensure stretch and challenge for pupils of all abilities. It also allows the teacher to build trust with the pupil in that if the pupil is arguing for a specification that appears, in terms of previously demonstrated achievement, to be too demanding the teacher can discuss this with the pupil, and strike a bargain involving the pupil working more diligently, acquiring new skills, doing extra homework etc. as the requirement for tackling his/her desired specification.

Devising units of work

This section will begin by considering how units of work which focus on 'designing without making', 'making without designing', 'designing and making' and 'exploring technology and society' can be devised such that taken together they provide a coherent learning experience. To achieve this it is important that there is a clear relationship between the learning in each unit. Hence it is important that the making skills that the pupils learn in making without designing can be utilized when the pupils are designing and making. It is important that the exploring technology in society activity has some relationship to the both the designing and making activity and the designing without making activity. It is probably best to begin with defining the designing and making activity, and for the purposes of this section a relatively 'low risk' approach will be adopted i.e. the pupils will not be very much involved in deciding the nature of the designing and making activity that they will tackle. It is important that the activity has clear educational objectives. These can only become clear if the task is sufficiently specified. For example, 'Design and make an educational aid for two-year-olds' is an identified task in that it can be chosen by a teacher and set for a class, but it is barely specified. It is impossible to list what pupils need to be taught to tackle this task, or what they are likely to learn through tackling it. 'Design and make a series of flash cards (no more than six) to teach two-year-olds the names of household pets' is the same identified task, but highly specified. It is quite possible to work out what needs to be taught and what is likely to be learned. An intermediate position is clearly possible 'Design and make an educational aid to help two-year-olds learn the names of familiar objects'. A team of teachers can use the framework shown in Table 3 (adapted from the Nuffield Design & Technology Project) to specify the designing and making assignment.

Inspection of the above framework reveals that the preliminary tasks might be configured to include a making without designing activity, and that the case studies could easily involve the pupils in activities in which they explore the relationship between technology and society. At this stage it is important to develop a relevant designing without making activity. Imagine that the team had devised a designing and making assignment that required pupils to produce a child's toy that worked by means of an electric motor. The question is what could pupils consider designing

Table 3 The Nuffield Design & Technology Framework for specifying a design and make assignment

1. A short assignment statement that indicates the type of product that the pupil will design and make
2. A description of the setting in which the assignment is tackled, this is sometimes referred to as the context of the assignment
3. A description of the learning that can be achieved through the assignment and these can be categorized into designing, making, technical matters and commercial matters
4. A description of the design decisions to be made in tackling the assignment and whether these have already been made by teacher or whether they will be made by the pupils as they progress through the assignment
5. The values which might be taken into account in tackling the assignment which can be considered under the following headings: technical, moral, social, aesthetic, economic and environmental. Note these do not represent mutually exclusive sets and there will often be overlap between the categories
6. A sample brief which teachers can use as is, or adapt
7. A sample specification using three sub headings: what the product has to do, what the product has to look like and other features. The teachers can use this as an example and individual pupils can then either use it as it stands or discuss possible changes.
   It is essential that every pupil has a written specification against which to compare developing design ideas and the performance of the final product.
8. Preliminary learning tasks that cover learning likely to be required for success in the assignment
9. Case studies that are relevant to the assignment
   Engaging with case studies enables pupils to understand about technology in the world outside school: the way firms and businesses design and manufacture goods and how goods are marketed and sold. Through case studies pupils can also learn about the impact that products have on the people who use them and the places where they are made. Case studies can be presented to pupils through a wide variety of media and it is important that the way the case study is presented provokes an active response from the pupils.

without making that is related to, and builds on, their learning in the designing and making assignment. One possible strategy is to consider how the product might be manufactured in a circular economy. This would involve the pupils using cradle to cradle thinking (Braungart & McDonough 2009) and devising a manufacturing process that was closed loop. In such a process the materials and components used in the first place would need to come from a sustainable source or waste stream from another manufacturing process. In addition when the useful life of the product was over there would need to be systems in place to return all the materials and components to the manufacturing systems for other products. Devising such a manufacturing process would be an unusual example of designing without making. This would be an interesting and relevant challenge and provide a means of introducing pupils to new and very important thinking about the way manufacturing industry needs to adapt if global resource depletion is not to have a serious and deleterious effect on world economies.

Consider what might happen if the planning team start with a designing without making exercise such as that envisioned in Change of Place (Barlex, 2007b). This assignment requires pupils to consider the limitations of current transport systems and design alternatives that take into account the development of intelligent infrastructure. This activity would certainly involve an exploration of the relationship between technology and society and be the starting point for considering the needs of those who travel. It could provide an introduction to designing and making a wide range of 'traveler products', embracing for example information systems, signage, luggage, food on the move, travel games and clothes for travelling. Such a wide range of product possibilities would probably need to be organized amongst teachers with different specialisms, and require different making without designing activities according to those specialisms.

Implementation

The way in which a unit of work can be implemented depends to some extent on the way those teaching can use time. In a conventional time table the teaching and learning will be organized into discrete lessons, perhaps two lessons of one hour duration each week across as many as 10 weeks giving a total of 20 hours teaching time. The difficulty with this 'drip feed' approach is that it can fragment those activities that take more than a single lesson to complete and time is spent in each lesson getting out and putting away the tools, materials and equipment required. An advantage is that pupils have dwell time between lessons and can use time between lessons for related activities e.g. case study work or aspects of designing without making. An alternative approach is to conflate the time of the individual lessons and carry out the unit over three days teaching. The three days can be organized into a single block in which case there is no time between lessons and little dwell time but if they are managed as three separate days separated by a week then this difficulty is overcome. The advantage of this 'immersion' approach is that the learning can be very intense and efficient, as much less time is spent 'getting out and putting away'. A big disadvantage is that this is often outside normal school practice and requires additional organization. Primary schools are more easily able to adopt this practice (Barlex 2008), but some secondary schools in England have recently adopted so called 'drop down' days for interdisciplinary activity, so in principle this approach could be applied to technology lessons in these schools (Nuffield Foundation 2010).

The implementation of designing and making assignments requires that the teacher is active in driving the task forward, but in such a way that pupils retain as much autonomy as possible. Teachers can use the series of questions shown in Table 4 to help decide on their actions as the pupils move through the assignment. The teacher can see the ♦ as a slider that can be moved to the action that is appropriate

Table 4. Teacher decisions during a designing and making assignment

Designing and making assignment activity	Teacher decisions
Introducing	How will you introduce the assignment? Talk start Walk start Hand start Read start Computer start See start Self start
Linking	Which other area of the curriculum do you want your pupils to use in this Capability Task? Is it . . maths, science, art and design, IT, one of the key skills, literacy, citizenship?
The brief	What is the scope of the brief? Just how open or closed should it be for your pupils? **Closed** ← – – – – – – – – ♦– – – – – – – – → **Open**
Trapping ideas and first feedback	Use getting design idea strategies for pupils to produce initial design ideas. Do you want them to produce just one idea each or lots of different ideas? Display the ideas so that each pupil can get feedback from the rest of the group **Just one idea** ← – – – – – – – – ♦– – – – – – – – → **Lots of ideas**
The specification	How complex should the task be for particular pupils? Negotiate the specification with individual pupils to achieve good differentiation. **Simple** ← – – – – – – – – ♦– – – – – – – – → **Complex**
Modelling solutions	What's the diversity of experience here? How many different sorts of modeling will be happening in your class to produce prototype products? **Just one sort** ← – – – – – – – – ♦– – – – – – – – → **Several different sorts**
Second feedback	Working in pairs pupils take on alternate roles of client and designer. Client has specification and designer has prototype product. Will the product meet the specification? Will it delight the client? What questions will the pupils ask ? Will you give them questions or will they make them up? **Given questions** ← – – – – – – – – ♦– – – – – – – – → **Free questions**
Teacher feedback	Use prototypes and pupil's work books to give three point feedback to each pupil • a comment about the design • a comment about the production • a comment to motivate either overall or a point of detail personal to the pupil
Production	What range of tools, materials and technical components will pupils use **Narrow range** ← – – – – – – – – ♦– – – – – – – – → **Wide range** Will all the pupils be able to make their design? How much help will you need to give? Can they help each other? Will you need to demonstrate? Will you need to set up specialist making stations? ?
Final feedback	How will your pupils evaluate their products? On their own? In pairs or small groups? Through general class discussion? What criteria will they use for this evaluation?
Performance review	How will you help pupils identify future targets for the class as a whole and for individual pupils?

Key: See the ♦ as a slider which the teacher can move to the correct teaching decision for the class being taught. An important function of the information in Table 4 is that it can provide the basis for discussions among members of the teaching team. It is perfectly acceptable for teachers with different classes to position the slider at different positions from one another in response to their understanding of their pupils. In terms of progression as pupils through a sequence of designing and making assignments the slider would move towards the right hand side. This approach was developed by the Nuffield Design & Technology Project and more details can be found in the Teacher Guide available at www.nationalstemcentre.org.uk/elibrary/file/3599/ks3_teacher_guide.pdf

Evaluation and revision

At the end of the teaching of a unit of work it is important to evaluate it from a variety of perspectives. Initially this section will consider how evaluation and revision at the local level in a single school might be informed by the views of pupils, parents, prospective employers and teachers. Then consideration will be given to larger scale evaluation, and how this can inform curriculum development on a wider scale.

It was noted earlier that in most technology curricula pupils have only very limited influence on the nature of their curriculum experience. The teachers are the gatekeepers of pupil curriculum experience. Be this as it may, the views of pupils can be extremely useful. Obtaining answers from pupils to the following questions provides a starting point

- Overall on a scale of 1 – 5 how do you rate your enjoyment of this unit?
- Which parts of the unit were the most enjoyable?
- Which parts were the least enjoyable?
- Describe what you think you learned in the unit
- Which parts did you find the most difficult?
- Which parts did you find the most straightforward?
- If you were the teacher what would you do differently next time?

In asking pupils to provide this sort of feedback it is probably necessary to give them time to discuss the questions in small groups before answering on an individual basis. If the pupils are to take the exercise seriously it is important that they can see that their views are taken into account in subsequent iterations of the unit. This can be made quite explicit to the pupils by explaining to future groups of pupils tackling the work the changes that have been made as a result of pupil feedback. General points for improvement of the pupil experience of all units of work may well emerge, and again the ways this is taken into account can be explained to pupils.

Obtaining feedback from parents is less straightforward. Bill Nichol (2008) has reported that parents often value very conservative technology curricula because they do not appreciate the learning intentions or the learning experience of more innovative approaches. However this research revealed that once parents become informed they develop positive views with regard to ways of learning that are outside their own previous learning experiences, and develop creativity and innovation in their children. Hence in obtaining feedback from parents it is important that they are aware of the learning intentions and the range of learning outcomes. One way to achieve this is for the technology department to produce a termly newsletter for parents, which describes the work carried out each term with a brief commentary on the learning intentions, and celebrates pupil success. Part of the newsletter can invite feedback. In many places this newsletter could be electronic and customized for parents of particular classes. Hopefully this request for feedback will encourage parents to talk to their children about their learning experience in technology. It is important that the feedback is not time consuming and probably inevitable that it will be general. The limited set of questions below will probably suffice:

- Did your child find the experience rewarding?
- Do you think it was a worthwhile experience for your child?
- Any other comments?

As with pupils it will be important to find ways of informing parents as to the way their comments are being used and it may also be worth asking if any of the parents have relevant expertise or experience with regard to the work.

The views of prospective employers are important because their support for the technology curriculum can have a positive influence on the level resources provided. It is unrealistic to expect local employers to give detailed feedback on individual units of work. It is important that they know something about the technology curriculum, and in particular the personal qualities and competences it develops in young people. It is important that they value the qualifications pupils might achieve. Hence it will be useful to provide an 'employer update' on the technology curriculum. An effective way to do this can be through the schools governing body, which will have local employer representation, and this can be used to establish a dialogue about the technology curriculum.

Teachers will be able to provide detailed and useful feedback and it is important that all those who have taught the unit have the opportunity to discuss their thoughts, and develop a considered view that can be used to inform further iterations of the unit and teaching of subsequent units. It will be necessary to consider the extent to which the unit was manageable in the following ways: time available, consumable materials required, availability of tools and equipment including ICT provision. It will be necessary to consider the extent to which the unit met the learning intentions. There will be a range of concrete evidence available here e.g. products made or designed and made, design proposals from designing without making, various media concerned with views on the interaction of technology and society plus pupils' design portfolios. Much of this evidence can be used to assess pupil's individual levels of performance. During the teaching there will have been opportunities for assessment for learning (Moreland, Jones and Barlex 2008) and those teaching the unit will be able to recall instances of the difficulties and successes pupils experienced during the unit. On occasions pupils may have taken a formal end of unit test and these results can be taken into account. There will also be the opportunity to discuss the effectiveness and accessibility of any learning resources used during the unit. And of course there will be the teachers' overall impressions, an almost gestalt sense of the worth of the unit. Teachers will also be able to take into account feedback from pupils, parents and local employers. There is such a wealth of data here that it is easy to become overwhelmed. Hence it is probably worth establishing a system of different intensities of scrutiny. For a well-established unit that is known to be successful the evaluation can be light touch seeking to confirm that it is performing as expected. For a completely new unit of work then a much more detailed evaluation will be required. These different levels of curriculum unit evaluation can be used with the Interactive Curriculum Development Matrix tool described earlier, and in this way the evaluations can lead to revision as part of a strategy for manageable change.

