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**Total Technology Practice:
Preliminary study for application in
New Zealand schools**

**A Thesis presented in partial fulfilment of the requirements for the
Degree of**

**Master of Philosophy
in
Technology**

**At Massey University, Palmerston North,
New Zealand**

JOHN A GAWITH

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ABSTRACT

The purpose of this research was to identify the important generic elements of total technology practice and to develop a preliminary list of the important techniques, knowledge and actions used by technologists. The research was based on the hypothesis that in technology education in New Zealand schools, the important elements of technology practice could be represented in the form of a model that could be used to organise and communicate the elements and knowledge involved in total technology practice.

The research was undertaken with technologists working at Massey University and teachers involved in teaching technology. A product development research methodology was used to test ideas and develop a model of technology practice for use in New Zealand schools. The first phase of the research used the experience and knowledge of product development technologists to identify the important elements of technology practice and develop preliminary lists of techniques and knowledge involved in each element. A group of specialist technologists were used to verify these elements and identify detailed content.

This research showed that total technology practice can be structured using seven elements that together provide a simplified description of total technology practice. The elements of practice associated with the human context and goal of technology practice were identified as society, the work environment, and purposeful action. The elements technologists bring to the context were organisation, information, resource use, and an extensive knowledge of techniques and the skill, ingenuity and experience to apply and adapt techniques to specific contexts and problems.

Individual technologists were interviewed to identify the important practices and knowledge within their area of expertise. Technological knowledge was structured into a framework that reflected the way technologists broke complex systems into subsystems to solve problems and develop solutions.

The detailed model developed with the technologists was evaluated by groups of teachers using focus group techniques and a small survey. The study indicated teachers perceived the model as a useful tool for communicating knowledge and understanding of technology practice and for structuring teaching units in technology education.

This preliminary study indicated technology practice can be described in terms of seven elements and communicated in the form of a model. Technologists organise their knowledge into structures that facilitate application in practice. This structure and much of its knowledge can be made explicit and used to help students understand technological products and develop capability in their technology practice.

This study has identified a structure for technology practice and technological knowledge that is common to all seven technological areas and nine contexts identified in the New Zealand technology curriculum.

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CHAPTER 1. INTRODUCTION

Technology is a new essential learning area in New Zealand schools. It is expected to stand along side the other six essential learning areas of Science, Mathematics, Social Sciences, Language and Languages, The Arts, Health and Physical Well-being. In the past, new subjects, such as Biology and Geography, have taken considerable time to develop a teaching pattern and a defined area of knowledge (Goodson, 1983). Goodson (1983) observed that interest groups with a stake in the new subject area initially tended to develop the subject in different ways until either a consensus was reached, or one group established a dominant position. It is expected that technology will go through a similar process in New Zealand.

Teagust (1990) described how Australian schools, in common with England and Wales, had approached technology education from four different interest group agendas - craft teaching, "hi-tech" (computers and electronics), engineering, and finally as a subset of science. He argued that none of these approaches were suitable for a compulsory technology education curriculum. In New Zealand, a similar pattern of interest groups has occurred (Jones, 1997), particularly as workshop craft and home economics teachers have had their traditional subject areas revoked with the introduction of the technology curriculum (Ministry of Education, 1995). During the period of synthesis for this new essential learning area, it is important that all aspects of technology practice are considered to ensure that a well-balanced curriculum evolves.

Modern technology is a complex subject that is difficult to understand and define in its entirety. It involves the complete process, from identifying and examining problems and opportunities in society, through to technological development, and the introduction, use and disposal of solutions. It is not practised in isolation but is contextualised and networked with other areas of human activity and endeavour (Mitcham, 1994). This wider concept of technology can be referred to as a 'total technology system'. Without an overview of total technology, it is difficult to recognise the interactions and influences of the various components that comprise this discipline. As Dehejia (1995) explained, technology "has to do with certain kinds of knowledge, allowing the adaptation of means to ends. Part of this knowledge is embodied in machines, but most

of it is not. It is embodied elsewhere, too - in the brains of people, in organisational structures and in behavioural patterns, which in turn, are conditioned by the strategies of different social factors and their patterns of conflict and co-operation.” (p233). The study of total technology practice should include a broad knowledge of many areas but should also foster an ability to apply this knowledge to specific problems within a particular context.

The purpose of this study is to examine the components and characteristics involved in total technology practice in New Zealand and to develop a theoretical structure that can be used for teaching technology education in schools. This thesis is intended to add to the web of understandings and alternative views of technology thus contributing to the development of a mature and robust technology education learning area in New Zealand schools.

1.1 DEFINITIONS

As there is some confusion about terms in technology practice and teaching, the following section defines the way important terms will be used. In this study, a clear distinction was drawn between *knowledge* and *information* in order to emphasise the processes and cognitive procedures that students might undertake in their practice. Likewise a clear distinction was drawn between *technology* and the *products* that result from the practice of technologists.

Total Technology refers to the wider understanding of technology and reflects the continual interaction of technology practice with society, in the development of solutions that are compatible with notions of progress, and ethical, social and environmental responsibility. Technology practice involves an inseparable link between society and the actions involved in developing or modifying products (Fleck, 1997; Dehejia, 1995; Pacey, 1983). Individual and societal values and concepts are built into the products as they are developed (Mackenzie and Wajcman, 1993). Earle and Earle (1999) described total technology from a company’s perspective as the “...internal organisation, the market and marketing, the customer and consumers, the technological ambience surrounding the company including competitors, and also the social and physical environments in which the company operates” (p1). Total technology implies

an interaction with the relevant groups in society, from the initial identification of the problem or opportunity, through all the steps involved in product development, to the use and disposal of the product.

Technology practice is the process of improving existing products or developing new products while at the same time recognising and managing the tension between the constraints arising from the cultural, organisational and technical aspects of practice (Pacey, 1983). Technology practice requires an ability to work at a specific level involving outward manifestation of the development or modification of a product, and at a strategic level involving the organisation and control of actions (McCormick, 1997). Technology practice involves a 'reflective conversation with the situation' (Schön, 1983). Technologists could be said to be '*reflecting-in-action*' when working at the specific level, and '*reflecting-in-practice*' as they work at the strategic level. Thus technology practice involves an ability to critically examine one's personal practice in a conscious effort to improve and innovate the way in which techniques and processes are used to develop solutions. This process of reflection leads to new techniques and processes being developed. It adds to the technological knowledge base and is a component of technology practice.

Elements of practice refers to the categories of knowledge, thought and action that technologists use in their practice. These include the consideration of society and users, the recognition of strengths and constraints in the work environment, problem identification and solution achievement, organisation and management the acquisition of information, knowledge of resources and materials and application of appropriate techniques.

Technologist(s) refers to the people or the person involved in the practice of total technology. It is important to keep in mind the definitions of both total technology and technology practice to appreciate the breadth of factors and knowledge technologists use when developing and implementing solutions. These people are generally involved in developing or modifying products, and/or the production processes for these products.

Products refers to the outcomes from total technology. These can be *tangible* outcomes, (goods), or they can be *intangible* outcomes (services). Most products have both tangible and intangible components. Products can be industrial (capital) products used by other industries, or consumer products used for consumption. Further outcomes from technology practice are firstly the development of conceptual knowledge required by technologists in areas not adequately explained by other disciplines; for example, the knowledge involved with airflow patterns over aircraft wings (Vincenti, 1990), and with freezing rates for boneless beef cartons (Earle, 1997). Secondly the development of instruments to measure and quantify attributes of tangible products. Two example of this are the instruments developed to measure aspects of flying quality, and the development of large wind tunnels to test aircraft design as described by Vincenti (1990).

Knowledge in technology can be defined as the body of information and actions embodied within an individual, that is able to be expressed and applied in a knowing and appropriate way through their technological practice (Reber, 1985). Knowledge is embodied in individual action, both cognitive and manipulative (Fleck 1997; Dehejia, 1995). Recent industry research on what people know and the actions they perform in technological contexts has highlighted a number of different components to their knowledge (Fleck, 1997; Nonaka, Takeuchi & Umemoto, 1996). These studies provide useful insights into how technological knowledge might be developed in schools. In this research the term 'knowledge' will be restricted to what the student knows to be true, usually through their experience of application and use.

Information is defined as "any material with content, any attended input, any idea, image, fact, [or] knowledge" (Reber, 1985, p354).

With the growth of accessible information through electronic databases, the Internet and libraries, it is important to highlight the difference between information and knowledge. By using these definitions of knowledge and information, a distinction can be made between what the individual knows and is able to apply to a specific problem and what information is relevant from the vast array of formal texts, experimental results, the world-wide web and other information sources.

1.2 TECHNOLOGICAL KNOWLEDGE

A number of researchers have studied the role of knowledge in the context of problem solving, and the importance of knowledge organisation structures or schema that allow people to organise their knowledge and incorporate new information and understandings (McCormick, 1997; Hennessy & McCormick, 1994; Glaser, 1993). Other school subjects like science and mathematics have evolved ways of progressively developing students' knowledge structures through the various levels of schooling. Technology requires a similar knowledge structure. However in the case of technology, such a structure must recognise that knowledge is embedded in practice. "Technology is not so much the *application* of knowledge as a *form* of knowledge, one persistently dependent on technical skill" (Mitcham, 1994).

Research indicates a need to possess and utilise an organised body of conceptual and procedural knowledge when problem solving (Glaser, 1993; Layton, 1993). This includes an accessible and usable knowledge of the subject (McCormick, 1997). Expert knowledge is organised around principles and abstractions and "knowledge about the application of what they know" (Glaser, 1993). It is not just a matter of knowing, it is also necessary to know when and how to apply the knowledge (McCormick, 1997). This research on problem solving has important implications for teaching technology education, which as Lewis (1991) observed, currently lacks an ordered conceptual framework of knowledge and concepts.

Total technology practice has implications for the development of this conceptual framework. It recognises that technology practice does not take place in a vacuum but is influenced by the knowledge embodied in the culture or community, the organisational structures and the technical environment in which the practice takes place (MacKenzie and Wajcman, 1993; Pacey, 1983). It also requires students to consider the nature of the problem and the effect the solution might have on the various stakeholder groups in society.

There are problems in teaching technology practice, as much of this practice is not explicit (de Vries, 1997) and appears mainly intuitive (Burns, 1997). Vincenti (1990) used the development of aircraft to describe engineering practice and developed a

schema to classify engineering/technology knowledge. However, while categories for this knowledge can be described, the knowledge itself is bound to the practice of individual and the context in which they work. This makes it particularly difficult to generalise and teach as it involves observation and practice.

1.3 RESEARCH QUESTIONS

The technology curriculum introduced into New Zealand schools requires teachers to teach three inter-related strands (technological knowledge and understanding, capability, and the interaction of technology and society) across seven different technological areas and in several different contexts (Ministry of Education, 1995). This would seem a daunting task without the use of a generic structure of knowledge and practice that can be applied in each teaching project.

The New Zealand curriculum statement and subsequent publications have not identified conceptual or procedural knowledge important for problem solving in technology. This makes it difficult for teachers to plan a coherent, progressive programme of knowledge and skill development, important in developing expertise in technology practice. It also makes the task of deciding what to assess and a picture of progression difficult.

The actions and knowledge structures used by New Zealand technologists in their technological practice can be identified and adapted to provide teachers with generic elements of practice and appropriate knowledge structures for teaching technology across the seven technological areas. These elements of practice and knowledge structures may provide teachers with clear learning objectives and opportunities for assessment and planned progression through the eight levels of the curriculum.

This study focused on identifying the important elements of total technology practice, how these elements interrelate and the ways technologists structure knowledge in order to solve problems. This required answers to the questions:

1. What are the important elements of total technology practice?
2. What techniques, knowledge and actions are involved with each element?

3. How can the technological concepts and knowledge involved in total technology practice be structured and communicated effectively to technology education teachers and students in New Zealand schools?

The research was based on the hypothesis that in the essential learning area of technology in New Zealand schools, the important elements of technology practice can be represented in the form of a model that can be used to organise and communicate the concepts involved in total technology practice.