A review of the literature on the impact of design & technology in schools in England (Harris and Wilson 2003) concluded that 'the development of the D&T curriculum and learning and teaching would benefit from more funded and systematic research in D&T generally' (p62). Large-scale evaluation would fall into this category and is especially important for curriculum development that is attempting to influence technology curricula across a large number of schools. Such evaluations are necessary if technology education is to have the credibility afforded to other subjects in the school curriculum, which have a large bank of research evidence to inform their practice. Here are two examples of such research in technology education. The first is provided by the mathematics infusion project, bedroom design, described earlier (Burghardt and Hacker 2010). Pupil participants were from 8^{th} grade classrooms in 13 middle schools in New York State. 15 teachers taught the mathematics infusion lessons and 14 different teachers taught the control (business as usual) curriculum. 811 pupils (484 infusion and 327 control pupils) took part and were assessed pre and post infusion on relevant forms of mathematical ability. There was no discernable increase in mathematical performance in the control group but comparison of pre and post mathematical test scores for those experiencing the infusion of mathematics revealed that three out of the four quartiles achieved higher scores post infusion. The most dramatic change was for those in the first and second quartiles, indicating that those pupils who were lower performing in mathematics improved the greatest. Evaluations such as this are time consuming and expensive and require a high level of research expertise. It is perhaps not surprising that enhanced learning in mathematics was achieved given the effort to engage pupils with mathematics. Some have cautioned that technology educators should be wary of such endeavours, which may be seen as subverting the purposes of technology education away from technology to achievement in other subjects, particularly those that are subject to high stakes testing (Kimbell 2011, Williams 2011). However, at times when technology education is under threat, as is the case in England at the time of writing (Design & Technology Association 2011), it is useful to have indicators of the positive impact of technology curricula.

Another example is provided by the Young Foresight project described earlier (Young Foresight 2000). The evaluation took place across 12 schools which included urban mixed comprehensives with very high proportions of pupils identified as having social, economic disadvantage and special educational needs, urban mixed comprehensive specialist technical colleges, a rural mixed comprehensive with restricted ability intake and an independent single sex school

The data collected included:

60 hours of observation, video/audio recorded and field notes
15 teacher interviews
60 pupil interviews
11 interviews with mentors from industry who worked alongside teachers
Pre and post questionnaires of pupil learning (N=145)
Samples of pupils' work
Samples of teachers' worksheets
Teachers' journals

As with the previous example this was a time consuming exercise requiring a high level of research expertise. There is a significant difference between this evaluation and that carried out by Burghardt and Hacker. In this case it was not intended to be an evaluation of a finished project. This evaluation was set up to inform the development of the project with particular regard to the following:

- Teachers', mentors' and pupils' views on the approach and resources
- The impact on pupils' learning
- The characteristics of effective mentor support

The effectiveness of the project in meeting its aims was clearly an important issue, but the data collection was designed to answer many more questions than whether the project, in its initial form, worked. Rather the questions were in what circumstances does the project meet its aims, what circumstances undermine the achievement of the project aims, and to what extent is this attributable to the project materials, approach, training and/or factors associated with teachers, pupils and schools? Formative evaluation of this kind is rare. It is however, essential if curriculum interventions are to succeed in effecting change in teachers' practice and pupils' learning. The findings of the evaluation were invaluable to the curriculum developers, and informed significant revision of the final resources, and clarification of the required pedagogy (Barlex 2011b, Murphy 2003). The Young Foresight project was able to use the evaluation findings to convince both government and industry that it was worth funding professional development for teachers into ways in which they could use the project and its approach to develop pupils' collaborative creativity and design skills. This eventually led to the Young Foresight project being adopted by the National Strategy for design & technology in England (Department for Education and Skills 2004). It is extremely unlikely that the project could have had this dissemination and impact without the extensive and insightful evaluation provided by Patricia Murphy and her team at the Open University.

The most recent curriculum development in technology education in England, the move towards a digital design & technology curriculum being carried out through professional development managed by the Design & Technology Association, provides an interesting example of the way that government funding for such development is being related to impact. The initiative receives only modest funding and in the current economic conditions this is not likely to continue. Hence the teachers who attend the courses this year will be required to provide details of their actions in an on-line survey. The Design & Technology Association hopes to be able to show that the professional development provided is leading to beneficial curriculum change. The intention is that such evidence can be used to convince government that it is worth continuing and perhaps increasing the level of funding for this professional development. The evidence can also be used to persuade commercial and professional body stakeholders that it is worthwhile for them to invest in the programme.

CONCLUSION

Technology is one of the newer subjects in the school curriculum. It is different from many school subjects in that it is less concerned with the acquisition of knowledge (knowing that) and more concerned with the development of capability (knowing how). The rapid pace of technological developments in the world outside school inevitably challenges the teaching of technology in schools to reflect these changes and it is through curriculum development that such challenge is addressed. The landscape of technology education is in no sense homogeneous. There are considerable national differences. Professional institutions may influence the technology curriculum in different ways in different countries. Also there is often considerable regional variation. This variation can play out in the extreme at the local level where stakeholder support may be different in different locations. Hence the role of the curriculum developer is complex. He or she has to contend with this variation in the light of assessment requirements, resource provision and different approaches to implementation. Empowering teachers to become curriculum developers in such complicated situations is an important facet of initial teacher education. Hence individual teachers can play a useful role in developing new curricula in their own schools. If successful these innovations can be adopted by and promoted by technology teacher professional associations, which extends the impact of the development.

As in most development activities the role of collaboration is important. During the introduction of technology into a curriculum the subject will be taught by those who had previously taught other related subjects. It is important that teachers from these different disciplines collaborate in making their contribution to the fledgling technology curriculum, and this collaboration should be both acknowledged and utilized by curriculum developers. Technology teacher professional associations can be proactive in supporting curriculum development through instigating the provision of professional development that encourages and supports teachers in being curriculum developers. In this way the professional association can contribute to the development of a creative community whose achievements will far outweigh those of individual teachers. There is of course a place for large scale curriculum development projects which are intended to have wide influence in clarifying the nature of the subject, and the ways in which it can be taught and assessed. It is important that such projects take strong steps to involve teachers in the development process. In parallel with this it is important that the voice of those engaged in 'doing' technology is heeded by curriculum developers. In the world outside school technology is a highly interdisciplinary activity and this can be reflected in the school curriculum. Such interdisciplinary approaches offer considerable scope for curriculum developers and the STEM agenda provides a particularly rich environment for such activity.

The challenge facing curriculum developers in designing a technology curriculum is that they must respond to any national or regional requirements. In addition the sum of the units of work comprising that curriculum has to provide breadth and balance, achieve progression and enable differentiation. Providing breadth and balance in a subject as broad as technology is particularly demanding and some attempts to meet this requirement leads to pupils being taught by a succession of teachers with particular expertise for short periods. This has been criticized as leading to fragmentation and a lack of continuity. Achieving progression in such a fragmented learning environment may then become particularly difficult. However several curriculum development initiatives have developed approaches and devices that can be used repeatedly over time and contribute to progression albeit within a disjointed situation. It is important that all pupils make optimum progress although they are operating at different levels of achievement. Achieving this differentiation through pupils tackling widely different tasks may lead to considerable classroom management problems. The approach of differentiation through negotiation in response to a common task that will require pupils of differing levels of achievement to have access to virtually identical resources avoids such difficulties.

Devising a unit of work plunges the curriculum developer into the detail of the learning activities that take place within individual lessons. Teachers acting as curriculum developers are in a strong position to deal with such detail and curriculum developers who are not teachers must take strong note of the views of teachers with regard to what is possible in the classroom. It is important that the development is not stymied by undue conservatism but it is essential that the suggested learning activities are realistic and provide new approaches and content that whilst challenging for both teachers and pupils are not daunting. It is important that the learning that takes place in a unit of work, both conceptual and procedural, is clearly identified and enabled by the suggested learning activities. There are usually several different ways to implement a given unit of work unless it is overly prescriptive. One important consideration concerning implementation is the extent to which time in the school timetable can, on occasions be organised to provide an immersion experience, during which pupils can enjoy long periods of time concentrating on a single subject, in this case technology. Whether the pupil is learning through a sequence of separated lessons or an immersion experience the role of the class teacher is crucial in maintaining motivation and a high expectation of progress through the demands of the task. Given that pupils are often expected to be self directed during technology lessons, especially those concerned with designing and making, it is important that curriculum developers provide details of the scaffolding which teachers scan use to support pupils in ways that do not detract from pupil autonomy.

Evaluation of a technology curriculum can take place at a variety of levels. In a single school such evaluation might focus on a single unit of work, the achievements of pupils through that unit and the views of local stakeholders – parents, pupils, teachers and local employers. This data can be used to decide the extent to which the unit was successful and enjoyable and what changes if any are required to meet any shortcomings. Evaluation across a large number of schools is a much more demanding affair and requires academics with experience and expertise in evaluating educational endeavours. It is important that such evaluation is independent of the developers and those teaching the curriculum. But it is also important that the evaluators have sufficiently close links with the developers to be familiar with the educational intentions of the development, and the means by which these were expected to be achieved. For technology, which has a wide range of educational intentions, it is important that there are evaluations at different scales. Such evaluation is of course important to inform the work of future curriculum development but it has a more important role, which is to indicate the powerful learning that can be achieved and endorse effective pedagogy. This is particularly important in situations where technology education may be seen as less valuable, and hence have a lower profile and receive less resources, than education in subjects that are long established in the school curriculum. It is important that such evaluation can be extended to include the effectiveness of professional development in helping teachers implement new technology curricula. The demonstration of such effectiveness may be used to leverage funding for continuing professional development.

The technology curriculum is highly variable, strongly contested and subject to continual change, as it tries to reflect technological activity in the world outside school. The task facing curriculum developers in championing the subject and moving it forward will always be challenging and at times may appear daunting but without continued effort to maintain, develop and enhance a modern and rigorous technology curriculum an essential component of young people's education may disappear.

REFERENCES

Ambrose Brown, H. (2011). *Optical Illusions STEM Careers Resources*, Wellesbourne: Design & Technology Association. Available at http://www.data.org.uk/index.php?option=com_content&view=article&id=637&Itemid=566

Arthur, W. Brian. (2009). *The Nature of Technology.* London, England: Allen Lane

Barlex, D. (2011a). Dear Minister, This is why design & technology is a very important subject in the school curriculum. *Design and Technology Education: An International Journal*, *16*(3), 9–18

Barlex, D. (2011b). Young Foresight Project: a UK initiative in design creativity involving mentors from business and industry in France, B. & Compton, V. (Eds.) Bringing communities together: Connecting learners with scientists or technologists, The Netherlands, Sense

Barlex, D. (2008). Nuffield Primary Design and Technology Project: a retrospective in W Gwyn Lewis (Ed) Education *Transactions Design and Technology in The Curriculum* Bangor: School of Education Bangor University

Barlex, D. (2007a). Assessing capability in design & technology The case for a minimally invasive approach. *Design and Technology Education: An International Journal*, *12*(2), 9–56

Barlex, D. (2007b). Change of Place, a unit of work concerning what's wrong with cities and transport systems and what can be done about it? Available at http://www.interactive.bis.gov.uk/foresight/TeachersGuide/Index.html Accessed 4 June 2011

Barlex, D. (1995). *Nuffield Design and Technology,* Harlow: Longman.

Barlex, D. and Miles-Pearson S. (2008). Introducing CADCAM into primary schools Part 1 of a case study – developing the curriculum In Norman, E. W. and Spendlove, D. (Eds.) *Designing the curriculum – making it work* The Design and Technology Association International Research Conference 2008, 5–10, Wellesbourne, Design & Technology Association

Braungart. M. & McDonough, W. (2009). *Cradle to cradle* London, England: Vintage Press

Burghardt, D. M., Hecht, D., Russo, M., Lauckhardt, J. & Hacker, M. (2010). A Study of Mathematics Infusion in Middle School Technology Education Classes *Journal of Technology Education*, 22, 58–74

Burghardt, M. D. & Hacker, M. (2004). Informed design: A contemporary approach to design pedagogy as the core process in technology. *The Technology Teacher, September,* 6–7.

Csikszentmihalyi, M. (1999). Society, culture and person: A systems view of creativity. In R. J. Sternberg (Ed.), *The nature of creativity* (pp. 325–339). Cambridge, UK: Cambridge University.

Davies, L. & Steeg, T. (2005). Slow Down: how to stop spinning at KS3 Pearson In Norman, E. W., Spendlove, D. & Grover P. (Eds), *Inspire and Educate* The Design and Technology Association International Research Conference 2005, 51–56, Wellesbourne, Design & Technology Association

Department for Education and Skills (2004). *Key Stage 3 National Strategy Foundation subjects design and technology Framework and training materials* London, England HMSO

Design & Technology Association. (2011). Manifesto can be found at http://www.data.org.uk/generaldocs/Manifesto/data_manifesto.pdf Accessed August 3 2011

Design & Technology Association. (2010). Information about open starting pints can be found at http://www.ectcurriculum.org/index.php/starting-points Accessed June 4 2010

Education Scotland. (2011). Renewables available at http://staging.ltscotland.org.uk/stemcentral/contexts/renewables/index.asp Accessed 4 June 2011

Gardener, P. & Ambrose Brown, H. (2011). Private communication concerning in service training from West Midlands Digital D&T Support Centre www.digitaldt.co.uk

Harris, M. & Wilson, V. (2003). *Designs on the Curriculum? A review of the literature on the impact of Design and Technology in schools in England*. Glasgow, University of Glasgow

Institute of Electrical and Electronic Engineers. (2012). http://www.ieee.org/education_careers/education/preuniversity/index.html

International Technology Education Association (2007). *Standards for Technological Literacy*. Virginia: International Technology Education Association

John-Steiner, V. (2000). *Collaborative creativity*. England: Oxford University Press

Kimbell, R. (2011). Handle with care … *Design and Technology Education: An International Journal*, *16*(1), 7–8

Kimbell, R. (2007). e-assessment in project e-scape. *Design and Technology Education: An International Journal*. *12*(2), 66–76

Kimbell, R. & Perry, D. (2001). *Design and Technology in the knowledge economy*, Executive Summary, Engineering Council, London

Layton D. (1995). Constructing and Reconstructing School Technology in England and Wales. *International Journal of Technology and Design Education*. *5*, 89–118.

Mitchell, A. (2009). Private communication with the author at the Design & Technology Show at the National Exhibition Centre, Birmingham. Andy Mitchell is an Assistant Chief Executive in the Design & Technology Association

Moreland, J., Jones, A. & Barlex, D. (2008). *Design and technology inside the black box Assessment for learning in the design and technology classroom*. London England: GL Assessment

Murphy, P. (2003). *The Place of Pedagogy* in Barlex, D (Ed*) Creativity in crisis? Design & technology at KS3 and KS4*. Wellesbourne, UK: Design and Technology Association.

New Zealand Curriculum. (2007). available at http://nzcurriculum.tki.org.nz/Curriculum-documents/The-New-Zealand-Curriculum Accesses August 3 2011

New Zealand Qualifications Authority. (2011). available at http://www.nzqa.govt.nz/

Nicholl, D., McLellan, R. & Kotob, W. (2008). *Understanding creativity for creative understanding*. Cambridge, UK, Faculty of Education, University of Cambridge

Nuffield Foundation (2010). *Nuffield Key Stage 3 STEM Futures Project* available at http://www.nuffieldfoundation.org/nuffield-stem-futures Accesses August 3 2011

Office of Assessment Policy, Development and Administration (APDA) with information available at http://www.p12.nysed.gov/apda/ Accesses August 3 2011

Parker, J. (2003). *Weaknesses revealed* in Barlex, D. (ed) *Creativity Creativity in Crisis Creativity in crisis*? *Design & technology at KS3 and KS4*. Wellesbourne, UK: Design and Technology Association.

Qualifications and Curriculum Authority (2007). *National Curriculum in design & technology*

Robinson, K. (1999). *All our futures: Creativity, culture & education*. London: Department for Education and Employment.

Rutland, M & & Spendlove, D. (2007). *Creativity in design & technology* in Barlex, D. (ed) Design and technology for the next generation A collection of provocative pieces, written by experts in their field, to stimulate reflection and curriculum innovation. Shropshire, England: CliffeCo, STEMNET (2010) Information about the STEM ambassador scheme can be found at http://www.stemnet.org.uk/content/ambassadors Accesses August 3 2011

TENZ (2011). The Technology Education New Zealand website is available at this url: http://www.tenz.org.nz/

Williams, P. J., (2011). STEM Education: Proceed with Caution, *Design and Technology Education: An International Journal*, *16*(1), 26–35

Young Foresight. (2000). London: Software Production Enterprises

AFFILIATION

David Barlex
Formerly
Senior Lecturer School of Sport and Education
Brunel University,
Director Nuffield Design & Technology,
Educational Manager Young Foresight

SUSAN V. MCLAREN

10. CONSIDERING SOME BIG ISSUES AND THE ROLE OF TECHNOLOGY EDUCATION IN TRANSFORMATIONAL CHANGE

INTRODUCTION

This chapter aims to encourage further exploration and consideration of some key issues for 21st century Technology Education. It discusses challenges with specific reference to implications of teaching and learning, the role Technology Education has the potential to take, and the contribution is has the possibility to make.

The intention is not to provide a definitive list of every issue facing us as Technology Education practitioners. Indeed, the rate of change in Technology, and by implication, Technology Education, renders such an idea impossible. There is also no intention of examining and discussing any individual national curriculum guidelines for Technology Education from the current international portfolios. These documents tend to be reviewed, revised, and may be fairly transient; subject as they may be to political and economic imperatives and interference.

Rather, this chapter intends to encourage educators to reflect on some of the broader, complex aspects of the purpose(s) of curriculum, pedagogy in the 21st century and the impact and influence on Technology Education.

For example, how does Technology Education deal with the exploration of values and ethics of actions and behaviors; emotional literacy; uncertainty and compromise; controversial and topical issues without due disorientation? What can be done through Technology Education to respect and value technological traditions, heritage and contributions to national cultures while responding to globalization, worldwide networks and shared concerns, and enable our young people to be active citizens in the international arena? Such questions serve to promote reflexive scrutiny and may lead to alternative models and pedagogies.

There is some overlap in the content of this chapter with other chapters in this book. While the previous chapters have dealt with the 'big' recognizable issues such as assessment, curriculum, and design, this chapter takes a more thematic approach which enables it to be inclusive of a range of issues and considerations in relation to change. The key inter-dependent issues discussed in this chapter relate to

- Technology Education and Thinking: This section includes using designerly thinking as a model of how to learn and become more self directed; learning

P. J. Williams (Ed.), Technology Education for Teachers, 231–260.

and questioning as life skills to inform choices and decision making; developing confidence to deal with uncertainty in the 'knowledge' economy.
- Technology Education and Changing Worlds: This section discusses the place of ethics, value judgments and critique which helps make sense of the world, read scenarios from various perspectives, discuss controversial issues, dilemmas and seek alternatives.
- Technology Education and Global Citizenship: This section examines the role of world views; sustainable development; inter-connectedness, systems thinking, circular economy.
- Technology Education and the value of making in 21st century: This section considers the nature of learning through practical, artisanal making in the context of the industrial world of mass manufacture; new emerging and 'smart' technologies; issues of consumerism and desire for individualism, personalization and choice.

Generally, the questions and issues explored cluster around opportunities for transformation which are appropriate for Technology Education in the 21st century. They urge teachers to consider the big issues and big ideas impacting on Technology Education. In turn, these will influence the construct of Technology Education and have consequences for what is demanded of Technology teachers.

Perhaps after reading this chapter different, more pressing issues, further questions, dichotomies, dilemmas and debates will be identified, and alternative implications recognized. If this is the case, then this chapter has served some purpose.

THINKING ABOUT THINKING AND LEARNING TO LEARN

Meta-cognition and Designerly thinking

Effective teaching aims to develop autonomous learners who are equipped to continue their learning throughout the rest of their life. Meta-cognitive skills, thinking about thinking skills, are those that enable a learner to identify and / or interpret a task, check progress, set goals, evaluate progress and predict outcomes with a high level of self regulation and awareness of the decisions being made, approaches being adopted and implemented and the resources being allocated. The learners have active control and have a repertoire of strategies which support them in making choices related to, for example, the order they wish to tackle a task in order to complete it. They can engage, unprompted, in self evaluation of the quality of their work and reflect on their own strengths and weaknesses and set themselves targets or further goals.

Technology Education offers great potential in the development of these skills. However, meta-cognition is not something that is 'caught'. Teaching the skills of thinking about thinking, and thinking about knowing, demands explicit introduction and exposition of thinking skills and strategies for learning (Flavell, 1979). Creating technologically based learning experiences which focus on thinking about thinking and learning how to learn involve making designerly approaches more explicit. The language used in teaching can model the vocabulary of thinking and encourage learners to adopt this language themselves in their own learning, planning and reflection. This is something that teachers may consider is common practice in the project portfolio that often accompanies an extended design task. Less common perhaps is the expectation that each learner compiles a design journey log book, or a *real time* portfolio, of their individual design story throughout the duration of a design activity. This has been the subject of research and the development of unobtrusive tools in projects instigated by Goldsmith's Technology Education Research Unit with the title of '*e-scape'*. (For further information, see for example, Kimbell, 2012; McLaren, 2012) At various points, the learner's designerly thinking can be enhanced by providing them with self evaluation tools and decision making strategies, for example, 'two stars and a wish' (cf. Northern Ireland Curriculum, 2007) or 'Thinking Hats' (cf. debonoforschools.com). Such meta-cognitive subtasks can be considered as scaffolds for all learners, adding to a repertoire of approaches which, subsequently, an individual can select from to utilize when and where they deem appropriate.

Designerly thinking requires learners to explore problems, situations, scenarios and to interrogate them to identify issues, happenings, people, needs, wants, and opportunities. It is a way of thinking that helps raise questions about unknowns, and ignite the sparks of curiosity that instigate activity; and in turn design activity. Through designerly thinking learners develop the ability to challenge the past, scrutinize the present and create the future. Designerly thinking encourages learners to have ideas, generate concepts, be playful with purpose, and spend time in useful fun. They take on intellectual challenges (risky or cautious), where the end point is often totally unknown, although a goal of some sort might be in the mind's eye (Kimbell & Perry, 2001). This requires a learning environment that accepts uncertainty and allows some intellectual risk taking. Such a learning environment serves to encourage the learners to engage actively with creative and innovative thinking and action (Jones &Wyse, 2005). The learners research and test their thinking on a 'need to know' basis. Learners grow and develop their ideas through frequent iterations and arrive at potential solutions by following a learning journey that is unique to them. In short, they learn how to learn through the motivation of wanting to engage in the challenge as they find it. The ownership of the learning and implementation of actions promotes confidence in the proposal they, learners as designers, present.

Providing explicit strategies, skills and frameworks within which the learner makes autonomous procedural decisions to drive their own design ideas also fosters meta-cognition. Similarly, teachers can adopt explicit language to cue thinking about the thinking when teaching the learners how to realize their ideas through physical modeling and the psychomotor skills required in manufacturing a proposal or prototype. At times, this aspect is at risk of being demoted by the language of 'doing' used by the teacher during guidance, exposition and instruction. The central tenet is that learners are encouraged to recognize the need for self direction, self evaluation and become more aware of their own thinking, and learning. Meta-cognition in relation to designerly thinking is discussed by Kimbell and Stables (2008); Schon, (1983 & 1987) and others.

The role of the Technology Education teacher in transformational change

In a ‘knowledge economy’ with easy access to ‘knowledge’, learners may be wary and less inclined to engage pro-actively with a school syllabus of pre-determined content. However, there may be advantages in being involved in learning technological content, some of which is identified by the learners themselves, within an open, partly self-determined, framework, through which the learning is facilitated by a teacher. This creates opportunities for informed and authentic decision making and personalization of learning. The learners are required to make connections and apply their prior learning to construct new understandings as they transfer these to an unfamiliar and messy scenario or challenge they are engaged in. This model of teaching and learning blurs the boundaries between technical skills and knowledge and other subject disciplines. Learners can be given opportunities to take greater responsibility for what it is to be learned and how to learn it. This pedagogical construct creates learning experiences for the learners where the teacher is central, yet the teacher is not at the centre. The role of the teacher is as an enabler, a choreographer of improvised learning. The teacher devises ways of introducing, developing and facilitating the learning and engages the learners in deeper understandings. The teacher is responsible for creating a framework which challenges the learners to see things through a different lens, from different perspectives, and recognize that there may be many resolutions to the complex situations or needs that they are examining, rather than only one solution.

Technology Education that engages the learner in reflecting on and critiquing existing systems and models of the macro- and micro-world, and the place of technologies and design within those models, creates a classroom that is enquiring and sometimes challenging. For example, such critique based study in Technology Education might raise issues of the un-democratic distribution of some technologies, ill-proportioned distribution of wealth, use of the world’s resources, the exploitation of some of the population for the benefit of a minority, and may prove to be uncomfortable. This approach connects the concrete nature of design, designing, working with materials, modeling and creating to realize what is in the mind’s eye, (the explicit concern of the school curriculum) with the world as it was, as it is and how it could be; the pedagogies of learner-centered, active, and experiential processes. The skills of reflection and critique develop the importance of consequence of these concrete actions as an educational experience. Central to this model of Technology Education is the considered development of scaffolding for the young people to learn how to learn and the creation of frameworks which permit learners to arrive at an individualized response. The emphasis here is on teaching that is not solely centered on Technological curriculum content with teacher as 'master' and learner as 'apprentice'. [The role of an apprenticeship model is acknowledged and its value is discussed further later in the chapter.]