1.4 THIS STUDY

The research questions will be answered by examining technological practice in New Zealand. This study identified the elements involved in total technology practice by observing and working with a small group of practising product development technologists at Massey University. The validity of these elements was verified using a case study, discussion with a wider group of specialist technologists and the construction of a packaging teaching unit.

The study identified seven elements of total technology practice and the important generic information and technological concepts involved with each element. The interaction and combination of the elements were incorporated into a preliminary model of total technology practice. This model of total technology practice was examined by a group of technologists who used their knowledge and experience of technology practice to critique the model structure and content.

The implications of the model and its elements for teaching and learning in technology education were examined and the effectiveness of the model to communicate these was evaluated. A broad perspective of the elements and the issues involved was deliberately pursued to allow for a discussion of cultural differences and perspectives on technology practice. The scope of the study prevented the examination of different cultural perspectives but nevertheless, it was seen as important in the New Zealand school context that these issues are considered in the design of the model.

The study examined knowledge in the context of technological problem solving. The literature on the nature of technological knowledge and its development, was used to examine the detailed knowledge involved in technology practice. Implications of knowledge structures for creativity, innovation, and problem solving in school contexts were discussed and a structure proposed for the development of technological knowledge in schools. The study focused on generic aspects of technological knowledge but also considered specific technological areas and how these differed in the type and organisation of knowledge.

The aims of the research were:

- To identify the generic elements of total technology practice.
- To identify the techniques, knowledge and actions associated with these elements.
- To propose a structure for the technological knowledge and technological concepts involved in total technology practice.
- To develop a model for use in New Zealand schools, that communicates effectively the knowledge and technological concepts of total technology practice.

CHAPTER 2. MODELLING TOTAL TECHNOLOGY PRACTICE

Empowerment is an important goal for general technology education in New Zealand schools (Ministry of Education, 1995; Burns, 1993). If students understand total technology practice - the process and ideologies involved in developing the products that surround them - they are more likely to be empowered to influence the technological world in which they live. The technological process is a social construct. It has developed and changed over time and will continue to change in the future and New Zealand students can influence future changes.

This chapter reviews the literature and examines total technology practice and its associated knowledge. Previous studies of technology practice identified generic elements and in a general way the techniques, knowledge and actions used by technologists in their practice. Research on problem solving and knowledge structures provided a theoretical base for the technological knowledge structure proposed in this research. Finally, models developed in other countries were examined and used as the starting point for the development of a model that reflects total technology practice in New Zealand and that meets the requirements of the New Zealand technology education curriculum. The review attempts to draw concepts from distinct areas within the literature such as: the study of sociotechnical change, the philosophy of technology, technology history, education psychology, and industry practice and research.

2.1 TOTAL TECHNOLOGY PRACTICE

Technology practice takes place within the constructs of society (Mackenzie and Wajcman, 1993; Bijker and Law, 1992; Staudenmaier, 1985; Pacey, 1983). People control, influence, and mould the products of technology depending on their cultural values, goals, and notions of progress. These influences on practice need to be examined along with the knowledge and technical elements involved in the development and modification of products, in order to provide a comprehensive view of technology practice.

Mitcham (1995) proposed three phases in the perception of technology over time. The first, pre-modern technology or technics, was seen as part of human action and not separated from the other actions such as art and religion. The second or modern technology has been with us for the last 150 to 200 years. During this phase technology was separated from the complexity of its context to enable it to be studied, as were the other areas of study such as art, religion, economics and science. He argued that what used to be part of a holistic perception has now been reduced to a series of 'unlinked disclosures' which are studied in isolation and developed along their own narrow lines in pursuit of greater knowledge and expertise. In the third phase, meta-technology, he predicted a new interrelating and interconnecting of the realms of science, politics, economics, religion and technology. This view was supported by Link (1998) who argued for a total view of technology consisting of technological objects, operations, procedures, and systems, including sociotechnical structures and technological action systems.

A similar perception is evident in the literature on the history of technology. Pacey (1983) perceived technology practice as involving three widely differing 'disclosures' that are embodied, either consciously or unconsciously, into the products of technology. He saw three aspects as contributing to technology practice, *cultural* aspects involving people's beliefs and values, *organisational* aspects reflecting society's management and encouragement for technology. The final *technical* aspect recognised the knowledge, techniques and the physical outputs from technology practice and is the limit of many people's concept of technology. See Figure 2.1.

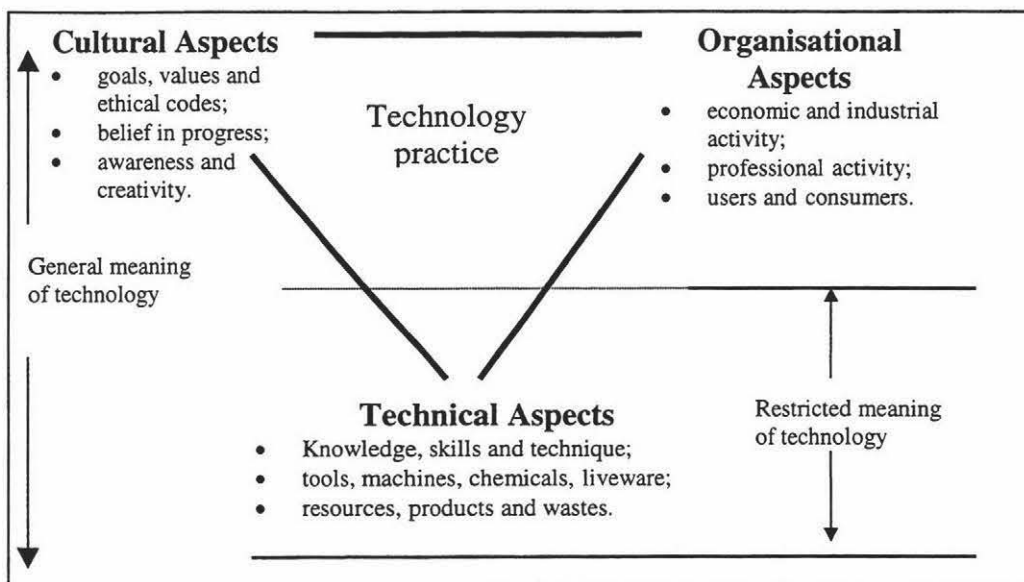


Figure 2.1 Definition of Technology Practice

(Pacey 1983 p6)

2.2 GENERIC ELEMENTS OF TOTAL TECHNOLOGY PRACTICE

Mitcham (1994) described total technology as encompassing eight characteristics. (1) has material outcomes, (2) fabricates or is constitutive of those outcomes, (3) is purposive, (4) is resource based and resource expending, (5) utilises or generates knowledge, (6) is methodological, (7) takes place in a sociocultural-environment context, and, (8) is influenced by individual practitioners' mental sets. These eight characteristics of total technology practice complement Pacey's (1983) three aspects of technology practice and provide a starting point for the identification of generic elements important in technology education in New Zealand. In this study the first characteristic, materials outcomes, was interpreted in a wider context to include intangible products developed by technologists. For example, in the fast food industry, the material products might be food and packaging but an important aspect of the product comprises a large intangible, (service) component.

Models developed for design and technology education identify a number of elements important in technology. Eggleston (1992) identified human purpose, restraints and resources. Peters, Verhoeven and de Vries (1989) included in their conceptual framework for technology, cultural elements such as norms/values, human needs and scientific knowledge. They included elements of matter, energy and information.

These models, along with the work of Mitcham (1994) and Pacey (1983) provided a foundation for the important elements of total technology practice developed in this study. These elements are: society, the work environment, purposeful action, organisation, information, resources, tools and techniques.

2.2.1 Society

Technology practice cannot be isolated from the culture and societal norms that surround it. The products developed by technologists reflect these cultural norms. Hansen (1997) and others support this view. Pacey's (1983) study of the snowmobile and the water pumps in India, demonstrated how modern products reflect the ideologies and processes that developed them. Staudenmaier (1985) concluded from his analysis of the *Journal of Technology and Society* that "the values and world views, the intelligence and stupidity, the biases and vested interests of those who design, accept, and maintain a technology, are embedded in the technology itself" (p165). Some argue that technology and society cannot be separated (Bijker and Law, 1992). In the present study, to facilitate an understanding of the knowledge and actions associated with the generic element of society, the three aspects of technology practice identified by Pacey (1983) were used: cultural, organisational and technical.

Cultural aspects involve goals, values and ethical codes, belief in progress, and awareness and creativity. Chant (1989) described the impact of ideology on technology, particularly the American ideology that all problems can be seen as technical problems able to be solved through rational instrumental techniques. Pacey (1992) discussed how the technical ideal of rational systems of machines and automation might lead to the social ideal of a good life for all. The culturally centred epistemological approaches of Ernst Kapp saw technology as an extension of the human organism, while Francis Bacon viewed technology as a humanisation of the world or conquest of nature (Mitcham, 1994). In 1930 Mumford argued that products e.g. machines should be appraised in aesthetic and ethical terms as much as their technical aspects (Mitcham, 1994). The comments of these writers reflect goals, values and beliefs in progress and serve to illustrate the cultural aspects of their concepts of technology.

However, goals, values and ethical codes are continually changing. For example Kotler & Armstrong (1997) described how the philosophy of marketing has developed over time as societies' values and concepts of progress, have changed. They described five philosophies or concepts that reflect the changing cultural, political and economic pressures on businesses and which help to explain some of the changes in the way new products are developed and the resulting form these products take. The first philosophy, *the production concept*, emphasises production and distribution efficiencies. Ford's black model T car is a classic example. The second, *the product concept*, is driven more by the technical aspects of the product without considering or consulting consumers' needs in great detail. The third philosophy, *the selling concept*, advocates a large scale selling and promotion effort which is often used for products consumers would not normally seek to purchase. The emphasis is on the sale and not so much on consumer satisfaction. The fourth philosophy, *the marketing concept*, takes the market as the starting point, and is based on customer needs and on retaining customers by providing customer satisfaction. The final and most recent philosophy is the *societal marketing concept*. This is similar to the marketing concept but adds to it by striving to produce products that maintain or improve customers' and society's well being. These changes since the beginning of this century indicate how rapidly values and goals can change.

Mitcham (1994) maintained that technological practice is not just involved in using knowledge and other cognitive processes but also involves volition. He saw volition as involving will, drive, motive, aspiration, intention and choice, all of which are culturally grounded.

Organisational aspects involve economic and industrial activity, professional activity, users and consumers, and trade unions. Institutionalised expectations such as national traditions have considerable effects on technology (Agassi, 1997; Chant, 1989). Professional norms related to areas of expertise and practice are influences on technology practice. These professionals contribute to traditions of practice which consist of complex information which is physically embodied in a community of practitioners and also the hardware and software they use (Constant II. 1980). Societies develop different organisational structures to constrain or promote technological developments. Such things as patent and copyright laws, research and development

policies and access to risk capital are examples of organisational aspects in most modern economies (Chant, 1989).

Technical aspects include knowledge, skill and techniques, tools, machines, chemicals, liveware, resources, products and wastes (Pacey, 1983). Besides the cultural and organisational differences between countries, there are also the differences in technical aspects. Examples of this are the availability of resources such as raw materials, machinery, equipment and technological knowledge between New Zealand and North America.

The wider society influences discussed above form one element of Mitcham's (1994) social and cultural (sociocultural) environment. The second element is the immediate environment or work context in which particular products are developed and produced.

2.2.2 Work Environment

The work environment is the place in which practice occurs. This environment encourages and constrains the technologist as they develop solutions to problems. Staudenmaier (1985) described the work environment as a pervading atmosphere that surrounds and influences the technologist(s) as they work, and used the term 'technological ambience' to describe this pervading atmosphere. Such things as the physical surroundings, the people present, the equipment, the working space, and concepts of beauty and quality are all part of the pervading atmosphere, which is itself a reflection of a society and its resources. Fleck (1997) described this context as involving domains, situations and milieux, and argued that over time, the 'milieu' in which practice takes place, has a profound effect on the types of products produced. This context might be a university, a company or a school classroom.