Working with learner-centered, project-based pedagogies demands personal and professional confidence of the teacher. As creative professionals, Technology teachers cannot afford to be risk adverse. There may be those who argue that designerly, learner-centered approaches result in less technological content being 'covered' or 'delivered' in the time available. However, an internationally acceptable definitive list of 'content' is yet to be agreed (if indeed such a thing ought to exist). In the dynamic world of technology, engineering, materials and design, with the accessibility of information, and the challenge of the unknowns in the world in which the learners exist, it could be argued that it is more important to develop their meta-cognitive capabilities in learning and thinking skills, their self awareness and confidence in taking informed action. A Technology Education which takes a focus on technical content only could prove to be static, problematic, subjective and irrelevant. The development of dispositions towards life-long learning, discriminatory appraisal strategies and the capability to create and manage knowledge will perhaps serve learners more positively.

Technology Teachers as agents of change

Ideally, education authorities should assert trust in the professional skills of their teachers to interpret whatever the policies, rationale, guidelines, and so on, into relevant teaching and learning experiences. When teachers are given the intellectual space to exercise professional judgment, to develop teaching and learning through a creative partnership with the curriculum, a meaningful learner-centered experience is possible. There has been increased recognition of the importance of teachers being given the creative pedagogical space to present learning experiences and related assessments for the specifics of the learners in collaboration with colleagues. Over the past decade the argument for the development of professional learning communities has been developing traction (Lieberman, 2000; Hargreaves, 2002; Goleman et al 2002; Muijs and Harris,2003; Donaldson, 2010). Teachers, as part of their identity as a teacher, are directly involved in enquiry and action research. This is what Dana & Yendol-Hoppey call 'enquiry by stance' (2009, p8). When adopted it has been noted that teachers are empowered, collaboratively and individually, to challenge 'top down' ideologies and are active in transformational change. Ultimately, the responsibility for innovation in curriculum design, and implementation through practice, lies with the schools and within the school community. Teachers are the agents of change in this process. There is evidence that deep change and sustained improvements are possible when teachers feel empowered and are placed at the heart of curriculum development. This may mean, for some, a re-envisioning of what it means to be a teacher. A teacher can not think of themselves as being a gatekeeper to content knowledge, revealing to their learners only what they deem to be of importance. Hence the argument for developing the attributes and skills embedded in technological capability. Learning through technology and about technology has the potential to create a learner who has the skills of questioning and identifying what it is they do not know, yet need to know to progress their ideas further. Therefore the role of the teacher, in part, is to teach learners how to identify and source the necessary information and concepts on which to build. Learners will become more discriminating in their appraisal of the world in which they live, create and manage their own skills and understanding with increasing autonomy. The concept of a proactive teacher of Technology is exciting, given the pace of the change as it is now and unknown future(s), and requires enthusiasm, energy and spirit.

TECHNOLOGY EDUCATION AND CHANGING WORLDS

The trans-disciplinary nature of a design-centered Technology Education encourages teaching and learning to draw from a wide range of learning areas from all disciplines in order to respond to the challenges of finding a solution to a specific task, or an ill-defined problem, or being proactive in creating proposals to address a hitherto unidentified issue. Technology Education, as described by Kimbell and Perry (2001:3) 'is about creating change in the made world; about understanding the processes of change and becoming capable in the exercise of change-making.' In addition to developing the motivation and disposition to engage in change, it is necessary to consider whether change, and whatever is brought into being, is necessarily an improvement on what came before. Teachers of Technology Education must recognize that they are operating in an arena which is heavily value laden and this demands them to develop creative and interactive approaches to explore ethics and consequences explicitly with their learners and the personal values and world views of those learners.

Disruptive technologies and transformational change

There are many case histories which illustrate transformational change driven by Technologies. For example, Halliday (2001) provides a vivid account of Joseph Bazalgette's horror at the disease and squalor he observed around him and his determination to take action and change the status quo. The health of the inhabitants of London improved through the implementation of Bazalgette's designs and the introduction of a system of sewers which were constructed between 1859 and 1865 and the provision fresh water supply. Ayars (2009) illustrates transformational change using the invention of the mobile phone and subsequently the 'smart' phone. For some people, the advent of the cellular mobile telephone was an incremental change in their lifestyle, an addition to the home land-line telephone. For some people, there was no change, as they chose not to adopt the new technology, but for others there was transformational change. The invention allowed them, in one device, the facility to text, speak and send/receive e-mail; take, store and display pictures (still and moving); tell the time; use a calculator; keep diary; access a notepad; navigate by global positioning satellite; play games; listen to music and much more. A personal cellular, phone provides access to new markets, information, trade, and has transformed ways of working, communicating, and living generally.

Disruptive technologies are known as such due to the impact they have and the transformational change they drive. The disruption created by the advent of the technology changes the pace of life, the way things have been accepted, or traditional methods of production. The change is deep rooted, systemic and yet can be subtle. Clayton Christensen (1997) contrasts 'disruptive technologies' with 'sustaining technologies' which are also described as incremental developments in design terms. Incremental improvements in a system or a product, in performance or process is a typical way of adding value or marketing improvements and change, yet at little risk to business, brand and market position. Disruptive technologies, on the other hand, often emerge as low quality, underground and maverick ideas, taken up by niche and interested consumers/ users. They appeal to anti-corporate, perhaps anti-profit, consumers and generally offer novel thinking, innovative technologies, with some open, unknown potential in application. Their very existence challenges large scale corporations and traditional operations and systems and can alter, and disrupt, behavioral patterns.

The study of disruptive technologies in Technology Education, such as the worldwide-web/internet, the steam turbine, the personal computer, the zipper, open source programming code or; 'copy-wrong' publications, for example, helps to develop a technological sensitivity which considers values and appreciate consequences integral to the world of design, engineering and technology. Perhaps an innovative idea utilizing new technologies is introduced for a new set of consumers, and creates a new market. This unexpectedly causes disruption and challenges existing processes, procedures, employment, economies and markets, and eventually displaces them. By using authentic contemporary examples, and those from many years ago, the influence of design thinking can be illustrated as it stretches well beyond any impact on economics, business, markets, technical and manufacturing advances and processes. There are inevitably consequences for the environment, culture, economics, politics, and society. Learners can be challenged to source an example of a disruptive technology, examine what it displaced and why. They can explore the effects it had on local and more global society. They can go on to investigate new examples, and suggest what will be challenged, disrupted, displaced and why, and again consider the consequences in the wider context.

Technology Education as an agent for change

There are assumptions that, from the evidence available, the skills and creativity of designers, technologists and engineers equip them to be active agents in change. Some of the most influential technologies in history can be credited to designers, engineers and inventors who had an interest beyond science and engineering. It may be that at the root of their creative energies was their desire to bring about changes in quality of life, social justice and democracy. Alternatively, there may have been more selfish and malevolent intent. The act of designing and making which is central to Technology Education is not in itself enough to develop informed citizens. The non-neutrality of technology is part of the big picture. The positive benefits and advantages offered by innovations and technologies versus the negative impacts and disadvantages brought to people and place offer rich study.

Technology teachers are educated as designers, technologists and engineers. By implication therefore, they may have the mindset, skills and disposition to engage with the known and unknown challenges and opportunities of the 21st century and be similarly equipped to be active in change. They may be familiar with the requirements of a 'knowledge economy' where 'in contrast to the typical worker of the industrial era who was required to learn a relatively stable set of competencies, the knowledge-based worker is experiencing a blurring of boundaries between work and learning' (Seltzer and Bentley, 1999). Here, creativity, innovation and knowing how to learn carry greater value than knowledge itself. This offers a challenge to traditional educational models and curriculum design for Technology Education. Those involved in Technology Education may argue that they have focused on a process driven approach for decades and have not been centered on the remembering of facts and knowledge, but even they may have to delve deeper to create the most conducive and appropriate learning environments for a meaningful Technology Education in the 21st century.

Technology Education has the potential to play a central role in transformational change, i.e. a deep change in culture, attitudes, strategies, systems, and organizational behaviors. There are implications for Technology teachers and the curriculum design for Technology Education. Programmes of study can furnish learners with the skills, dispositions and attitudes for being involved with change, cope with uncertainty, appraise and discriminate the technologies encountered. The pedagogies adopted for this learning to be purposeful and unique to Technology Education require careful consideration to ensure an active, concrete, experiential and hands-on experience is offered and celebrated as a major contribution to developing deep learning.

Technology Education and making sense of the world

Within the general construct of Technology Education which encompasses designing, making and critiquing engineering and technologies (artifacts, environments, systems), there are some issues, from the 'real' world, that require attention. These issues include current thinking which aims to address the depletion of resources, the exploitation of others, the reduction in biodiversity, and to encourage democratic, ethical global citizenship and social justice.

Technology Education classrooms can model different practices and make decision making explicit to their learners. This in turn can influence learner behaviors in decision making in the market place and society. In so doing, Technology Education can contribute to social change through heightened awareness of the positive and negative contribution and influences of technologies to society. Learners begin to appreciate that although some technological solutions may be acceptable to some they may be unacceptable to others. The design and make Technology Education model, in workshop, studio and classroom, can be used to highlight topical and controversial issues at macro infrastructure at local and / or global levels particularly when teachers choose to integrate them into their curriculum design. Rethinking Technology Education to broaden the scope and range of contexts for learning to encompass technological critique (from economic, political, cultural, societal, ethical and moral, environmental perspectives) while still championing the value of creative designing and making, may prove uncomfortable. As has been discussed previously, this demands that the realization of a *product outcome* is not seen to be the sole purpose of the technological learning experience.

Technological Critique and Value Judgments

Learners can develop critical thinking and a language of technological critique by being engaged in active exploration of values, of products, systems, environments, and ideas resulting from design and technological based human actions, their own and those of others. Current topical environmental, scientific and technological issues offer opportunities for learners to stretch their critical thinking in a range of contexts, familiar and unfamiliar, local and global. Teachers can select/devise appropriate approaches to introduce un-structured, ill-defined, complex challenges based on authentic scenarios where learners are required to use a systems thinking designerly process to resolve 'problems', or arrive at proposals, for specific users, communities or individuals. An important concept within these project, problem or design based approaches, is the development of technological sensitivity, where action proposed and/ or taken is informed and cautioned by the appreciation of consequences for others. Learners develop alternative perspectives and examine consequences of local action from the potential or actual impact on the inter-connected global system. Creating active and practical learning approaches for learners to access concepts such as technological sensitivity, critique and capability is challenging.

Complexities of critique

Technology Education has the potential to explore psychology and sociology through the symbolic and emotional meanings of products, systems and environments. It has the potential to help learners understand how products define identities, create social relationships, signal personal and collective values. As stand alone sessions, or integrated within project work, learners can examine and debate decisions, impacts and consequences of designing, engineering, manufacturing, and consuming. Reviewing and analyzing consequences of actions taken, or proposed, enables the learners to understand the interdependency of the planet and the impacts and influences technological activity can have on environment, society, cultures and economies. Practical Action (http://practicalaction.org) provide some useful classroom tools which suggest some probing questions to ask when engaged in analysis (products, systems or environments). These include an ever expanding portfolio of ideas to incorporate into projects and design challenges, such as

'design abacus';
'belief circle prompts';
'lifecycle analysis';
'winner-losers web';
'line-ups';
'let's negotiate' and
'carbon footprint calculators'.

It is complex to calculate environmental impact at each stage of the product lifecycle. This is maybe more than would be asked of learners studying Technology Education in the school sector, yet an indicative value of the carbon dioxide produced throughout the product's life serves to illustrate the issue under scrutiny and increase general awareness of the discussion, so often at the core of governmental and international reviews.

Life cycle analysis can involve considerations and judgments against a wide range of criteria incorporating social, economic, environmental and cultural. Developing the skills and dispositions to examine the benefits, and disadvantages, the 'winners and losers', the consequences and impacts of emerging materials, processes and possibilities within an interrelated planet and a closed loop system is critical to Technology Education. As citizens and consumers, and potential engineers, designers, politicians etc., young people require the skills of non-discriminatory discernment and informed decision making. The questions and prompts below can frame a holistic enquiry from subjective, but also objective, perspectives:

How necessary is this product? Who has decided it is needed?

What is the need that is being addressed? To what extent does the idea meet people's need? How was it addressed in the past? What is a 'real' need? Is meeting the need a worthwhile investment of time and resources?

What does it say about the people who buy it? Use it?

Is there an alternative method of achieving the same function?

Who would want to own or buy this product? Who do you think it is intended for?

How is it to be used? Does it need input of more energy/batteries throughout its use? What alternative uses could it be put to?

How was it made? Where was it made? What materials were used to make it? What impact did that have on the land and how were they processed? What energy was involved in the extraction of materials, processing, transporting and manufacture? What effect will its manufacture have on people's lives and relationships? What effect will its manufacture have on the built and natural environment?

Is the product well enough made to carry out its purpose as well as in principle?

How was it sold, distributed and marketed?

What effect will its use have on people's lives and relationships?

What effect will its use have on the built and natural environment?

What will happen to it after its primary use? How is it disposed of? Reused? Disassembled? Recycled? Re-aggregated? Reconstituted? Reconditioned? Repaired? Re-allocated? Dumped in landfill? What factors lengthen/limit its life-span?

Does the proposed solution have other consequences which should be taken into consideration?

Teaching through value judgments and controversy

People will still want 'stuff'. Human beings are thing-users and they covet beautiful things. They like to have embellishments, decoration and sentimental mementos which hold some personal or spiritual meaning. Some of the questions in the list above intend to highlight the difference between *needs* and *wants/desires*. They attempt to tease out the function and purpose that the design activity and / or outcome intend to fulfill and for whom. They prompt thinking about the role the resultant environment, system, artifact serves, and in what context. These are uncomfortable questions, in an arena of value judgments, where personal and societal worldviews are unearthed, and potentially challenged.

This conception of Technology Education takes learning beyond the neutral technical 'know how' and 'know why' in technological science and engineering principles into value laden, socially situated and political arenas. These are big, and often, controversial, issues for the learners and teachers. A Technology Education which ignores such fundamental aspects would be limited. To adopt, plan and present learning that has these embedded within, demands new pedagogical thinking.

In the world beyond school, Design, Engineering and Technological activities have tangible outcomes that influence the ways people go about their daily lives and impact collective behaviors. These outcomes cannot be considered as value free. The ethics and values of those involved in such activities deserve scrutiny. School students can explore the consequences through debate and discussion, research and hypotheses, engagement with professionals involved in past, present and future projects.

Assumptions and decision making

Implications can be examined and considered through a wide range of active learning approaches. For example, learners can be asked to describe their immediate stereotypical impression of a 'business entrepreneur'. They may offer suggestions such as *he* wears a smart suit and tie, carries a brief case, drives a fancy car, and lives in a big house with more rooms than is needed for him and his family. And now, what do the learners offer as a snap shot impression of a 'charity worker'? They may suggest *he or she* wears slightly scruffy in jeans, T-shirt, carries a rucksack, uses a bicycle, and lives in shared accommodation with a mix of other like minded people. Next, the learners are asked what comes to mind when asked for their description of a 'social entrepreneur'. This baffles them. It is not something they are familiar with. This introduction serves to open the topic for further scrutiny. They learn that social entrepreneurism is a model of business that combines money-making with purposeful social and or environmental aims. Profits are reinvested in the community, or for example, to support projects in partnership schools in other countries. This learning challenges assumptions of business and enterprise. It can demonstrate that there are always a range of perspectives and a number of ways of working, each with unique implications. The relationship between decision making, innovation and enterprise, ethics and goal orientated thinking is also illustrated. With a deeper understanding of social enterprise, the learners can establish an initiative themselves. Current examples, in Scottish schools, related to Technology Education, are bicycle repair and recycle, fair trade café, school uniform reconditioning, market gardens, compost sales from school kitchen, console games rental, fair trade cotton bag design a manufacture, where the learners source the cotton directly from producers in Malawi (Social Enterprise Academy- http://www.theacademy-ssea.org/).

There are opportunities to examine the complex issues of decision making in design and manufacture. To illustrate: the learners are presented with a scenario of social enterprise, whose aims are to be sustainable in environment, economic and social terms. Their company produces jute bags which are printed with customized graphics to the specifications of the clients, such as supermarkets, conference organizers, etc. The learners take on the role of the managers and are required to make decisions in response to various scenarios that reflect the design, make and market cycle of enterprise. E.g. some clients have asked for a brighter color imprint onto the surface of the bag and a change to chemical dyes will do this; new sewing machines can be bought which are faster and are 25% more energy efficient; moving production to a different country where labor is cheaper and an intermediate company will be manufacturing the bag. Learners are asked to 'line up', with those who make the decision to change as outlined in the scenario at one side and those who will not at the opposite side. Discussion then follows exploring the justifications for the decision. Diverse and controversial issues arise. These tend to include keeping the clients happy and retain sales; toxic waste; health and safety issues; job losses; disposal of functional machines; need for retraining; capital outlay and for what gain, by when; additional carbon miles in transportation; decreased costs; loss of quality control; exploitation of workforce; increased sharing of income generation through fair trade negotiation. This type of activity, in the context of Technology Education, serves to deepen understanding of the complexities, the ethic dilemmas and inter-connectedness of systems and people beyond the immediate locale and globally.

Technological Perspectives

Presented with alternative perspectives from other parts of the world, and searching for innovative solutions past and future can stimulate creative thinking and help young people re-appraise their thoughts on past times and unfamiliar cultures. Recognizing the variety of ways in which stories of technology are told, from different voices through different media, can begin to encourage a critical analysis and discourse with young learners in an exciting way. These could include investigating media coverage of an innovative design, piece of architecture or manufacturing process, natural disaster, predictions and debates of the influence of nano-technologies or artificial intelligence, or advances in medical technologies, resource ownership and political repercussions of protectionism, demand and depletion. Studies of the cultures of technologies and the histories of technological learning and actions local to communities, national and beyond can reveal much too. Science-fiction novels and films also provide stimulus for relevant debate and surprise.

The contrast between rich and poor is evident in consumption and markets. There are several useful strategies for developing discussion and scrutinizing artifacts, systems and environments using criteria to guide evaluation, some of which were described previously. Examples of product artifacts to compare, contrast and review will help highlight needs, wants and issues of sufficiency. Consider the energies, resources and consequences of the existence of an automatic hot chocolate stirring mug, a solar powered fridge, solar-cooker 'cooKits', GPS enabled training shoe, a 'blue tooth enabled hugshirt', a prosthetic running foot, all-terrain wheel chair, SegwayPT (two wheel personal self balancing transport), etc.

A group activity, 'room 101', adopted from 'The Sustainability Handbook for Design and Technology Teachers by Practical Action (2007) challenges learners to debate and decide whether each item of a selected handling collection deserves to exist in a world striving to be sustainable and equitable. The products or systems they determine have no contribution to make and are considered as entirely at odds with sustainable thinking for the planet are 'removed' (to be banished to room 101 with other detested and feared phenomena). The decisions of what to banish and what to keep are dependent on the role adopted or perspective taken, associated values, and facts. Complex compromises can be highlighted. A local decision may seem inert and neutral. Transposed to the global arena, the existence of an artifact may take on a very different role.

Teachers of media literacy may have strategies to share with Technology teachers, for example, deconstructing the different voices of the various stakeholders as their stories are told, and exploring the perspectives of those involved in the commissioning, funding, manufacturing, and consumption of a proposal as reported in news media. Learners can take on roles and be playful with the authentic scenario, researching the underpinning concepts, examining words and reportage forms to create new and or alternative scenarios and futures. Creative young minds challenging and scrutinizing what was, what is, and what might be, has a place in Technology Education.

TECHNOLOGY EDUCATION AND GLOBAL CITZENSHIP

At present, it may be difficult to contemplate a world without oil, plastics, fossil fuels, and various related derivates), minerals, agricultural land and drinking quality water so common to everyday living in the rich and, increasingly, the developing worlds. These are thought of as essential components to the systems, products and environments created through the processes and outcomes of progress and growth of design, engineering and technology. Manufacturing and creative industries are considered as wealth generators for nations. Industrial manufacturing is a major user of energy, water and finite and natural resources. It is becoming ever more pressing that designers and makers are aware of the source and provenance of the resources which are being specified and used. Technology Education offers opportunities to help learners to understand the differences between:

- renewable energy sources and power generation from carbon emitting and finite sources;
- sustainable resources and non-sustainable;
- reusable components or metals and minerals, and waste;
- reprocessing, recycling, down cycling, up-cycling and reusing;
- local supplies and distance global supplies (carbon miles versus wealth creation / fair trade);
- a linear economy and a circular economy;
- systems thinking and closed loop, whole systems thinking.

Linear Model of Production

Technology Education teaches respect and recognition of the sources of the resources, materials, technologies and energy transfer used in design, engineering and manufacture activities. Generally, learners are guided to be more aware of the product lifecycle from inception through manufacture, transportation, marketing and use, to disposal. However, the world is shifting from fossil fuel-based systems to more renewable and low-carbon sources and yet a ‘cradle-to-grave’ system tends to be perpetuated with some product lifecycle analysis tools available and through the language of texts. The wasteful ‘take-make-dispose’ approach is diluted by encouraging the learners to consider how products and components can be recycled or manufactured using a bit less resource. This may result in schools promoting the message of recycling and using recycled resources as the key priority without questioning if it is the most effective approach or if it *optimises* the system to the greatest potential. Webster and Johnson, in Sense and Sustainability (2008), discuss this further. They argue, with a matter of urgency, the importance of re-thinking the 'take-make-dispose', linear industrial model of design and production.

In summary, a linear system (*Figure 1*.) tends to involve extracting and transporting various materials from different parts of the world, with energy use and waste streams related to every stage and every process. The various components are manufactured and assembled to create a product which is transported to various destinations to be sold, and transported to yet another destination. After the product has served its purpose, it is recycled, and /or dumped, often in landfill. In current systems, it is unlikely that every component part or all of the materials can be accessed to be recycled. It may not even be an economic proposition to recycle. A huge amount of additional energy, water and resource is required to disassemble, extract the different materials in order to recycle and decontaminate them. The recyclate is commonly acknowledged to be of lesser quality. In order to incorporate the down-cycled material into a subsequent manufacturing process it is common to add some virgin material and accept the reduced specification, or utilize the recyclate as the primary material for a product of less value. This serves to slow down the rate the resource is dumped, but basically has just gone a detour to slow the journey, and ultimately it is still dumped. The linear system is common in the current model of industrialized

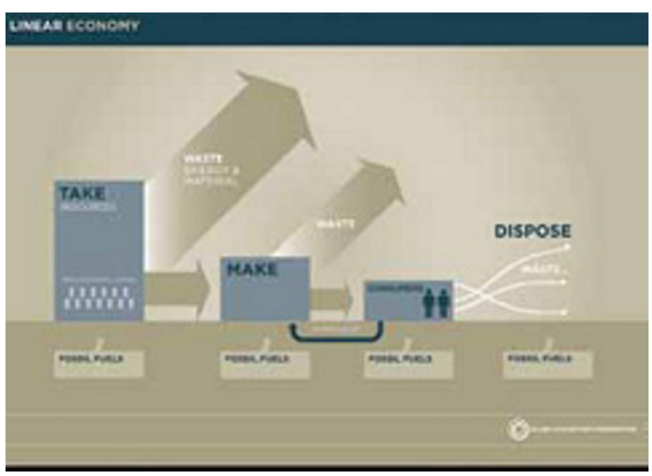


Figure 1. Linear Economy (image provided by Ellen MacArthur Foundation 2011)

world. Technology Education should be well placed to be a key player to challenge this mindset, rethink and redesign the model.

Nature as Teacher: Circular Economy

Technology Education currently exists, for the main part, within a linear model of production. However, there are strong arguments, from the design, manufacture, engineering worlds beyond schools, which challenge the notion of 'waste' and encourage rethinking of systems to devise holistic, zero waste enterprises and communities These arguments build on an alternative model which uses 'nature as teacher'. Braungart and McDonough, in their book 'Cradle to Cradle: Rethinking the way we make things' (2002) developed Walter Stahel's proposition of the 1980's. Stahel and Reday (1987) recognized the economic advantages and waste prevention strategies of 'cradle back to cradle' or 'looped economy'. Braungart and McDonough drew inspiration from Stahel's arguments and developed 'cradle to cradle' further. In nature, waste equals food and/or shelter or purpose for some other organism or species. Material cascades without any reduction in value, quality or purpose. There is no need for additional energies and resources to be utilized in the process, other than solar energy and natural bio enzymes. To simplify, 'waste' from one living thing is perhaps fertilizer or food for another species or itself to allow further growth or propagation and so the *cycle* continues and continues to the benefit of all. This model serves as an alternative for production, within a circular economy, which closes the loop (*figure 2)*. Waste within a circular economy production process is useful as energy. Waste can be utilized for additional related production, and as fertilizer, generating growth and restoring what had been used initially. Like Stahel, Braungart and McDonough, Webster and Johnson (2008) examine living systems to create a framework for a system that designs out waste, works within a restorative model of production and optimises resources and material cascades.

A circular economy requires whole-systems rethinking, not only of established networks and infrastructure, but also the way products and buildings are designed and manufactured. A circular economy model is about design for optimization.