Technology practice involves value judgements about what is possible and worthwhile and how a product is developed and produced. Layton (1993) supported this view. These values originate in society and are brought into the technology practice context by the people involved. Bijker & Law (1992) went further and described technology practice as involving continual compromise. These compromises involve such things as politics and economics but also concepts of materials and what is beautiful and

worthwhile. Not only will the technologist have views on these, but also the people with power in the work environment and the people for whom the product is intended.

Technology practice then, involves a dynamic process of negotiation and compromise between the various stakeholders within the company and with the user group for whom the product is being produced. Bijker's (1992) case study of the development of fluorescent lighting, and Cowan's (1993), account of the development of domestic refrigeration both provide examples of factors within the work environment that influence the development of products.

2.2.3 Purposeful Action

Technology is a purposeful activity. This is recognised in most models of design and technology as a progression through a process and is usually depicted by arrows. However, as indicated above purposeful action takes place within a sociocultural-environment, and technologists should recognise the problem or opportunity as arising within society and that the final solution will be used by society.

Total technology practice involves the development of solutions within the strengths and constraints of the society and working context in which it occurs. The New Zealand curriculum document describes technology as a creative and purposeful activity that produces products for identified needs and opportunities (Ministry of Education, 1995). Vincenti (1990) talked about 'bringing into being' or 'doing' when referring to engineering practice. Technology practice is goal orientated and directed towards developing solutions. The modern technological process, knowledge and actions involved in achieving these solutions have developed over the last two hundred years.

Edison used a systematic approach to developing solutions at his invention factory at Menlo Park and combined all elements – economic, political, and social in his purposeful action (Hughes, 1993). Layton (1993) described the systematic empirical enquiry approach as important in modern technology practice. This systematic approach or 'method of invention' has been described as the greatest invention of the nineteenth century (Mitcham, 1994). The steps in this 'method of invention' can be described as analysis, synthesis, simulation and evaluation (Roozenburg and Eekels, 1995).

Earle and Earle (1999) described the modern product development process in four stages – (1) Product strategy development; (2) Product design and process development; (3) Product commercialisation; (4) Product launch and evaluation. Within this process the work environment surrounding the purposeful action will profoundly influence the methods used. It may involve a hard ‘scientific’ approach involving quantitative data and empirical methodologies or a softer hermeneutic approach using qualitative data and action research methodologies. The present study proposed a model of total technology practice, which depicted this purposeful action as taking place within societal settings and the pervading atmosphere of the work environment.

2.2.4 Organisation

Modern practice involves using systematic methodologies to organise and progress the purposeful activity within the constraints and strengths of the work environment (Savage,1991). Mitcham’s (1994) description of technology as methodological implies the need for organisation and management of a systematic process. The inclusion of this element of practice promotes empowerment in that students develop skills and techniques to set and realise appropriate goals in ways that recognise the cultural context and other influences on their practice. In Hughes’ (1993) account of Edison and the development of the electric light, he recognised Edison’s ability to organise and manage the process as playing a critical part in the success of this innovation.

Earle and Earle’s (1999) product development process focused on the decisions that are made so that the product proceeds through to its final launch and evaluation in the market place. The technologist maintains a global perspective that guides the process and ensures both the product and the process followed are evaluated. The process involves thinking through three levels of organisation and using this to direct and control the development of the product. The first level involves the key decisions and actions that must be made as the product is developed. The second level involves the outcomes needed to inform and support these decisions, and the final level comprises the activities needed to gather and collate the information for the other two levels.

Technologist work through the process using appropriate organisation, knowledge and resources, as well as techniques which they apply in undertaking the activities. These processes cannot be simply applied as each context and problem will be different.

Technologists must make judgements on the appropriateness of the steps within the process, and record the proposed direction so that it can be evaluated after it has been applied and used to build further knowledge (Ulrich & Eppinger, 1995).

In the process of their practice, technologists organise time, physical space, people, resources, knowledge and information. Specific techniques are utilised to do this. Time and money are often constrained and must be managed carefully to ensure they are not wasted and that the most appropriate solution is developed within the constraints. Technologists use techniques such as Gantt charts and budgets to manage these constraints. People are the most important component of practice; organisational techniques such as meeting procedures and management structures encourage their involvement and creativity. Nonaka and Konno (1998) described metaphor techniques for this purpose. Resources must be organised in order to reduce wastage and ensure the appropriate resource is available at the right time and place.

This process of organising the 'purposeful action' is done within the work environment and must recognise the strengths and take account of the associated constraints outlined in Section 2.2.2 (Staudenmaier, 1985). The development of organisational knowledge, abilities, and skills is an important aspect of capability in technology. Both the conceptual and procedural knowledge associated with organisation needs to be developed in each context so that generalised strategies and applications can be built up.

2.2.5 Information

In the process of developing specific solutions to particular problems, technologists will draw on information from a wide range of sources. Technologists use information to construct knowledge within the context of the problem on which they are working (Nonaka and Takeuchi, 1995). This aspect of practice requires the ability to recognise the need for information and an ability to find, select and analyse the information and apply it to the specific issue involved in developing the product (Kimbell, 1991). The models of Peters, Verhoeven & de Vries (1989), and Savage (1991) used the term 'knowledge' and described it as a resource used by technologists. If the definitions for knowledge and information outlined in Section 1.1 were applied, this resource would be called information.

Information associated with technological knowledge is carried in a variety of media. Interpretation by human experts is required to give the information meaning. Fleck (1998) described formal knowledge as embodied in codified theories that can be found in textbooks in the form of text, diagrams, and 'dense symbolic inscriptions'. He also identified guidebooks, manuals, catalogues and plans as containing information used by technologists.

Scientific theories and laws will be an important component of the information element. However, technology practice is not the direct application of scientific rules and laws to the solving of technological problems. Mitcham (1994) summarised the arguments against technology as applied science. These arguments identified the way technologists modify scientific concepts, use problematic data, depend on technical skill and build up a unique body of technological and engineering theory. Vincenti (1990) acknowledged the use of scientific information, but as one source among others, such as information from technological experimentation and information derived directly from experience and practice.

2.2.6 Resources

Resources are the items and inputs needed to accomplish the technological ends. This element is identified in Savage (1991) technological learning model. Examples of resources used in technology practice are resources such as raw materials and components, energy, buildings and equipment, people, information and time.

Technologists have an extensive knowledge of resources, particularly the raw materials used in processing and the materials and components used in developing products. Selecting an appropriate resource from a range of alternatives may involve extensive study to ensure that the resource is suitable for the job, at an acceptable price, and within the constraints of the work environment and society's values. Raw materials selection may also involve examining the chain of production steps from the original source in order to ensure consistent quality and continuity of supply (Earle and Earle, 1999). Other issues might involve ethical, environmental and social issues involved in the use of particular raw materials. Selecting the optimum resource and understanding and measuring the composition of raw materials, particularly biological materials, appears to comprise much of the knowledge and action in this element of practice.

The resource aspect was recognised in most models of technology practice. However, by placing resource use within a sociocultural context, issues of cost, environmental concerns and social impacts become important considerations in resource selection and use. For example, the appropriate resource to use may depend on the technological expertise and material wealth of the society or organisation within which the technology practice is taking place.

2.2.7 Techniques

Over time the community of technologists have developed a considerable library of techniques that can be used in technology practice. Techniques could be seen as tools used by technologists in their practice, for example, the use of a matrix technique to identify needs and specifications (Ulrich and Eppinger, 1995).

Models of technology practice depict a systematic approach but do not explicitly identify the extensive use of tools and techniques at every stage of product or process development and production. For example, Walker, Dagger and Roy (1991) described creativity techniques and explained how they can be used as utilitarian tools by technologists, while Roozenburg and Eekels (1995) described what they called 'methodics, methods, rules and recommendations' used in engineering design.

Roozenburg and Eekels (1995) described the rules and methods used by technologists as heuristics that help in finding a solution for a problem. These rules and methods do not guarantee a solution but rather, improve the chance of finding a solution if used appropriately. Methodology provides a conceptual tool for technologists to organise the development process effectively and efficiently. Examples of these tools are the diagrammatic models of the design process and the associated rules and methods used.

Schön (1987) discussed the way technologists share conventions of actions and tools. Technologists must use 'reflection in practice' to choose and adapt techniques to the situations that arise (Schön, 1983). They must develop the art of 'seeing as' - in other words, the ability to see in an unfamiliar or poorly understood problem, similarities or principles from previous experience or knowledge and to apply an appropriate technique (Schön, 1987).

Simply learning and applying techniques and methodologies in the same way to all situations reflects a technical rationality approach and positivist concept of practice (Schön, 1983). A positivist approach to engineering design is reflected in an unconsidered application of methodology and techniques. For example those identified by Simon (1969) as: “utility theory, statistical decision theory, algorithm, and heuristics for choosing both optimal and satisfactory alternatives, imperative logics, factorization and means-end analysis, resource allocation schemes, and so on” (Sighted in Mitcham, 1994, p99).

Schön (1983) described technical rationality as the application of scientific theory and technique to the instrumental problems of practice and argued that this approach in itself is not sufficient in technological problem solving. Technological practice required a more reflective approach and a willingness to be surprised and investigate anomalies. However, given this proviso, technologists do use a wide range of techniques in their practice.

2.3 TECHNOLOGICAL KNOWLEDGE STRUCTURES

The development of technological knowledge is fundamental in technology education and is discussed extensively in the literature (Johnson, 1997; McCormick, 1997; Mitcham, 1994). The present study has confined itself to recent studies of technological knowledge involved in the context of technology practice.

Nonaka and Takeuchi (1995) drew comparisons between Western concepts of knowledge and knowledge creation, and Eastern concepts, primarily those in Japan. These comparisons resulted from a number of industry studies that clearly demonstrated cultural differences. These researchers saw knowledge as naturally residing in the individual and essentially tacit in nature. The challenge for industry is how to convert this individual tacit knowledge into explicit knowledge that can be shared within the organisation. This is in contrast to the predominant concepts of knowledge in Western organisations where it is seen as explicit in nature and so can be measured, managed and distributed (Cohen, 1998). However, this may not be the case for technological knowledge, which is mostly tacit and intuitive in nature (Burns, 1997; Dehejia, 1995).

Nonaka and Takeuchi (1995) made three observations concerning the differences and similarities between knowledge and information. Knowledge is about *beliefs* and *commitment*, It involves *action* and is used to achieve an end, and it is about *meaning* within a context. Information is also context-specific and relational but unlike knowledge does not involve beliefs and action. Teece (1998) on the other hand, defined knowledge as 'information in context'. 'Context' in this sense included language, images and gestures, historical information, physical settings and future strategies and trends. This definition is rather narrow and does not include the cultural context involving beliefs and commitment or that knowledge is about action.

These authors generally saw knowledge as existing in two forms within an industry context. It is either explicit, and able to be measured and exchanged, or it is tacit and exists within the individuals and communities of practice.

2.4 TYPES OF TECHNOLOGICAL KNOWLEDGE

From an education psychology perspective, McCormick (1997) made a distinction between two types of knowledge, which he saw as important in technology practice. The first, procedural knowledge, involved the 'know-how-to-do-it' knowledge. The second, conceptual knowledge, involved an interrelated knowledge of facts and theories, along with a knowledge of devices and systems. In this way, conceptual knowledge was more than a collection of unrelated facts, but rather the relationships between items of knowledge within a context. He made the point that both procedural and conceptual knowledge were necessary and that without an adequate conceptual knowledge, the effective use of procedural knowledge in problem solving will be limited.

This is supported by de Vries and Tamir (1997) who reported on studies in technological problem solving that revealed the use of concepts, or declarative knowledge, as well as process knowledge such as procedural, situational and strategic knowledge. Conceptual knowledge has traditionally been a core component of education. However process knowledge is being recognised as equally important. It is evident that both types of knowledge are required in technology practice and need to be

taught and applied in a balanced way (McCormick 1997). For progression in technology practice, conceptual knowledge in ever-increasing depth will be required, along with process knowledge in increasing complexity and sophistication.

The two *types* of knowledge identified by McCormick (1997) can exist in the two *forms* identified by Nonaka and others. Both areas of study see knowledge, or knowing, as residing within individuals. In this sense a distinction is made between information and knowledge as outlined in the definitions in Chapter 1.

2.4.1 Components of Technological Knowledge

Fleck (1998) noted the current interest in analysing the knowledge involved in technology developments and identified six components of technological knowledge important in practice. He did not see each component as separate but rather integrated in different ways depending on the context and the focus of the expertise involved. These components of technological knowledge provide a further useful way of breaking down the practice of technologists in order to facilitate the development of technological capability in school curricula. The six technological knowledge components identified by Fleck (1998), are discussed as follows.

Formal knowledge embodied in codified theories, is the intellectual knowledge typically gained through academic courses and textbooks. Fleck (1998) emphasised that textbooks carry information in the knowledge area, but this information must be given significance by human agency. Historically, this form of knowledge has enjoyed a high status.

Instrumentalities refer to the use of tools, instruments and specific techniques, and are the central focus of engineering and technology (Fleck, 1998). This knowledge goes beyond a basic knowledge of the tools and techniques themselves, to their use, application and maintenance.

Informal knowledge involves the knowledge learned on the job, usually through verbal interaction with fellow workers. Such things as 'rules of thumb' or 'tricks-of-the-trade' are examples. Mitcham (1994) described this component of technological knowledge as technical maxims. It is the information often necessary for the application of formal

knowledge and instrumentalities. Some of this knowledge is recorded in publications such as guidebooks and working manuals. However, much knowledge is not formally recorded and is exchanged between communities of practitioners in informal (verbal) ways.

Contingent knowledge is the knowledge built up from experience within a specific context. It is often included in informal and tacit knowledge. However, Fleck (1998) argued strongly for a separate category. He saw it as having the characteristics of being distributed, apparently trivial, highly specific to the particular application domain and as a result, accidental to the general process of technology development. This type of knowledge stems from an intimate familiarity with the context in which a person is working.

Meta-knowledge is the knowledge of values and 'taken-for-granted' assumptions that exist in cultural contexts. Pacey (1983) identified these as the cultural and organisational aspects of technology practice. Fleck (1998) described meta-knowledge as the standards and rules for perceiving, interpreting, believing, and acting which are typically used within organisations. This form of knowledge reflects the accepted norms of power structures within organisations, and defines what knowledge is legitimate and worthy of status.

Tacit knowledge has been discussed extensively in the literature. Fleck (1998) described this form of knowledge as embodied in individuals, developed through practice and experience, expressed through skilful execution and taught by apprenticeship and training through watching and doing. This form of knowledge involves skills that are not easily communicated and therefore constitute a constraint on the expansion of both science and technology. He lists tacit knowledge as one of six components of knowledge. However, other researchers see tacit knowledge as central to technology and innovation (Senker, 1998). Leonard and Sensiper (1998) described knowledge as existing on a spectrum between purely tacit at one extreme to totally explicit at the other. Polanyi (1969) described all knowledge as tacit or rooted in tacit knowledge (cited in Senker, 1998).

Fleck (1998) depicted the interactions and linkages of each knowledge component in the form of a diagram. This diagram is reproduced in Figure 2.2

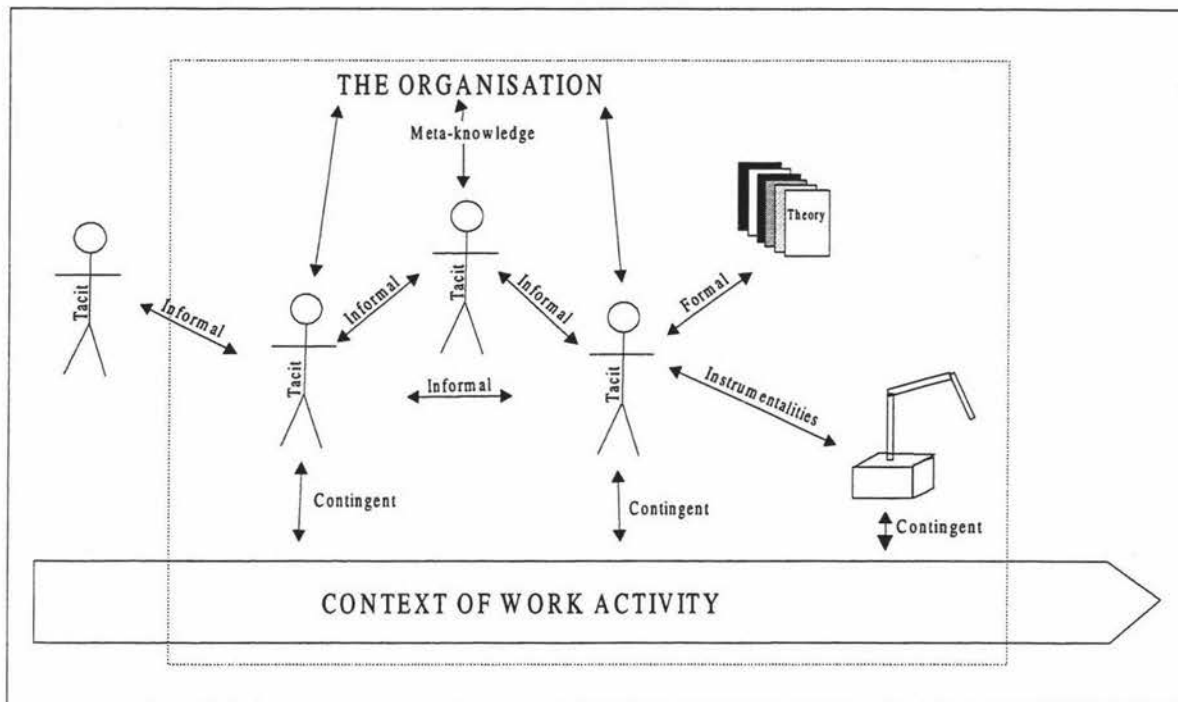


Figure 2.2 Interaction of Technological Knowledge

(Fleck, 1998, p10)

In engineering, further taxonomies of knowledge are recognised. Ropohl (1997) identified five knowledge types: *technological laws* – a transformation of natural laws, *functional rules* – specifying what to do, *structural rules* – assembly and interplay of components of a technical system, *technical know-how* – tacit knowledge involved in technological practice, and *socio-technological understanding* – a systematic knowledge about the interrelationship between technical objects, the natural environment, and social practice. The first three, technological laws, functional rules and structural rules, could be seen as part of the ‘formal knowledge’ component, while technological know-how encompasses all six knowledge components outlined by Fleck (1998). Socio-technological knowledge is partly covered by meta-knowledge but adds the knowledge involving the interaction of technology with the environment and society that could be seen as lacking from Fleck’s (1998) list.

This discussion of technological knowledge identifies a number of concepts that can be applied to technology education. Knowledge exists within the individual and when applied is internalised in a tacit form. To be effective the technologist must have both conceptual knowledge of the relationships between the various components of the product, the constraints of the work environment, how these interrelate with the development process, and procedural knowledge of how to actually develop the product in practice. This internalised or tacit knowledge can be described as comprising the remaining five components of technological knowledge described by Fleck (1998). These components of knowledge can be seen as applying in varying degrees to the seven elements of total technology practice. The degree of application will vary depending on the context and the issues involved with the problem. Table 2.1 demonstrates how the components of technological knowledge might interact with the elements of practice. The pattern of interaction will change depending on the particular project involved.

Table 2.1 Knowledge Matrix

	Formal knowledge	Instrumentalities	Informal knowledge	Contingent knowledge	Meta-knowledge	Tacit Knowledge
Society	xx	x	x	x	xxxx	xxx
Work environment	x	xx	xxx	xxxx	xxx	xx
Purposeful action	x	xxxx	xxx	xxx	xx	xxxx
Organisation	xx	xx	xx	xxx	xxx	xxx
Information	xxxx	xx	x	x	x	x
Resources	xxxx	xxx	x	x	xx	xxx
Techniques	xxx	xxxx	xxxx	x	xx	xxx

These components provide a possible structure for teaching technological knowledge. Each component characterises a body of expertise that can be assessed and reported. Figure 2.3 illustrate a spider diagram indicating expertise in each component. However, Fleck (1998) stressed that technological expertise cannot be reduced to just a list or measure of quantity in each category.

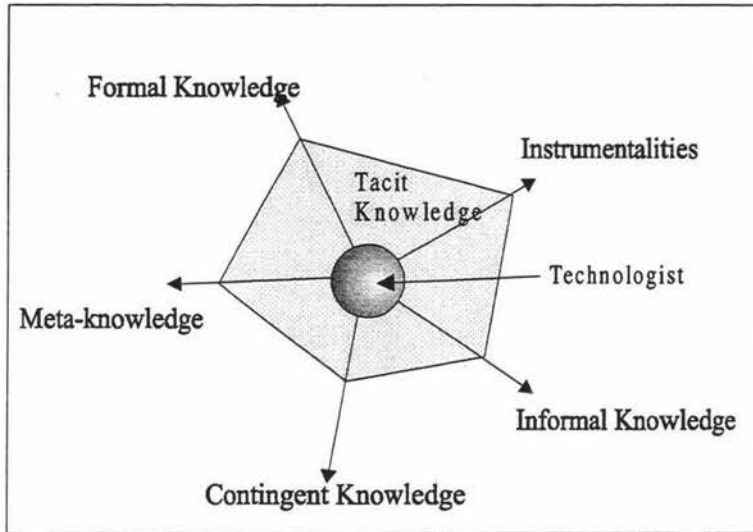


Figure 2.3 Components of Technological Knowledge

(Adapted from Fleck's 1998 Comparison of Expertise diagram p17)

Tacit knowledge has been included as centring on the technologist and as an essential part of the other five bodies of expertise.

2.4.2 Creating Knowledge

Innovation is an essential component of the modern capitalist economy and as a consequence has been the subject of much research. Nonaka and Takeuchi (1995) in their book *The Knowledge Creating Company*, describe how Japanese companies create the dynamics of innovation. This study highlighted significant cultural differences between Western and Eastern concepts. These authors and others see knowledge creation as the source of innovation. Effective industry 'knowledge creation practices' have relevance to technology education, as much of the knowledge is tacit and cannot be embodied in texts and taught in traditional ways.

Industry experience indicates that the development and transfer of tacit knowledge is a social process dependent on the structures, attitudes, and values of the working environment (Leonard and Sensiper, 1998). Nonaka and Konno (1998) described the Japanese concept of *ba*, which they roughly translate as 'place' but has the concept of a shared space that serves as a foundation for knowledge creation. This shared space

involves 'nurturing', 'love', 'trust' and 'caring' as opposed to the Western concepts of management and measurement. They see knowledge as embedded in this 'place' and when separated from 'the place', it becomes information that can be used by others in a different place.

Kimbell *et al.* (1991) demonstrated how the interaction of mind and hand can lead to more developed thinking and more developed solutions as depicted in Figure 2.4.

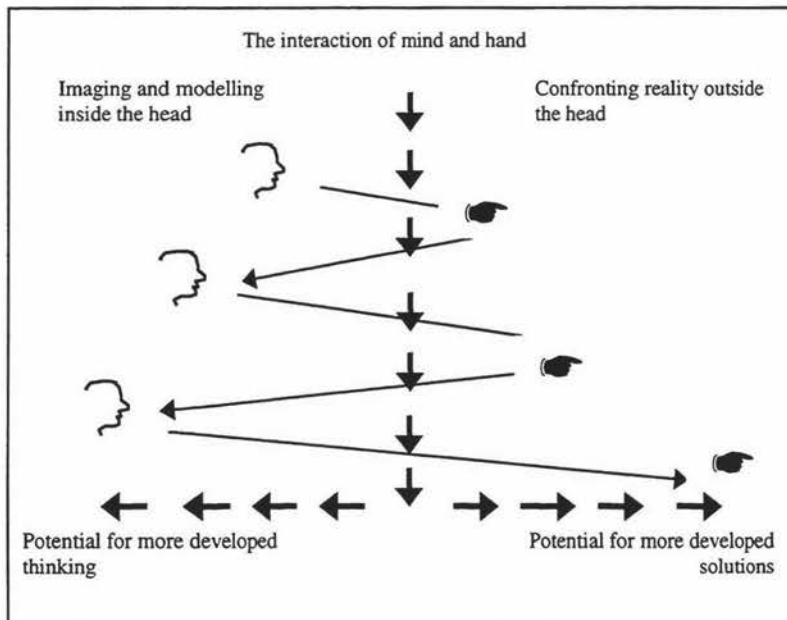


Figure 2.4 The Interaction of Mind and Hand

(Kimbell *et al.* 1991 p20)

Nonaka and Konno (1998) added two important concepts observed by Layton (1993) as missing in Kimbell's diagram. Firstly, knowledge creation takes place within a context that embodies values and cultural perspectives and secondly it nearly always involves groups of people. From his study of technology and society, Staudenmaier (1985) identified three dimensions of emerging technology:

Invention - a personal act shrouded in mystery.