Design for ease of disassembly becomes central to the economy. The efficiency with which the 'technical nutrients' can be separated, recovered, reconditioned or reused directly is paramount. In order to design for ease of extraction there may indeed be more copper or rare earth metals used rather than less. The product can be on lease to the user and returned to the company, who not has the responsibility of ensuring return, but now also the incentive, namely to protect the valuable materials embedded in the item. These technical nutrients can be considered as capital and as a consequence the rise and fall in commodity trading prices has less influence on costs. Companies have greater control of their own resource stock. This means the company is less likely to become a victim of rising commodity and energy prices, quantity rationing, industrial disputes and wars and other potential obstacles.

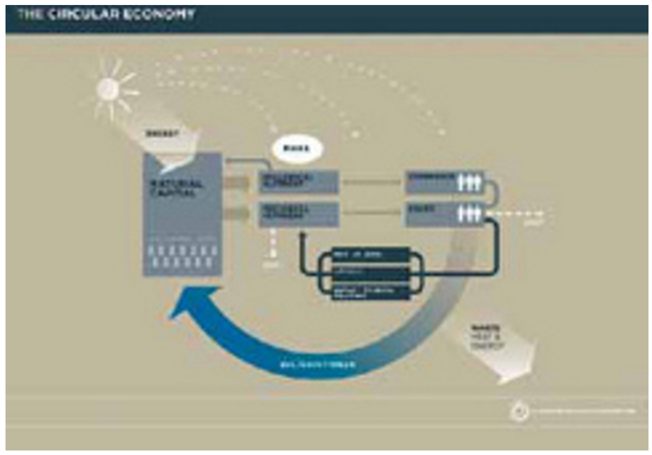


Figure 2. The circular economy (image provided by Ellen MacArthur Foundation 2011)

Likewise, with 'Nature as Capital', and designing with the principles of cradle-to-cradle at the fore, the bio-nutrients resulting from the processing of the primary source can cascade as food, or a primary resource for a complimentary manufacturing process. Alternatively, the 'waste' bio-nutrients can be utilised for bio-fuel for machinery, transport or electricity production. There may also be products which are designed with bio-nutrients only, which means after use they can be safely returned to the soil

Design for a circular economy demands a different way of thinking about materials and energy. Technology Education can develop an understanding of different and creative ways of thinking and can expose the complexities of design, engineering and technologies through different scenarios of teaching and learning. The role that designers, engineers and technologists have in promoting rethinking, influencing behaviors and patterns on consumption through implicit and explicit decisions and actions ought not to be under estimated. They have the tools and the skills to influence institutional change. Education for the whole systems thinking required by a circular economy relies on technologically capable and literate people being involved in specifying, commissioning, creating policies, and reporting, as clients, politicians, financiers, journalists, clients, politicians and citizen consumers. There is currently an increasing range and number of companies and businesses worldwide which are developing profitable businesses using the principles of the circular economy. A report published in 2012 by the Ellen MacArthur Foundation and McKinsey & Co, 'Towards the Circular Economy – Economic and business rationale for an accelerated transition' provides compelling arguments to 'mainstream' the circular economy and accelerate the concept. Understanding the interdependent and complex nature of the living systems of world is central to understanding the inter-relationships of issues and challenges to be addressed.

Technology Education and living systems thinking

In her book, Biomimicry: Innovation Inspired by Nature (1997), Janis Benyus writes of those taking inspiration from living systems. She explores ideas that work well in nature and how humans have adapted them for the purposes of power generation and efficiency, agriculture, architecture, transport and products which have proved to be highly effective. Technology teachers often illustrate how designers seek inspiration and ideas from nature. Bio-mimicry is a useful strategy for developing creative designerly thinking with their learners. Bio-mimetic studies have shown that organisms never stop innovating; they continue to evolve and adapt. Some well known successful commercial examples of bio-mimicry products are Velcro/hook and loop fastening based on the burrs, or seeds, of the burdock plant and the advantage-giving swimsuit (and boat hull coatings) which is based on the shark's skin teeth, or dermal denticles, which reduce turbulence/friction drag at micro-scale and also auto-cleaning. The circular economy is an example of a system is inspired by nature.

This concept of being inspired by nature and living systems can be taken broader than product design, beyond the product analysis and systems thinking of input/process/output. Webster and Johnson (2008) propose a pedagogical frame-work drawing from the terms 'Nature as Teacher' and 'Nature as Capital' with a 'closed loop systems thinking'. They argue this offers a positive, optimized model for Technology Education to locate designerly activity. Technology Education can embed concepts of circular economies where technical components and materials are considered as valuable nutrients with which to re-grow / fertilize/ reuse; much as nature values the biological nutrients in its model of biodiversity. This closed loop systems thinking and 'cradle to cradle' designing transfers equally to products as it does to economic and physical infrastructures, manufacturing and agriculture processes. Consideration of the circular economy can manifest itself in decision making and actions which alter the way stuff is resourced, made, sold, used and given further afterlife in large and small scale endeavors. Circular economy principles such as designing for ease of repair, reuse, upgrade and disassembly; using materials which can cascade, bio-degrade, or be recovered without down-grading; considering embodied energies and renewable energy sources, enable young people to recognize the interdisciplinary and holistic nature of technologies, the mutual dependency and inter-relationships of the planet.

Teachers are challenged with incorporating contemporary and future issues of the world and making connections between them and the micro climate of the school workshops. They also aim to engage the learners in the active and concrete learning so that the big issues do not remain as abstract and de-personalized concepts. However, the concepts of circular economy, closed loop system thinking, designing for sustainability and zero waste present an even greater challenge when the range of actual materials for projects in schools is, at present, limited and often proves difficult to source, as is relevant information. There are some data bases which aim to support sustainable design decision-making in design and manufacture. They contain material characteristics, details of physical, mechanical, optical and electrical properties, costs and suitable manufacturing techniques and process. Some environmental impacts may be noted. It is less common to find easily accessed school friendly data-bases which provide the means to identify and procure alternative materials and processes that contribute to circular economy principles. Such a resource would go some way to enable teachers and learners to make informed decisions which 'close the loop'.

Technology Education and sustainable development

Making sense of the world in which we live and applying learning to new situations is what most designers, technologies, and engineers do. Most design engineers consider systems thinking as a core skill for their critical understanding and application of creative and innovative approaches to resolving a design challenge. Technology Education can encourage learners to recognize the systems they encounter in their everyday life and appreciate their interconnected nature. Developing an understanding of the networks and systems of the world in which they live can help learners make informed choices and decisions which take into account consequences from a wider variety of perspectives (Sterling, 2001 and 2005). Opportunities can be created where learners engage in dialogue with others and through new, and often unfamiliar, experiences respect the values and cultures of others.

In a world of those that have and those that have not, in a planet that is being ravished for its natural resources to a state of depletion and the inequality of access to water, energy, and food, Technology Education has a role. Sustainable development and education for sustainability has emerged as a champion of localism and raises awareness of the need to celebrate the ingenuity of cultures and times and the diversity of contexts. This also requires a deeper understanding of social justice and seeks appreciation of fairer trade and market transformation to ensure the nature of localism does not perpetuate the divide between rich and poor.

There are many examples where Technology Education can be the stimulus for international education and global citizenship through projects that compare and contrast solutions and consequences, exchange knowledge, design ideas in response to authentic issues. Technologies, appropriate to the resources, culture and societal values, and the environment, have, for example, altered the ways in which towns generate the electricity supply, improved health by redesigning cooking stoves and enabled young girls to participate in education for the first time by the introduction of engineered solutions which makes the access to and collection of safe water easier and less time consuming. As a consequence of the installation of a 'play-pump', the designers claim that girls have been released from this arduous chore, allowing them time to attend school. However, deeper investigation and discussion of a 'technical-fix' can reveal difficulties and disadvantages of what appears initially to be a positive contribution to good health and education of the next generation.

In 2011, the Institution of Mechanical Engineers published a report provocatively titled, ‘One Planet: Too many people?’ This report urges governments to adopt five engineering-focused development goals for priority action and crisis prevention. The goals are:

1. Energy: Use existing sustainable energy technologies and reduce energy waste.
2. Water: Replenish groundwater sources, improve storage of excess water and increase energy efficiencies of desalination.
3. Food: Reduce food waste and resolve the politics of hunger.
4. Urbanization: Meet the challenge of slums and defending against sea-level rises.
5. Finance: Empower communities and enable implementation.

The Institute of Mechanical Engineers (UK based) argue that it is possible for developing countries to avoid the ‘resource-hungry, dirty phase of industrialization’. There are opportunities for the ‘fastest-growing populations in the world leapfrog over the unsustainable failings of the wasteful energy solutions embedded in the infrastructure of mature, industrialised nations such as the UK.’(p.6) For example, the investment required for large scale infra-structure to create a centralised electricity generation plant, with the inevitable long distance, transmission and distribution network is most likely to be prohibitive. Many of the emerging energy generating technologies are simply too costly and inappropriate to meet the needs of rural population and small enterprises. Birkeland (2002) agrees, arguing the technologies exist for local solutions; using sustainable technologies appropriate to their scale and needs, context and interconnected initiatives.

Years of technological development (agricultural, industrial and commercial) have had significant impact on societies, economies and the environment. Yet, issues of social justice, technological democracy and inequity have altered little. Arguably, the outcomes and systems of technological advances have increased and exacerbated in-equality and created a more polarized global situation of ‘haves and have nots’, ‘winners and losers’, rich and poor. Technologies are not adopted and utilized in generic ways across the globe. For those in the poor and the developing (majority) countries of the world, people may have very different perspectives. Their priorities may be in direct contrast to those of others, for example in the rich (minority world).

Technology Education can engage young people in big issues of what it is to be a global citizen and help them begin to develop the skills and personal dispositions with which to challenge and tackle the status quo. Teachers of design, engineering and technology can make connections to the past, through the present to the future technologies and systems and expose issues, values and controversies, topical and future scenario thinking. Again, responsibility lies with the teachers. Careful planning and consideration of appropriate approaches is required in order to provide their learners with opportunities to apply their learning in context and practice active, focused, creative technological and designerly experiences.

TECHNOLOGY EDUCATION AND THE VALUE OF MAKING IN 21ST CENTURY

Learning through making

Technology Education has reason to be proud of it roots, and to value the art of the maker and the craft of producing, building, constructing and manufacturing. Technology Education promotes learning through hands-on / brains-on activity set in authentic contexts. It is as much about 'knowing how' and 'knowing why' as 'doing'. It celebrates the practical and includes opportunities to provide learners with the innately 'human' experience of creating bespoke artifacts, prototypes, and systems; realizing, in physical forms, what had been in their mind's eye. It also introduces learners to the industrial and commercial world of manufacture and enterprise.

Technology Education is not about preserving the historic tradition of the craftsperson at the expense of engaging young people in new processes and experiences of 21st century. The key issue is the learning purpose and intent of the education gained through the experience of making (Crawford, 2010). Consider the situated learning experiences offered to a young person through making (cf. Lave and Wenger, 1991). Learning through making can develop, for example, dexterity, organisation, decision making, sequencing, problem solving, accuracy, spatial perception and visualisation, adaptability, numeracy, self regulation and self efficacy. Making provides concrete experiences and thus opportunities for the enhancement of scientific and mathematical concepts which are, for some, as abstract ideas, tricky to grasp. The art of the maker, and learning from doing, requires thinking skills of the highest order. The revised Bloom's taxonomy of thinking skills by Anderson et al (2001) suggests a hierarchy from remembering, through understanding, applying, evaluating, analysing to the highest order, creating. And yet, to some, creative modelling and making is perceived messy and immature; exploring through making is what the younger learners do (Fisher 1998), in their early years of education; making is for those who are 'less capable', but 'good with their hands'. This needs to be challenged. There are globally respected design and innovation companies (for example, IDEO, Dyson) who advocate modelling throughout design and development activity. This involves crude lash-ups of initial concepts through design development models exploring configurations, ergonomics, style and function to synthesis detailing for manufacture and prototyping. The advances in CADD visualisation and CAD/CAM, although useful, have not displaced the human need to have some hands-on visualisation, problem solving and a tangible sensory model to make judgments from.

The human experience of making through engagement of hand, mind and soul is to be recognized, celebrated and nurtured. Learning through making has the potential to engage the domains of heart (affective), hand (psychomotor), and head (cognitive). Creating and making provides a sense of satisfaction and enjoyment, be it resultant from solo or collaborative effort. There are many who derive spiritual satisfaction from designing and making something which can be admired, valued and treasured, not only for itself, but for the energy, emotion and effort devoted to the realization and completion of the outcome. This can provide motivation for learning and personal development of young people. The act of making, with or without designing, can serve as a vehicle for the application of core life skills and instill a sense of personal achievement. Many would argue that a sense of purpose and worth can be gained by giving learners the opportunity to create something to cherish, be it manufactured entirely by manual skills or brought into being by a combination of old and new technologies, old and new materials and resources.