Development - almost always a group endeavour involving a series of goal directed experiments where inventive ideas are transformed from an abstract possibility into a physical reality.

Innovation - which is the entrepreneurial activity of producing and selling technological products.

These researchers consider the interaction within a group of practitioners as important in technology practice. Nonaka and Konno (1998) visualised knowledge creation as a spiral process that grows through a process of ever increasing levels of tacit knowledge that have been made explicit and shared with colleagues within the context of 'ba'. They visualised this process in the form of a diagram, reproduced in Figure 2.5

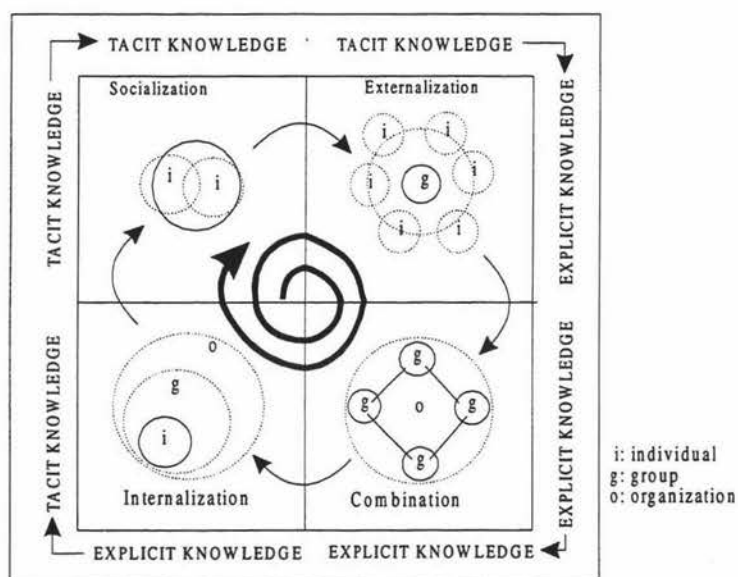


Figure 2.5 Spiral Evolution of Knowledge Conversion and Self-transcending Process

(Nonaka and Konno, 1998, p43)

Invention, development and innovation all form part of the New Zealand technology curriculum for schools. Nonaka and Konno's model of knowledge creation in industry (Figure 2.5) has relevance to knowledge construction in the classroom. As their diagram demonstrated, the process consists of four stages. *Socialisation* involves sharing experiences and as a result sharing tacit knowledge in the form of mental models and technical skills through experience within a context. *Externalisation* involves expressing the tacit knowledge in explicit ways using techniques such as

metaphors, analogies, concepts or models. This involves social structures and interaction within groups. *Combination* involves incorporating this knowledge into knowledge systems. This process involves the reconfiguration of existing information and the combining of knowledge to create new understandings. *Internalisation* involves converting explicit knowledge into tacit knowledge. This involves using the new knowledge in practice, or 'learning by doing'. In this way, the individual's tacit knowledge expands and stimulates further cycles of knowledge creation, or in education terms, knowledge construction.

2.5 KNOWLEDGE AND TECHNOLOGICAL CONCEPTS OF TOTAL TECHNOLOGY PRACTICE

Technology practice requires the combination of theoretical knowledge with practical application. This knowledge is developed through experience and 'doing'. Schön (1987) set out the professional's approach as one of framing the problem so that it suggests a solution even though the solution might be very tenuous. This might then suggest a strategy for enquiry. Technologists build a repertoire of examples, images, understandings and actions which can be used to frame problems and suggest further investigation and experimentation to gain a deeper understanding of the problem (Schön, 1987). Glaser (1993) and McCormick (1997) discussed the role an extensive, applied knowledge base plays in expert problem solving. These concepts have significant implications for the teaching of technology in schools. The development of technological knowledge in a holistic, structured way would appear to be an important component of any school curriculum in technology.

Technology practice can be observed as operating on two levels. Firstly on a 'specific' level involving the obvious outward manifestation of the development or modification of a product. The second or 'strategic' level, involving the organisation and control of the actions at the first level (McCormick, 1997). The strategic level involves an ability to critically examine personal practice in a conscious effort to improve and innovate in the way technology is practised.

Critical practice will necessitate a self-regulatory or metacognitive approach to learning and the need to make the techniques, knowledge and actions of technology practice explicit in order for students to develop their skills (McCormick, 1997). Technological knowledge must be used and applied for it to be understood and the associated tacit knowledge developed.

Balancing the constraints of the work environment with the development of innovative solutions is at the centre of technology practice (Staudenmaier, 1985). If students are to gain a realistic conception of total technology practice, the seven elements of technological practice discussed in Section 2.2 should be taught and applied within the strengths and constraints of the pervading atmosphere that surround the classroom. This practice is not just the development of new products, but also involves the development, adaptation and evaluation of the tools, systems and methods used by technologists (Ulrich and Eppinger, 1995). Students can model professional behaviour by recording and sharing new insights and knowledge with each other in order to modify and further develop their own knowledge in the context of practice. Nonaka and Konno's (1998) model of knowledge creation provides a structure for this process.

This discussion identifies three important technological concepts. Firstly that technology practice involves a holistic multidisciplinary approach that draws together all eight characteristics identified by Mitcham (1994) in the development of solutions. Secondly modern technology practice involves a systematic methodological process that empowers the technologist without limiting creativity or the potential to be surprised by unexpected results (Schön 1987). Thirdly technology practice always takes place within a context and as a result is influenced by the context. Models of technology practice should reflect these three technological concepts in order to provide an appropriate structure for the development of technological knowledge.

2.5.1 Models of Technology Practice

There are a number of different models depicting the characteristics of technology. Some focus specifically on the design process (Kimbell *et al.*, 1991; Roozenburg and Eekels, 1995). These models generally portray a stepwise process of identifying a problem through to the assessment of the proposed solution. The approach is methodological and focused on outcomes that are generally tangible. Most depict a

cyclical or iterative progression through the various steps. These models are mainly concerned with the technical aspects as identified by Pacey (1983) and generally do not include the sociocultural-environment context and the individual practitioner's 'mental sets' that Mitcham (1994) identified in his eight characteristics of technology.

Other models depict a more general process of technology (Eggleston 1992; Peters, Verhoeven and de Vries, 1989; Savage, 1991). These models of the technology process portray a wider perspective. The sociocultural-environment was included in Peters, Verhoeven and de Vries' (1989) model. This model recognised the constraints of the natural world and a societal and cultural context in the conceptual framework for technology practice. This perspective was missing in the models of the technology process presented by Eggleston (1992) and Savage (1991). However, these models included a consideration of human factors and the influences of constraints and resources on the process. Any representation of technology that does not recognise the 'politics of the activity' has a significant weakness (Layton, 1993). None of the models of the general technology process or design specifically identified the need for the process to be organised and managed by the technologist. These models may imply organisation and management but do not make this element of practice explicit.

Pacey's (1983) definition of technology practice represented in Figure 2.1 proposed a model of technology practice comprising cultural, organisational and technical aspects. While these aspects provide useful categories for examining technology in the context of the wider society, they provide little insight into how technologists' develop products in practice. Savage's (1991) model, which approached practice from an engineering perspective, identified the elements of knowledge and resources and implied a purposeful process in the development of solutions. This model emphasised the development of solutions and systematic methodology and is reproduced in Figure 2.6.

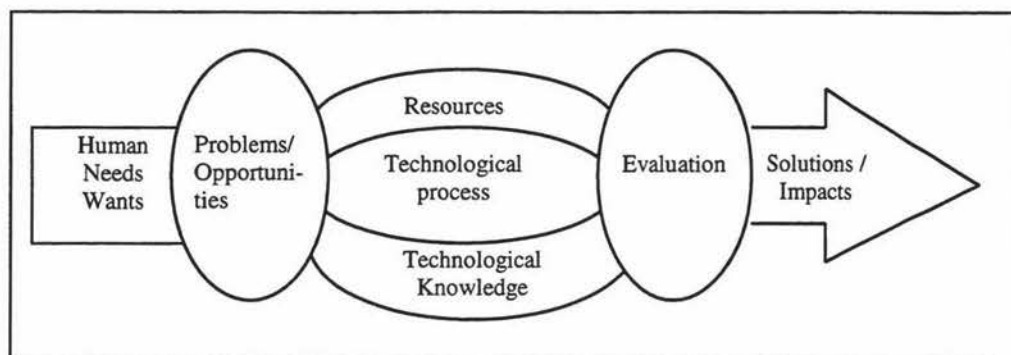


Figure 2.6 Technological Learning Model

(Savage 1991 p36)

These two models represent different perspectives on practice. Each model on its own highlighted important perspectives on technology practice relevant to the New Zealand curriculum statement. Pacey's (1983) model represents the third strand involving technology and society, while Savage's (1991) model highlights a systematic process and actions of technologists associated with the second or capability strand.

The present study will investigate the actual practice of technologists to see how they deal with the issues raised in each of the models described above. By using this approach it was expected a model of total technology practice could be developed that incorporated the perspectives of both Pacey and Savage into one cohesive model. Such a model would address the need to cover the three strands contained in the New Zealand technology curriculum in an applied and unifying way so that students might appreciate the multidisciplinary, holistic nature of technology practice. The method used to develop, validate and evaluate this model of total technology practice is described in the next chapter.

CHAPTER 3. RESEARCH METHOD

3.1 INTRODUCTION

A research method was chosen that was likely to achieve the purpose of developing a theoretical structure of total technology practice that could be used for teaching technology in schools. This required the identification of the important elements of technology practice, the knowledge and actions involved, and a means of effectively structuring and communicating these to teachers and students in schools. A graphical model of total technology practice was seen as an effective means of communicating technology concepts and knowledge. Thus a research method was required that would enable the development of an educational product that was technically accurate and could be used by teachers in the classroom.

The initial stages of the product development research method were used in this research to generate and test concepts, and develop a means of communicating these to teachers and students. This process is very similar to action research. Both use an iterative approach within a context of practice. They differ in that the result of product development research is a new product while in action research it is a change in practice itself. Kemmis and McTaggart (1989) described action research as a form of collective self-reflective enquiry that involves people working on their own practice. These authors saw action research as social groups involved in examining and improving their practice.

The focus of this research was on the development of a model for teachers to use in the classroom. Teachers may examine and improve their practice as a consequence of using the model, but the focus of this research project was on developing a tangible product. The product development methodology was seen as an appropriate research method for this purpose.

3.2 THE PRODUCT DEVELOPMENT RESEARCH METHOD

Product development is an industrial research method used to develop or modify products in ways that focus on the users of the particular product (Earle, 1997). The research method involves a structured approach to the development of new products that ensures all the important issues involved in new product development are considered and undertaken (Ulrich and Eppinger, 1995). Both qualitative and quantitative techniques can be used to gather information and test concepts.

This research project required an understanding of human action in the form of technology practice. It was felt that qualitative research techniques offered the most productive means of identifying and understanding the elements of total technology practice. Gordon and Langmaid (1988) described qualitative research as concerned with understanding things rather than measuring them. They characterised qualitative projects as having flexible interview structures that evolved in response to growing understanding and hypotheses. The database generated from qualitative research was greater than the resulting recorded tapes and transcripts as it contained many unrecorded and non-verbal interactions. This research project used a variety of qualitative techniques ranging from informal conversation to formal, recorded interviews. A more quantitative approach was used to gather user information on the product prototype.

Earle and Earle (1999) described the product development process as consisting of four stages – (1) product strategy development, (2) product design and process development, (3) product commercialisation, and (4) product launch and evaluation. Product commercialisation, and product launch and evaluation were not considered in this study and were seen as a subject for future research. The initial product strategy development stage involved model idea generation, model idea screening and model concept development. The second product design and process development stage involved model concept verification by technologists, model evaluation by teachers and model detailed design.

Four research objectives were identified and undertaken at appropriate stages of the product development process. These research objectives focused on answering the three research questions outlined in Section 1.3, and provided the structure for undertaking

and reporting the research. The first objective was to identify the elements of total technology practice and communicate these in the form of a model. This was the primary focus of stage one involving model idea generation, model idea screening and model concept development. Further changes to the model continued in stage two in light of the model concept verification by technologists and model evaluation by teachers.

The second objective was to verify the accuracy of the model and its elements. This was carried out in stage two of the product development process. The model concept was verified using a case study, an expert panel and the development of a packaging example, using the model of total technology practice as a structure for this purpose.

The third objective was to evaluate the model's effectiveness in communicating the concepts and elements of total technology practice. This was done using schoolteachers and teacher facilitators involved in technology education. The model evaluation by teachers commenced as ideas were screened in stage one but became an important focus in stage two of the product development process - model concept verification and evaluation, and the final model detailed design.

The final objective was to identify the detailed knowledge involved in each element of the model, and the way technologists structured this knowledge to facilitate practice. This detailed design commenced during model concept development and continued through stage two. Technologists were involved in identifying the detailed design of each element.

The stages of the product development process used in this research are illustrated in Figure 3.1. The process, techniques and sample groups used to achieve each objective will be described in detail.

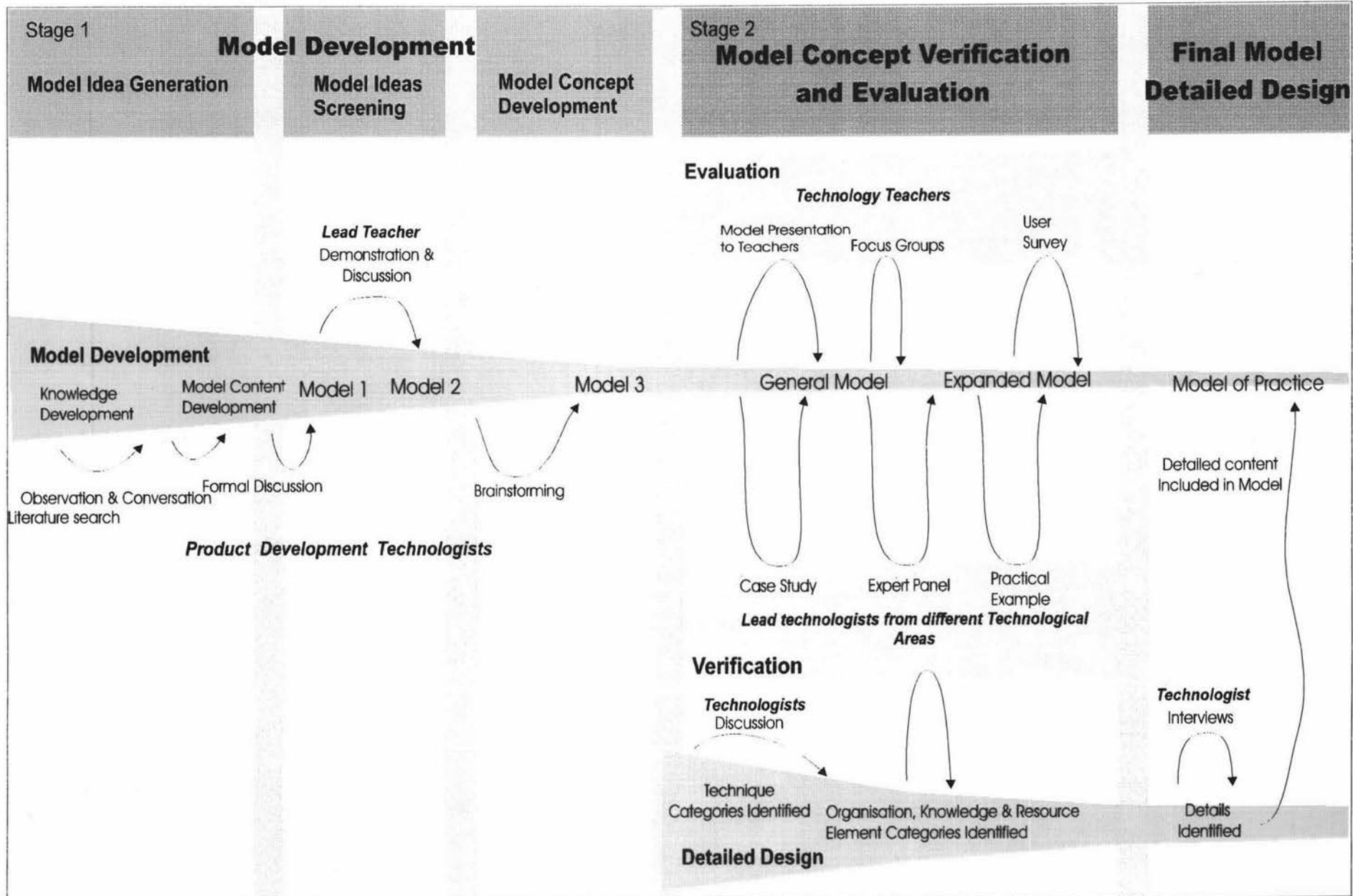


Figure 3.1 Diagrammatic Outline of Research Method

3.3 MODEL DEVELOPMENT

The model development research was undertaken within the Department of Consumer Technology, Massey University. This Department provided an environment where Bachelor of Technology students from all four year levels took classes and did project work in the same studios and tutorial rooms. This presented an opportunity to observe the progressive development of knowledge within a defined and easily accessible environment. The Department promoted interaction with industry, including a final year project where students worked with commercial companies to develop products for the New Zealand market. This presented an opportunity to observe political, social and economic influences on the development of products and the need for students to consider the work environments within their sponsoring companies. A group of seven technologists within the Department were involved in product development projects and private sector consultancy in the New Zealand manufacturing industry. The opportunity to observe and discuss issues and concepts with these technologists provided a productive context for this research. The product development technology lecturers involved contributed a wide base of specialist knowledge, such as market research, packaging, project management, design, creativity and prototyping, and the generic understanding of technology practice.

3.3.1 Model Idea Generation

This process began formally in July 1996 with an examination of the literature and discussion of Pacey's (1983) and Savage's (1991) models of technology practice. These models provided starting points for the identification of the elements involved in technology practice. The Bachelor of Technology course in Product Development was observed and many opportunities taken for discussions with staff on the important elements of practice. Formal weekly research meetings were held and concepts of technology practice discussed with a group of 4 product development technologists. Ideas discussed at these meetings were recorded in a Research Journal along with observations and further ideas developed during the week. Many of the informal conversations were not recorded individually, but contributed significantly to the development of knowledge and understanding of practice. Through this process a preliminary list of important elements of practice emerged which led to an initial model

in November of 1996. This initial model idea was developed into a physical model and diagram (Figure 4.4 Section 4.3).

Three techniques were used to develop ideas in this section of the research.

Literature search: This technique was used to develop an understanding of concepts involved in technology. Models of practice developed by others provided starting points and benchmarks for this research.

Insightful Observation: Anderson (1990) described this technique as an often unsystematic method used by researchers to develop understanding in order to formulate questions and concepts. This technique was used for gathering evidence and understanding and confirming concepts suggested by other data sources. A conceptual understanding of technology practice was developed through observations of lectures, tutorials, workshops involved in the product development option of the Bachelor of Technology Degree, and from observing technologists involved in industry contracts and industry projects. The understandings developed from these observations were discussed with the technologists and recorded as concepts within the initial model ideas.

Conversation: This technique allowed the researcher to learn about people's experiences, ideas and the world in which they live (Kvale, 1996). Casual conversations with product development technologists were used to develop concepts and knowledge of technology and the important elements involved in practice. The insights and concepts resulting from these conversations were recorded in the Research Journal and in sketches and diagrams that were used in further conversation.

3.3.2 Model Ideas Screening

The group of product development technologists at the research meetings screened the models developed from the idea generation. A further screening involving a technology teacher advisor was undertaken to introduce a different perspective on the model concept. From the screening process, no concepts were seen as adequately communicating the elements of technology practice.

Formal Discussion: This technique took the form of research meetings with a small group of product development technologists with the specific purpose of discussing technology practice and its associated literature. Kvale (1996) described conversational techniques as existing in multiple forms from everyday conversations to highly structured interviews. The key points of these discussions were recorded in the Research Journal.

3.3.3 Model Concept Development

Following the idea screening session, no existing model concept was seen as adequately identifying and communicating the elements of technology practice. A third model concept, which appeared to reflect technology practice, was developed using a group brainstorming technique described below.

Brainstorming: Roozenburg and Eekels (1995) described brainstorming as a method of encouraging a number of people to work together to produce divergent associations of concepts and ideas. This technique was used with four product development technologists and involved a general discussion of previous models and the important elements of practice. The question that was then put to the group was how could these elements be effectively communicated in a diagrammatic model of technology practice? The researcher acted as the group leader and recorded all ideas on a white board. The four product development technologists were very familiar with the brainstorming technique and developed a wide range of ideas. After approximately 30 minutes these were screened and the most promising concept developed further. This concept was recorded in sketches and later developed, with the help of one of the technologists, into a computer graphic (Figure 4.6 Section 4.3).

This concept was refined further during model concept verification and evaluation and final the model detailed design. The basic concepts of the model changed very little. However, four of the terms used to describe elements of the model changed. Evidence from the literature research resulted in the 'Knowledge' element changing to 'Information', and 'Tacit Knowledge' being simply referred to as 'Knowledge'. The 'Hands-on-doing' element changed to 'Purposeful Action' following the expert panel discussion, and finally, 'Technological Ambience' became the 'Work Environment' after feedback from teachers.

3.4 MODEL VERIFICATION BY TECHNOLOGISTS

Verification of knowledge involves the concepts of reliability, validity and generalisation (Kvale, 1996). Reliability relates to the consistency of the research findings. This research was a preliminary study of technology practice and further research will be required to test the reliability of the results. Kvale (1996) described three forms of generalisability: naturalistic, statistical and analytical. This research is based on personal experience of the researcher and the technologists involved. It can be generalised as naturalistic as "it derives from tacit knowledge of how things are and leads to expectations rather than formal predictions" (Kvale, 1996, p232).

Validation involved checking and questioning the concepts developed with the product development technologists to test their accuracy. Kvale (1996) discussed validation of qualitative research as resting on quality of craftsmanship, communication of knowledge and pragmatic proof through action. The model of technology practice was validated in two ways; firstly by using the model to deconstruct a case study of technology practice and to construct a teaching unit in packaging technology which verified the model by pragmatic proof through action.

The case study used in this research was the development of a process to extract cholic and deoxycholic acids from bile and the subsequent commercialisation in the form of the company New Zealand Pharmaceuticals Ltd., (Earle, R., 1999). Richard Earle, Professor Emeritus at Massey University, was directly involved with this technological development from its conception.

Secondly, the knowledge and concepts encapsulated in the model were communicated to a panel of expert technologists who critiqued and discussed the elements of practice and the way they were represented in the model.

It was considered important for the model developed with the product development technologists to be validated by other technologists before its effectiveness in communicating the elements of technology practice was tested with teachers. The techniques and methods used to validate the model are described below.

3.4.1 Case Study Deconstruction

New Zealand Pharmaceuticals provided an easily accessible technological development that progressed from initial concepts through to commercialisation. In April 1997 the model and its elements were used to deconstruct the practice followed by the technologists in developing this local innovation. Considerable time was spent with Professor Richard Earle discussing the technology practice involved in developing the process and how the model elements could be used to describe and portray the technology practice that occurred. This initial study was written up and published in the proceedings of the 1997 TENZ Conference (Earle, R., 1997). A further interview was used to relate the total technology practice involved to the model elements. The outcomes from the interview were recorded in a table format under the elements of practice identified in the model. The table's structure reflected, in a vertical form, the same relationships between the elements as depicted in the model developed with the product development technologists. Professor Richard Earle checked this table and added further detail and links between the elements.