At the same time, the importance of the economic contribution from manufacturing has long been held as a cornerstone of many countries. The political power of manufacturing sectors is evident in the reporting of its decline in one country aiding the 'growth' of another. Indeed, in many industrialized countries, the beginnings of Technical Education (in some countries, a fore-runner to Technology Education) emerged as being an apprenticeship model of specific training for whatever local or national industry required the skilled and semi-skilled workforce. The belief was, and still is, that the stronger the science, technology, engineering and mathematics education, the stronger the economy will be. A current example of this can be witnessed through some government dictates (e.g. UK and USA), and directed funding, with promote Science, Technology, Engineering and Mathematics education (STEM). The STEM educational initiatives (active at all stages of education from school sector through to universities) are founded on the supposition that they will address the business and industry STEM skills deficit and facilitate growth and wealth for a country.

Historically, in Technical Education, manual and machine shop skills were developed through the manufacture of workshop set pieces, with learners following instructions, advancing to reading blueprints for the dimensions and details. In this model there is little room for learners to be creative, make design decisions and explore the consequences of their decisions, if indeed they are expected to make any. The arguments against training-centred workshop learning experiences are that there is a focus on motor skills only. However, Brown, Collins, & Duguid (1989) and others argue that when cognitive apprenticeship methods are adopted, in conjunction with craft apprenticeship models, the 'apprenticeship techniques actually reach well beyond the physical skills usually associated with apprenticeship to the kinds of cognitive skills more normally associated with conventional schooling.' The situated nature of the learning makes direct and authentic connection with the practices and demands on knowledge and decision making, problem solving encountered in ordinary practice by the trades and makers. The dual model develops knowledge and capabilities in addition to motor and procedural skills with a view to developing a sustainable independence in the learner. Brown, Collins, & Duguid's argument supports 'inseparability of knowing and doing'.

If Technology Education positions itself with making and manufacture as a means to an end, the question is what does it offer in terms of general educational experience. It has been argued in this chapter that there is value in a Technology Education which develops designerly thinking, making and critiquing. It is in this context then that making has greater value than in a context of making alone. As Elshof (2006) argues, there is a danger that Technology Education perpetuates a 'productivism and product paradigm'. If it does not also incorporate opportunities for the examination of making-related issues such as of sustainability, values and the complexity of compromise (see Fry, 2009; Faud-Like,2009; McLaren, 1997) and encourages an uncritical workshop skills based curriculum, then the skills in making are also under valued.

Making in the context of the industrial world

Engaging young people in craft skills, designing and making takes time and demands emotional investment from them. It requires practice, experimentation, perseverance and develops judgment and discrimination. The process of creation and realization provides a sense of achievement. The art, craft and skill of making is considered as a personal and spiritual experience, involving the psychomotor and kinesthetic. When decision making in terms of the shape, the form, the function(s), and the aesthetic qualities and proprieties, and the technicalities are also determined by the maker, the maker becomes the designer-maker, much as is the traditional approach, creative practical engagement fundamental to Technology Education.

Learning through making will be authentic when placed in context of the wider realities, for example, when the learner is asked to consider issues and implication for users, society, economies and environments, traditions and/or cultures. Consider the place of the artisan in the 21st century, in rich and poor countries. The skills, knowledge and understanding developed through personal and direct connection with making, particularly making what has been personally designed, may have roots in traditions spanning centuries, but are also pertinent to current, new and changing practices too. (See Dormer, 1994; Crawford, 2010 and others)

It can be argued that globalization and interest in emerging technologies in the rich worlds has created a generic 'design style' at the expense of culturally located designs created from local, indigenous skills and materials. And yet, more recently, resurgence is evident in, for example, the importance of cultural identity, and preservation of local craft skills and food production. Mass manufacture, profit driven markets, manipulated market consumerism is clashing with the desire for individualism, personalization and choice, and rising interest in low-carbon economies, transition communities and initiatives. Technology Education can contribute to the growing interest in local production. Local manufacture creates the wherewithal to celebrate the bespoke, indigenous, vernacular, global differences and diversity. It respects the local resources, the cultural heritage and helps to discourage international homogeneousness that may be tempting with shared space 24/7 designers designing for a global corporate client base.

People enjoy personalizing generic products through customization in some way soon after acquisition. This desire by the user to have some direct involvement in decision making and interest in personally marking ownership, has been taken on by a globally recognized phenomena. Globally recognized companies such as the design and manufacture Swedish company, IKEA, have the premise that the consumer is not exactly the maker, but is the 'assembler' of the piece of furniture, lighting or cardboard stationary product. The consumer is directly involved in the pseudo-making of their purchase. They are required to manipulate tools, components and knockdown joints. A choice of surface 'finish' and decoration is also applied by the consumer themselves. This reconnects the consumer with their purchase through emotional and effort as the designer-maker. It serves to create an appreciation of the maker, the production worker, the system of manufacture. The consumer is not the craftsperson, yet connected with their personal environment, or products in some way through physical involvement with its final completion. There are increasing opportunities for the consumer to be directly involved in the bespoke design and manufacture of the 'stuff' they purchase and use. Computer aided design and manufacture (CADCAM) provides access to a highly personalized re-thinking of role of commercial manufacture and markets.

Technology Education and emerging and 'smart' technologies

As discussed throughout this chapter, Technology Education develops critical thinking and the ability to engage with appropriate technologies for the specific context and situation. Inculcating young people to accept new technologies and 'smart' materials as progress is not the premise. The processes of design, manufacture and consumption involve resolution of conflicting criteria and controversial contexts, the exploited and exploiters, the costs, materials, manufacture, conditions of labour, transportation, adding value, who gets what, who adds the value, and who received the profits. Concurrent with the issues of the contribution Technology Education can make to debates and futures of sustainability, global citizenship, and economic growth, there are additional issues related to designing, making and critiquing which offer rich contexts for teaching and learning, such as, emerging and 'smart' technologies. For example,

– disruptive technologies which often create new industries, and eventually change the world e.g. internal combustion engine, transistors, web browser, pod-casting, open-source software, CADCAM and rapid tooling**;**
– emergent technologies e.g. nanotechnology, biotechnologies, cognitive science, robotics, artificial intelligence;
– smart materials e.g. thermo-chromic, photo-chromic, pH-sensitive polymers, piezoelectric, shape-memory, magneto-rheological.

It is often noted that it is essential Technology teachers keep abreast of innovations, controversies and topical technological developments both locally and further afield. Teachers can make their efforts to do so explicit for the learners. Much can be drawn from the learners themselves when they are encouraged to undertake some primary research on how things were and how things are now, e.g. interviews with the older generations, or searching the media for articles on innovations, proposals for change and technologically based stories. Science fiction books and films, from archives and contemporary releases, offer interesting stimulus and are worthy of scrutiny. Awareness of research and development projects and the introduction of new technologies and smart materials is not in itself the key focus of the learning. The critique and debate surrounding their application, their availability, their place within the economy/ the market place, the consequences of their existence for society and environment and the considered application in design contexts is where the valuable learning begins. An effective Technology Education aims to develop confident, creative, collaborative citizens, who are equipped with a balanced thinking skills set. They have the ability to shift between the practical, mathematic, scientific, expressive and social knowledge, understanding and dispositions (Stibbe, 2009). They are only too willing to ask the 'what if…' questions.

As Technology teachers we can examine and evaluate 'new' technologies whilst respecting traditional skills. School workshops and laboratories may not offer the state of the art manufacturing capabilities. It may not be feasible to work with the 'smart' and emerging technologies, yet learners can be introduced to the way technologists, designers and engineers are exploring the applications of these technologies in the world beyond the constraints of the school facilities. Designing-without-making offers an alternative teaching and learning experience for learners to explore the potential within their own ideas.

The increasing availability of affordable CAD/CAM, rapid prototyping, 3d printing, rapid tooling, and open source software, creative commons and 'copy-wrong' designs offers localized manufacture and personalized prototyping, tooling and fabrication. Co-creation and closer collaboration between client/consumer/ user and fabricator provides personalized production, low number runs for manufacture. Previously, this would have been exclusive, available as high end, bespoke pieces, and the prerogative of the very wealthy. However, there are now technologies that permit more cost-effective and efficient access to customization and personalization. They allow the user to have direct involvement in decision making. The result is a shift away from the economies of global mass manufacture. There is greater potential to create more responsive products and systems, meeting specific needs in local contexts, with less overproduction, less market driven planned obsolescence, less transportation costs.

The music industry has been transformed with open source software. Anyone with a computer can make music, mix music, distribute music and market music freely. Likewise the web has provided the democratizing tools of the publishing, broadcasting and communication. Chris Anderson, previously an editor-in-chief of Wired and author of 'Long Tail: Why the Future of Business is selling less of more' (2006), discusses the changes in the design and manufacture of products as a result of open source, collaborative online platforms and enterprising thinking. In a

2009 interview (http://bigthink.com/ideas/17119), on the topic of how the internet is changing the face of manufacturing and democratizing the tools of manufacture, Anderson said,

> We now have the ability to target markets that are small. Because the global supply chains and manufacturing are now on the Web, are now easy to access, are now willing to scale down to our level, you see this explosion of amateurs and professionals and people who are moonlighting and sort of saying, "Well, you know, this isn't a big product, but it is a product and I can make it happen." The garage now has global impact.

This scenario, contrasting design and manufacture of the 20th century with the advent of what is to be in possible now, has consequences for appropriate practical actions and technological learning, and for technology teaching. The cultural and hands-on physicality, indigenous technologies have equal value and are treated with the same respect in the CAD/CAM practices and materials of Technology Education of the 21st Century.

Pedagogies for technological uncertainty

The adopted pedagogies to address some of the issues noted in the preceding section should avoid being over cautious. Risk adverse approaches all too often stifle learning before opportunities have even been opened up. It is the uncertainty and the undetermined connections, the exploration of value judgments and range of opinion that offers an environment of rich and deep learning through Technology Education. This inevitably has implications for teachers of Technology Education. They will require a varied repertoire of approaches to support young people to deal with uncertainty, while learning to deal with the unknowns themselves.

The key planning decisions which frame the learning experience can be made in advance. It is not possible, nor desirable, to identify all the necessary learning required by the learners, in advance of the activity. Designerly thinking and engineering involves developing the ability to deal with uncertainty. This is a *modus operandi* of creativity. With design thinking as a key learning intention, we encourage learners to ask the 'what if' and 'why' questions that act as drivers for seeking more information, sparking the need-to-know approach of learning for life. Planned teacher-learner interactions (from the predictable) and responsive interventions (from the unanticipated) remain important to the progression of learning. Handled well, these opportunities help students develop a breadth and depth of explicit technological knowledge and experience. Teachers need to ensure that their interventions also include explicit questioning and application, of mathematical and scientific understanding, in addition to knowledge of design practices.

TECHNOLOGY EDUCATION AND CHANGE

This chapter has discussed the strengths of technology education, and the unique skills and dispositions developed through the 'technology education experience'. It has proposed some big issues which impact on technology education. It has attempted to locate Technology Education in a role of enabling citizens to be in a position to cope with challenges and opportunities they may face in their everyday lives and careers they may follow. As a relatively new curriculum area, and by its very nature, Technology Education has a responsibility to continue to evolve and develop, respond and lead. As noted in the discussion on the place of disruptive technologies in the Technology education, there is a difference between incremental change (which carries less risk, but can lead to loss of traction, value and market) and transformational change.

Einstein urged the New York Times readers in his launch of a campaign in 1946, 'A new type of thinking is essential if mankind is to survive and move toward higher levels.' Einstein was a proponent of transformational change; change that is not merely an improvement on what has gone before, but change that is even more far reaching. Transformational change demands a shift in culture and in organization. It is change over a period of time which fundamentally changes underlying processes and guiding strategies. This is what distinguishes it from incremental change and evolutionary change, which are perhaps common to readers through their personal experience to date within the educational systems and organizations in which they teach, the way things are made, and how economies are grown and the manner in which resources are supplied can be examined. Technology Education has the potential to take a major role and be significant driver of transformational change if those engage in Technology Education value themselves as transformative learners and build the arguments to construct knowledge and skills to realize the potential.

Transformational change often involves questioning, challenging and destabilizing deeply held institutional and personal professional beliefs. It might challenge what was hitherto thought of as the essential and core to the very existence of what, in the case in point, is considered to be Technology Education. It might require a rethinking of the very purposes and values of what one does as an individual or as an institution. It requires engagement at strategic levels and a shift in mind set and behaviors. It demands professionals working together to re-orientate and create whole systems thinking.

Perhaps, Technology Education can provide the stimulus for asking questions such as, 'what if?', 'when?', 'why?' and 'then what?' Learning to adopt designerly thinking approaches to explore authentic scenarios can promote creativity, participation, shared responsibility and socially oriented actions. Carefully selected challenges from the global learning environment can illustrate the importance of the diversity of cultures and that this diversity can be celebrated and valued. Design, engineering and technological attitudes, skills, knowledge and understanding can contribute to unknown futures by creating a construct for being which values creating, making and thinking equally.

We need to provide space to develop the pedagogical repertoire necessary to embrace what is tricky, difficult, personal and global, namely, engaging learners in exploring the concept of self and their relationships with technologies. This learning goes beyond a product, environment or system evaluation 'task'. It incorporates more than the issues of design and make. It examines the result of such interconnection(s). The interdependency and interconnectedness of systems is at the core of this model of 21st century Technology Education.

This chapter attempts to raise some issues and only begins to consider implications of these ideas. It anticipates some dilemmas, questions the aims and intentions, and promotes the potential of Technology Education. It asks, what are the necessary mindsets for a 21st century issues-based design and technology education, and what implications are there for teaching and learning. It encourages a re-examination of purpose and practice, and suggests that some serious reflection and action is required. It concludes there are some big issues which have impacts and consequences for technology education and urges teachers to build their arguments to help construct knowledge which will serve as informed and well founded justification for future directions.

REFERENCES

Anderson, C. (2006). *Long Tail: Why the Future of Business is selling less of more* Hyperion

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J. & Wittrock, M. C. (Eds.) (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives* Longman.

Ayers P. J. (2009). *The Art of leading Transformational Change* Author House

Benyus, J. (1997). *Biomimicry: Innovation Inspired by Nature* Harper Collins

Birkeland, J. (2002). *Design for sustainability: a source book of integrated ecological solutions* Earthscan Ltd

Christensen, C. (1997). *The inventors Dilemma: When New Technologies Cause Great Firms to Fail* Boston: Harvard Business School Press,

Crawford, M. (2010). *The case for working with your hands: or why office work is bad for us and fixing things feels good* Viking

Dana, N. F. & Yendol-Hoppey, D. (2009). *The reflective Educators Guide to Classroom Resrach: Learning to teach and Teaching to Learn through Practioner Enquiry* CA: Corwin

Dormer, P. (1994). *The Art of the Maker: skills and its meaning in Art, Craft and Design* Thames & Hudson

Ellen MacArthur Foundation and McKinsey& Co, (2012). titled 'Towards the Circular Economy – Economic and business rationale for an accelerated transition'

Elshof, L. (2006). Productivism and the Product Paradigm in Technological Education *Journal of Technology Education*, *17*(2).

Einstein as cited "Atomic Education Urged By Einstein; Scientist in Plea for $200,000 to Promote New Type of Essential Thinking", New York: The New York Times Company, May 25, 1946), p. 11

Faud-Luke, A.(2009). *Design Activism* Earthscan Ltd

Fisher, R. (1998). Thinking about Thinking: developing metacognition in children, *Early Child Development and Care*, Vol 141 pp 1–15. http://www.teachingthinking.net/thinking/webresources/robert_fisher_thinkingaboutthinking.htm

Flavell J. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental enquiry, *American Psychologist*, *34*, 906–911

Fry, T. (2009). *Design Futuring Sustainability, Ethics and new practice* Berg publishers

Goleman, D., R. Boyatzis, R., McKee, A. (2002). *Primal Leadership: Realizing the power of emotional intelligence* Harvard Business School Press, Boston

Hargreaves, A. (2002). Professional Learning Communities and Performance Training Cults: The Emerging Apartheid of School Improvement, in A. Harris, C. Day, M. Hadfield, D. Hopkins, A. Hargreaves and Chapman, C. (Eds) *Effective Leadership for School Improvement*. London: Routledge.

Halliday, S. (2001). *The Great Stink of London: Sir Joseph Bazalgette and the Cleansing of the Victorian Metropolis* The History Press

Institution of Mechanical Engineers. (2011). *One Planet:Too many people?* Institution of Mechanical Engineers http://www.imeche.org/knowledge/themes/environment/Population

Jones, R. & Wyse, D. (2005). *Creativity in the Primary Curriculum* Taylor & Francis

Jackson, T.(2011). *Prosperity without Growth: Economics for a Finite Planet* Earthscan Ltd

Lieberman, A., Saxl, E. and Miles, M., (Eds.) (1988). *Building a Professional Culture in New Schools*. New York: Teachers' College Press.

Kimbell, R. & Perry, D. (2001). *Design and Technology in the Knowledge Economy* Engineering Council http://www.data.org.uk/generaldocs/dater/destech.pdf

Kimbell, R & Stables, K. (2008). *Researching Design Learning* Springer

Lave, J. & Wenger, E. (1991). *Situated Learning. Legitimate peripheral participation* University of Cambridge Press

McDonough, W. & Braungart, M. (2002). *Cradle to Cradle: remaking the way we make things*, North Point Press

McLaren, S. V. (1997).Value Judgments in Evaluating Design: A Scottish Perspective on Global Issue *International Journal of Technology and Design Education, 7*(3), 259–278

McLaren, S. V. (2012). Assessment is for learning: supporting feedback *International Journal of Technology and Design Education, 22*(2), 227–245. DOI 10.1007/s10798-011-9195-z

Muijs, D. and Harris, A. (2003). Teacher Leadership—Improvement Through Empowerment? An Overview of the Literature *Educational Management &Administration, 31*(4), 437–448.

Northern Ireland Curriculum. (2007). *Active learning and Teaching Methods for KS3* p73. PMB Belfast www.nicurriculum.org.uk

Practical Action. (2008). *The Sustainability Handbook for Design and Technology Teachers* Practical Action and Centre for Alternative Energy

Schon, D. (1983). *The Reflective Practitioner How professionals think in action* London: Temple Smith

Schon, D. (1987). *Educating the reflective Practitioner* San Franscico: Josey-Bass

Seltzer, K. & Bentley, T. (1999). *The Creative Age: Knowledge and skills for the new economy*. London: DEMOS

Scottish Social Enterprise Academy *http://www.theacademyssea.org/schools/schools_role_of_honour*

Silva, D.Y., Gimbert, B. & Nolan, J. (2000) Sliding the Doors: Locking and Unlocking Possibilities for Teacher Leadership, *Teachers College Record, 102*(4), 779–804.

Stahel, W. (1998). Product Durability and retake after use in, M. Kostecki, (ed) *The durable use of consumer products: new options for business and consumption* Kluwer Academic Publishers, pp. 29–39

Stahel, W. & Reday, G. (1982). *Jobs for Tomorrow, the Potential for Substituting Manpower for Energy* Report to European Commission Brussels NY :Vantage

Sterling, S. (2001). *Sustainable Education: Revisioning learning and change Schumaker Briefing No 6*. Green Books

Sterling, S. (2005). Linking Thinking education and learning – an introduction in S. Sterling, D. Irvine, P.Maiteny & J Salter *Linking thinking- New perspectives on thinking and learning for sustainability* WWF.

Stibbe, A. (2009). *The Handbook of Sustainability Literacy: skills for a changing world* Green Books The Six Thinking Hats Tool Kit http://debonoforschools.com/asp/six_hats.asp

Webster, K & Johnson C. (2008). *Sense and Sustainability* at http://www.ellenmacarthurfoundation.org/education/publications

Acknowledgements: Illustrations courtesy Ellen MacArthur Foundation
Figure 1: The linear economy
Figure 2: The circular economy

AFFILIATION

Susan V. McLaren,
University of Edinburgh

AUTHOR BIOGRAPHIES

David Barlex
David is an acknowledged leader in design & technology education, curriculum design and curriculum materials development. He taught in comprehensive schools for 15 years before taking university positions in teacher education. He directed the Nuffield Design & Technology Project and was Educational Manager for Young Foresight. David is well known for his interest and expertise in developing curriculum materials that support pupil learning from a constructivist perspective. He uses this approach to develop young peoples' ability to understand and critique the design decisions made by professional designers and those they make themselves in design & technology lessons.

Rob Cowdroy
Rob is a research professor specialising in learning and assessment of design and other forms of creativity, and in the mental processes of creative block. He was advisor to the Australian Productivity Commission on the value of design; advisor to the Dutch Minister of Education and guest of the French Ministries of Education and Culture for evaluation of EU design education standards, and three times guest professor at the European Summer Universities introducing new approaches to design education. He has been visiting professor at Delft University of Technology (Netherlands), the Universities of Louvain la Neuve and Brussels (Belgium) and the University of Quebec at Montreal (Canada).

Marc J. de Vries
Marc is a Professor of science and technology education and an affiliate professor of philosophy of technology at Delft University of Technology, the Netherlands. He serves as the editor-in-chief of the International Journal for Technology and Design Education (Springer) and as series editor of the International Technology Education Series (Sense). He was one of the initiators of the international PATT (Pupils' Attitudes Towards Technology) conferences and is still involved in the organization. Among his publications is a book that introduces philosophy of technology to technology educators ("Teaching About Technology", Springer). He also co-authored textbooks for technology education in the Netherlands.

Wendy Fox-Turnbull
Wendy is currently a senior lecturer at University of Canterbury's College of Education. She lectures in Technology Education and Professional Education Studies, Inquiry Learning and Teaching and Assessment. She is responsible for technology teacher education programmes and is currently deputy head of School

within the School of Sciences and Physical Education. Wendy is the current chair and member of the Technology Education New Zealand (TENZ) Council. Wendy's research special interests include authentic learning in technology education, the role and nature of effective conversation in technology and Inquiry Learning: Teaching and Learning Approaches for the 21 st Century. She has presented regularly at PATT and other international conferences and is published in a range of journals.

Richard Kimbell
Richard founded the Technology Education Research Unit (TERU) at Goldsmiths, University of London in 1990. Since that time, research sponsors include research councils (eg ESRC, NSF [USA]), industry (eg LEGO, BP), government departments (eg DfES, DfID), and professional/charitable organisations (eg Engineering Council, Royal Society of Arts). Kimbell has prepared reports for the Congress of the United States, UNESCO and NATO. He is Visiting Professor at the University of Stockholm. His latest book "Researching Design Learning" (with Prof Kay Stables) analyses the 20+ years of research output from TERU and was published by Springer in 2007.

Thomas Loveland
Thomas coordinates the M.Ed. Program in Career and Technology Education for the University of Maryland, Eastern Shore. He has twice been a Fulbright Foundation Recipient, travelling for educational purposes to Japan to write and present curriculum with Japanese colleagues at the secondary and graduate level. Dr. Loveland has received the Teacher of the Year Award (for Florida) and the Lockette/Monroe Humanitarian Award from the International Technology and Engineering Education Association. He has been published and presents regularly on the topics of professional development, assessment, Standards for Technological Literacy, and transnational curriculum.

Susan V. McLaren
Susan is currently Senior Lecturer (Design & Technology Education) at Moray House School of Education at the University of Edinburgh. She teaches initial teacher education through to continuing professional development. Her research interests are related to the development of principles, practice and values in Design Technology. They include the development of pedagogies to embed principles of design for sustainability; issues of transformational change and altered consciousness; perceptions of personal technological capability, discriminators of creativity and progression; and useful, real time multi modal assessment is for learning approaches. She is involved in national curriculum development and support resources.

Gary O'Sullivan
Gary's career began teaching design and technology and ICT in London. He was Director of Technology in the first girls' technology college in the UK. His current

position is Senior Lecturer in technology at the Institute of Education, Massey University in New Zealand. He teaches and co-ordinates teacher education courses at both undergraduate and graduate level. He has been the subject specialist for technology at Massey University for the last seventeen years. He has given keynote addresses and presented at conferences in Australia, Canada, England, New Zealand and Scotland. He has published numerous journal articles and book chapters.

David Spendlove
David is a former senior teacher who is now Director of Teacher Education at The University of Manchester and is involved in the development of new approaches to teacher education. He has current knowledge of international policies that are transforming the education sector and school and teacher education responses to them. He participates in, researches and has published extensively about these rapidly changing initiatives, including emerging curriculum trends, pedagogical practices and student teacher developments. David also has extensive understanding and knowledge of Design and Technology education. He currently co-edits Design and Technology Education: An International Journal and has written extensively about the teaching of Design and Technology.

Louise Wallis
Louise is a lecturer at the School of Architecture and Design at the University of Tasmania. Her research focus is on Design Studio Teaching, including areas on teaching methods, the influence of the setting and how academics conceptions of learning and teaching inform their practices. Louise has been a research team member of a number of national research grants investigating Architectural Education in Australasia, Assessing Creativity, and Assessing Teamwork in Design. Her research has been published in many refereed conference papers, both nationally and internationally, as well as contributions to books into Design Studio Pedagogy.

P. John Williams
John is Associate Professor and Director of the Technology, Environmental, Mathematics and Science Education Research Centre at the University of Waikato in New Zealand, where he teaches and supervises research students in technology education. He has published over 40 articles and has authored and co-authored 14 books, regularly presents at international and national conferences, consults on Technology Education in a number of countries, is a longstanding member of eight professional associations and is on the editorial board of four professional journals, and is the Editor of the Australasian Journal of Technology Education. In 2011 he was elected to the International Technology and Engineering Education Association's Academy of Fellows for prominence in the profession. He holds an adjunct professorial position at Edith Cowan University in Perth, Western Australia.

Anthony Williams

Anthony is Professor and Head of School of Architecture and Built Environment at the University of Newcastle and has extensive experience in project management in the domain of professional education. He is a winner of multiple University and National Awards for Teaching Excellence. He has worked extensively in curriculum design and implementation and is highly regarded in this area having worked as a consultant nationally and internationally. His research area is in Design Cognition with recent projects involving identification of core skills for effective participation in virtual design teams. He has contributed to 200 publications which have resulted from his research.