The local context and operation of the company could be examined over several years, illustrating the societal context and work environment of this technological development. The results of this case study are reported in Section 5.2.

3.4.2 Construction of a Packaging Teaching Unit

The model was used to develop a teaching unit in packaging technology (Gawith & Robertson, 1999). A packaging technologist at Massey University assisted with the development of this teaching unit. The use of the model elements in developing this teaching unit verified their application in practice. This teaching unit is reported in Section 5.4.

3.4.3 Expert Panel Group

In December 1997 the model was critiqued by a group of eight technologists who formed an expert panel. Each person on the panel worked in a different technological area and was not involved in the model development described in stage 1 of the product development process (Figure 3.1). The model was presented to the panel and a guided discussion followed. Communicative validity involves testing the knowledge and concepts in a dialogue in which claims can be argued and alternative concepts presented (Kvale, 1996). The arguments and alternative concepts of the panel were recorded

using audiotapes and notes. The panel was also asked to record information collection techniques on sheets of paper. The audiotapes were analysed on a thematic basis and the results reported (Section 5.3).

3.5 MODEL EVALUATION BY TEACHERS

Earle (1997) emphasised the importance of researching the product users and utilising these people in the development of the product. The users of this model will initially be schoolteachers and ultimately their students. At this stage of development it was more practical to utilise the experience and knowledge of teachers to evaluate the model prototype development. Further research would be required to evaluate the model from a student perspective.

The model represented a new concept in teaching technology which itself was new to many teachers. For this reason it was decided to develop the model from an expert technical perspective and use teachers to evaluate complete model concepts rather than using them to develop initial concepts from their limited knowledge and experience of technology.

3.5.1 Teacher Sample

The sample of teachers and the formality of the evaluation techniques were expanded progressively in a programme to evaluate the model. This allowed an appropriate use of time and resources as the model was developed through the product development stages described in Figure 3.1.

The model was presented to three groups of teachers and at a technology education conference in 1997. The teachers involved in this evaluation were participants at the conference, and at block courses in technology education at Massey University. They comprised a range of educational levels from primary through to tertiary. The teacher comments and suggestions were used to develop the model further.

In December 1997, the model was evaluated by a group of eight teacher facilitators involved in a Ministry of Education contract in the central North Island. A further group of four secondary school teachers from Palmerston North evaluated the model in

April 1999. Two teachers in this group were science teachers and provided an additional perspective on the model. A focus group technique was used with both groups.

In April 1999 the model was formally evaluated using a self-administered survey. The model was demonstrated to small groups of technology teachers who were then asked to complete a questionnaire. Thirty-five of these teachers were involved in courses on technology education. Approximately half were involved in block courses as part of Massey University papers in technology education, and the rest participants at a Ministry, professional development contract course on Biotechnology at Massey University. The remaining four teachers were the secondary teachers involved with the second focus group.

3.5.2 Techniques Used in Model Evaluation

The techniques used to evaluate the model were discussions, focus groups and a user survey. The use of conversation and discussion as a technique for developing understanding was covered in Section 3.3.1 above.

Presentation of Model to Technology Teachers: The model presented to three groups of teachers as part of an initial evaluation. These groups comprised fourteen teachers in Auckland, Fifteen in Palmerston North and eight teachers in Christchurch. All teachers were involved in Massey University technology education courses. A further presentation was made at the Technology Education New Zealand conference in Christchurch (Gawith 1997a). The model was demonstrated and explained to each group and followed by questions and a general discussion. Comments and impressions arising from the discussions were considered after each session and concerns with the model noted and reported in Section 6.2.

Focus Groups: Anderson (1990) described focus groups as a small group of people with certain characteristics, who focus discussions on a given issue or topic. Ulrich and Eppinger (1995) suggested the ideal size for a focus group was between eight and twelve participants.

The first focus group participants were teacher facilitators involved in running professional development courses in technology education. These people were selected for their experience with helping teachers understand technology education and the curriculum document. This focus group session was held at the College of Education Palmerston North.

The second group was selected to evaluate the model from a secondary teacher's perspective and was held in a small tutorial room at Massey University. Not all of these teachers were technology teachers. In both cases the model was presented and explained to the group and was followed by a discussion moderated by the researcher. The discussion was guided by five questions and recorded on audiotape. These were later analysed on a thematic basis and reported by identifying the themes and combining narrative summaries with actual quotes illustrating the views of the participants (Anderson, 1990). The results of this research are reported and analysed in Section 6.3.

User Survey: A Questionnaire was used to gather opinions of the model from a sample of 39 teachers. The sample was specifically selected to include teachers actively interested in developing their knowledge of technology practice. It was felt these teachers were more likely to have considered other models of technology practice. As a consequence they would be better able to evaluate the model of total technology practice developed in the present study. This preliminary evaluation was undertaken with teachers attending Massey University courses and does not represent a random sample of potential users. Further research using a larger, random sample of technology teachers will be required to evaluate the final detailed model prototype.

The questionnaire was designed to give an indication from potential users, of how useful they thought the model was to their teaching and to student learning, and how well they felt it communicated concepts and related to the curriculum. The sample comprised 5 primary, 10 intermediate, 3 identified as both primary and intermediate, 14 secondary, 3 identified as both intermediate and secondary, 1 tertiary and 3 as tertiary.

The survey was conducted after a demonstration and explanation of the expanded model and how it could be used. The expanded model included overheads that demonstrated how technologists move through a process from identifying problems to developing solutions, planning sheets based on the model and an example of a packaging unit. The components of the expanded model are reported in Section 5.5. After this discussion, teachers were invited to complete the questionnaire. The procedure for collection and processing of the results was carefully explained. Teachers were then left to complete the questionnaire, or not of they chose, with no further involvement by the researcher. The questionnaire was anonymous and completed forms were placed in sealed envelopes. An independent person recorded the responses on a data entry programme and typed written comments into a text

file. The numerical data was analysed using SPSS data analysis software and reported and analysed further in Section 6.4. Appendix 8 contains the full questionnaire form and Appendix 9 the frequency tables and written comments.

3.6 FINAL MODEL DETAILED DESIGN

The model development resulted in a model of technology practice that identified the broad elements involved in all technology practice. The detailed content of these elements of practice and the way in which this knowledge was organised by technologists were developed concurrently during the model concept verification and evaluation, and completed in the final model detailed design phase in Figure 3.1.

The initial detailed content was developed with the product development group described in section 3.3.1. This content was expanded in the discussion with the expert panel of technologists and developed significantly through individual interviews with technologists. These interviews provided insights into the knowledge involved in technology practice and the way technologists organised and structured their knowledge. The individual interview technique is described below.

Interviews: In May and June 1998 six technologists, each from a different technological area were interviewed individually. These interviews also provided an opportunity to test the validity of the model concepts through dialogue. The technologists were selected for their expertise in the technological areas identified in the curriculum and their willingness to be involved in teacher professional development. The technological areas represented were: Biotechnology, Production and Process Technology, Electronics and Control, Information and Communication Technology and Materials Technology. The focus of these interviews was to identify the techniques and processes used in the area and compare them with the generic techniques and processes identified in the model.

Each interview was audio-taped and analysed using the 'Meaning Condensation' method of analysis described by Kvale (1996). This involved a five-step process of:

1. Developing a sense of the whole interview by reading the transcripts or listening to the entire interview of those not transcribed.
2. The points expressed by the technologist were identified for the next step.
3. The central theme of each point or meaning unit was stated in a table.

4. The table was organised around specific questions that related to the three research questions (Appendix 2-7).
5. The tables were then condensed down into the essential themes expressed by the technologist and a descriptive statement developed which summed up each technologist's approach.

The tables developed from this meaning condensation analysis were taken back to the respective technologists to verify the accuracy of the analysis and to record any further comments. Finally, the central themes and descriptive statements for all the technologists were compared to draw out common themes and also the specific concepts present in each technological area.

3.7 REPORTING THE RESULTS

The research questions required that the important elements of technology practice be identified along with some detail of the knowledge and actions involved in each element. The technological knowledge and elements were to be structured and communicated in an appropriate form for use in New Zealand schools. The expertise and experience of technologists at Massey University were used to achieve these objectives. Teachers involved in technology education evaluated the model's effectiveness to communicate the concepts involved in total technology practice.

The product development methodology proved useful in drawing together the needs of the user and the technological knowledge and practice of technologists. The emphasis was on the development of a tangible model that could be used by practising teachers.

The initial ideas and concepts for the model were developed within an environment of technology practice that included industry pragmatism and academic study. The ability of the developing model to communicate the concepts of technology practice and meet the needs of the users was systematically researched. The results are reported in the next four chapters, in the same order as presented in Figure 3.1. The model development research is reported in Chapter 4, followed by the model verification by technologists in Chapter 5 and the model evaluation by teachers in Chapter 6. The final model detailed design results are reported in Chapter 7.

CHAPTER 4. MODEL DEVELOPMENT BY PRODUCT DEVELOPMENT TECHNOLOGISTS

4.1 INTRODUCTION

The focus of the initial research was to identify the important elements of total technology practice. This started with an examination of the literature and the concepts of technology practice identified by other researchers.

These were considered in light of the observations and discussions that occurred within the Department of Consumer Technology, Massey University. Through this process a tentative list of elements and their interactions was identified and ideas on how these could be communicated in the form of a model proposed. A number of models of technology practice were identified from the literature and used as starting points for discussions on technology practice in the New Zealand context. The advantages and disadvantages of the models were assessed and Pacey's (1983) and Savage's (1991) models used as a basis for the development of a model of total technology practice.

4.2 MODEL IDEA GENERATION

The idea generation phase of the research involved many observations and conversations with the product development technology group. This process was an important first step in building understanding and knowledge of technology practice. The important observations and concepts are listed below.

4.2.1 Observing Technology Practice

The following concepts were developed.

Observation of the BTech(Product Development) course:

- Students were taught many techniques, from thinking techniques to creativity techniques and analysis techniques.
- Techniques were used to force decisions and move the process forward.
- Technical and scientific knowledge were important.

- Group interaction and communication of ideas were important and were practised throughout the course.
- An ability to model ideas and concepts in both 2D and 3D was important.
- Students were expected to understand the wider environment and social context involved.
- An ability to organise projects was essential. Papers in project management were taught.
- The course literature emphasised the development of skills.

Discussion with staff

- Just knowing the techniques was not sufficient. Selecting the appropriate techniques and knowing how and when to apply them in particular situations were equally important.
- The same principle of appropriate application also applied to technological and scientific knowledge
- Practice was systematic and followed a methodology to ensure all important aspects were considered
- Technology was goal orientated which required the technologist to make decisions on when sufficient work /research had been done on a specific issue and it was time to move on and apply this research to the development of the product.

Observation of industry projects

- Companies have unique cultures and ways of doing things and students must work within these.
- Students must adapt and make compromises in their product designs to fit within the company context.
- The wider company philosophy and strategy influenced all aspects of practice.

Regular meetings were held with between four and six product development technologists. These meetings provided the opportunity to draw together observations and reflections on technology practice in a New Zealand context and develop ideas on how these might be represented in a model. The first issue discussed by this group was the importance of techniques and how modern technology used techniques.

The Technology Degree option at Massey University grouped knowledge and praxis into four skill areas:

- science, engineering and technology outcomes
- management outcomes
- personal skills
- ethical and social responsibility

The skills and knowledge from each skill area were reorganised under the headings used in Savage's (1991) model. Some skills applied to more than one area of Savage's model. Where this occurred, the list of skills was repeated. However this highlighted the way technologists may use the same techniques skills and knowledge at different stages of the process.

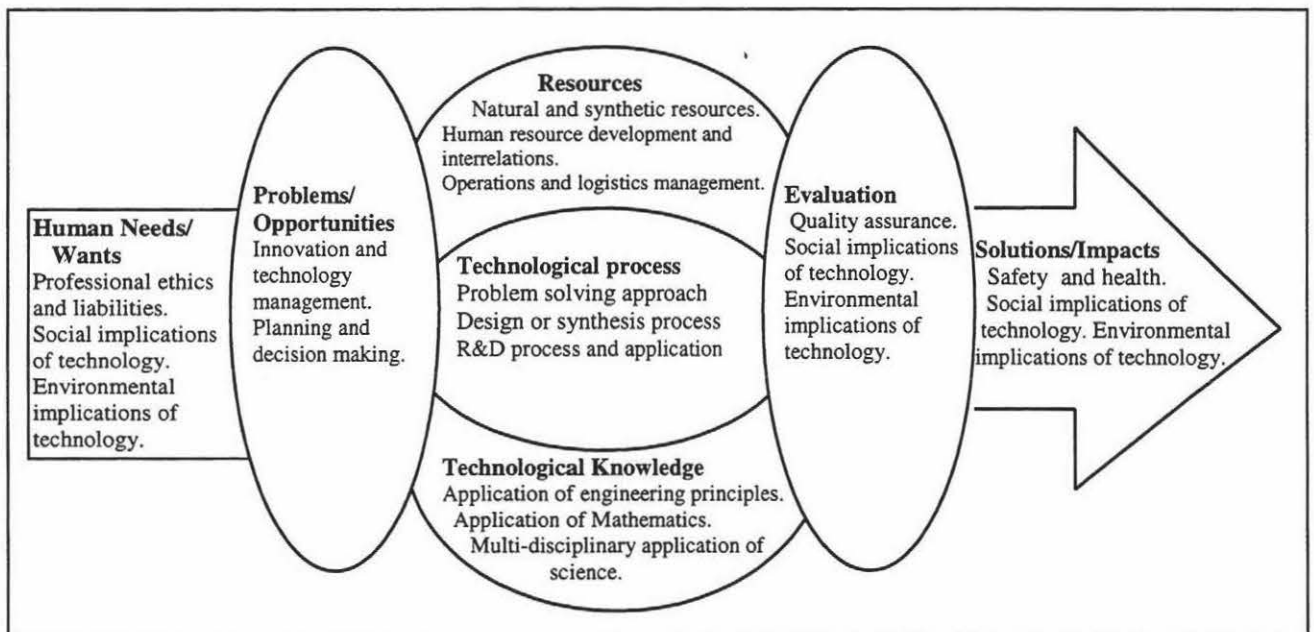


Figure 4.1 Bachelor of Technology Knowledge and Skill areas.

(Adapted from Savage 1991)

Within these skill areas, there is a range of techniques incorporating knowledge and praxis that students learn to apply. These skill areas were related to Pacey's (1983) diagram of technology practice. Each of the three aspects of technology practice is carried out by the technologists using techniques or 'tools'. These concepts are illustrated in Figure 4.2.

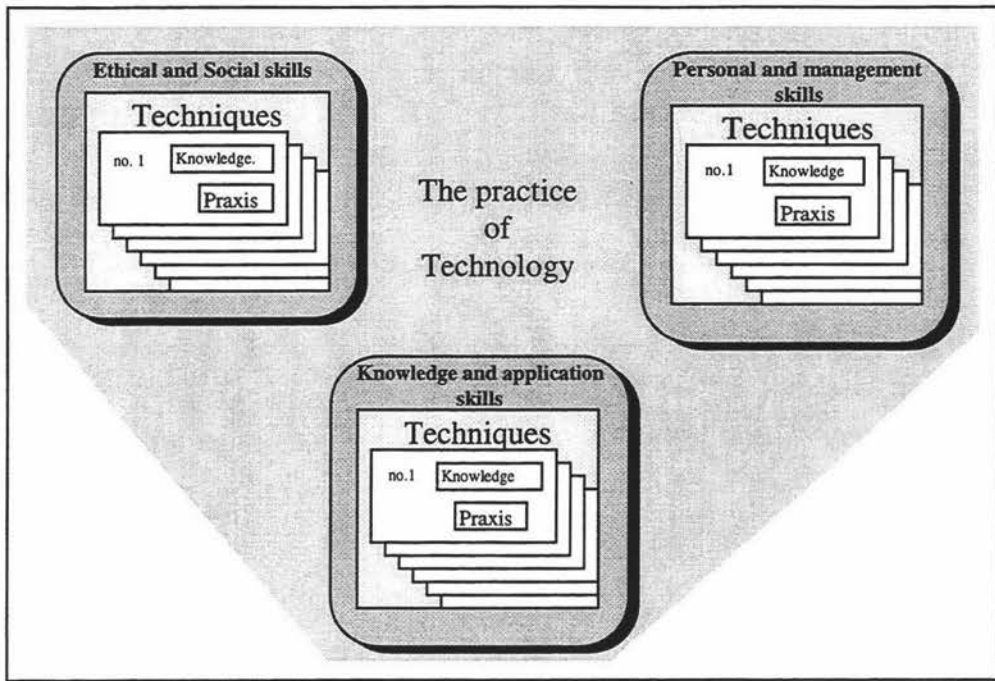


Figure 4.2 Praxis of Technological Techniques

Further concepts were observed, understood and recorded in the Research Journal.

- Technologists break complex systems into smaller units. For example, process technologists divide the process system into unit operations and unit reactions.
- Technologists use 'tool kits' of techniques to solve problems
- Technologists are creative and innovative, and use techniques to enhance their creativity
- Technologists manage their projects to ensure they are completed within the constraints.
- Technology practice involves taking action and doing things.
- Capability in technology involves an ability to draw together resources, knowledge, process and techniques in a systematic way.
- The importance of technological knowledge and expertise to companies requires technologists to make explicit as much of their tacit knowledge as possible.
- Projects do not take place in isolation but are very much influenced by the company philosophy and strategic decisions.
- Projects are developed within a multilevel company context (Figure 4.3).

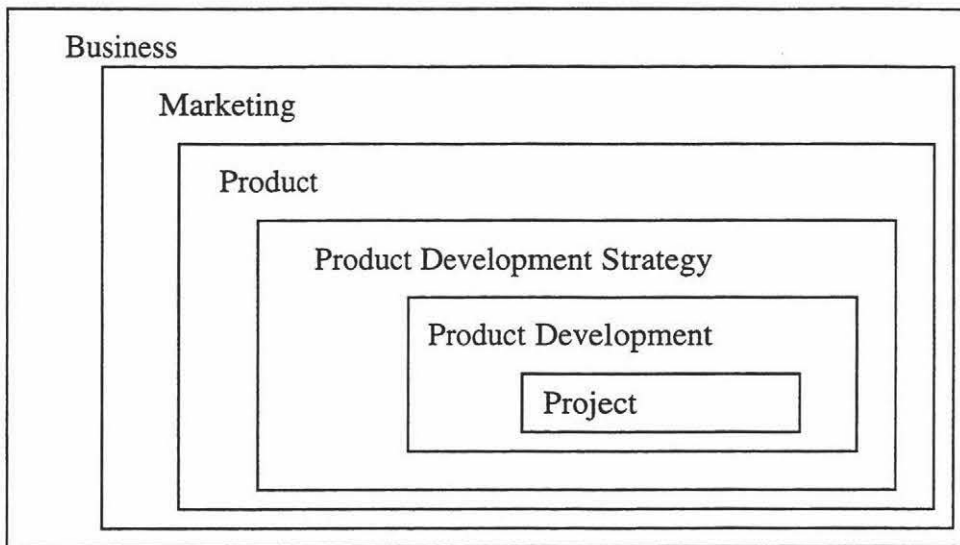


Figure 4.3 Product Development Within A Company Context

4.2.2 Initial Model Ideas

These observations, concepts and ideas were drawn together in an initial model of total technology practice. As the concepts were developed, they were discussed with the group of product development technologists and model iterations developed. The final version of this first model is depicted in Figure 4.4.

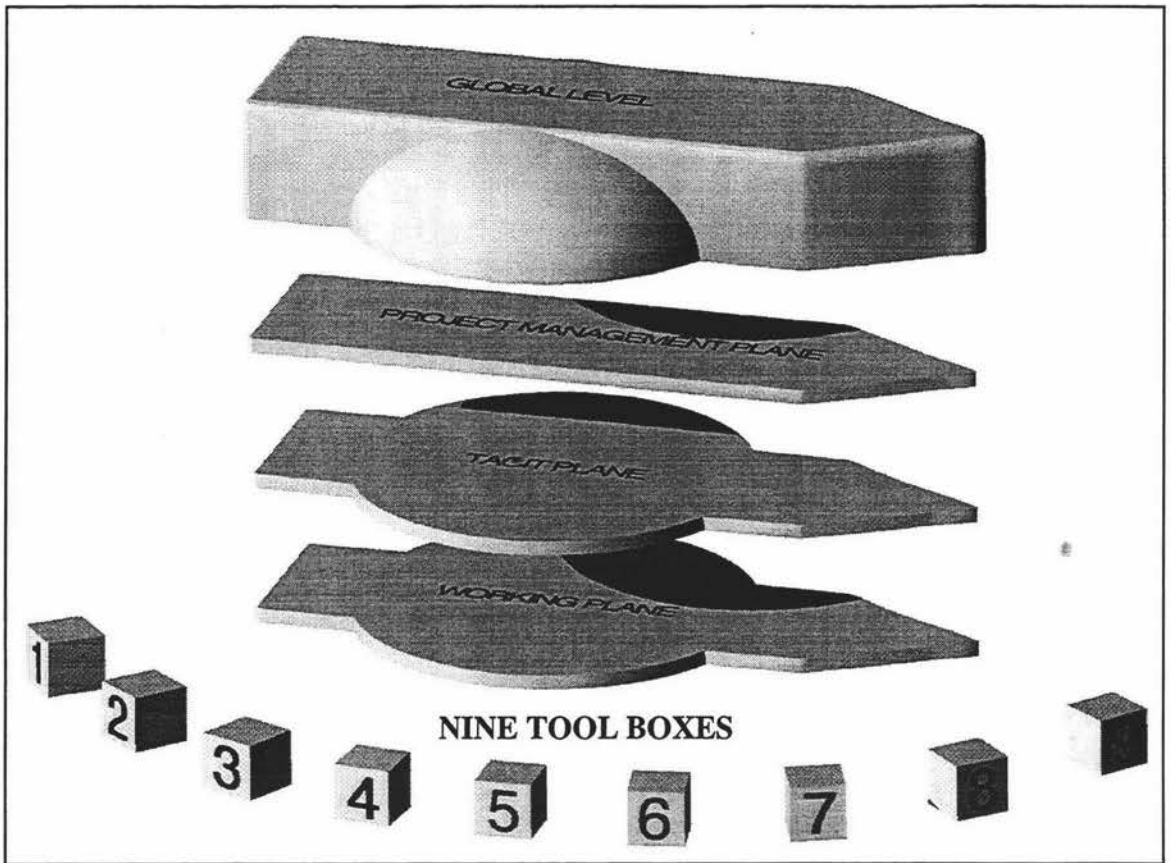


Figure 4.4 Model of Technology Practice: 1st Iteration

This model attempted to demonstrate the various elements of technology practice and the different areas of expertise, understanding and knowledge that technologists are expected to have. It was described in an unpublished paper (Gawith, 1996) as:

The practice of technology takes place on four planes of activity. The first plane is the global understanding and direction or strategic planning level of working. When working in this plane the technologist considers the wider issues such as ethical issues, the company philosophy and direction, statutory health and safety requirements, environmental issues, strategies on waste. These influences are considered and evaluated at every stage of developing a product.

The second plane is the project management level of thinking and working. It involves putting into effect the global policies and managing the product development process. The management of the process will reflect the global view of the particular company/group. At this level important decisions are made on personnel and how they are organised, the organisation and use of money, time, and other resources. The people assigned to the project team and their consultants will influence the level and types of tacit knowledge available to the project. The level of finance available for the project, where and when it is spent is managed at this level.

The third plane is the intuitive thought process or “inside the head” level of working. In this plane conceptualising, ‘reflection on action, reflection in action’ (Schön 1983), occurs. This layer represents the combined ‘brains’ or tacit knowledge of the team. The processes in this plane are influenced and directed by the management plane and in turn inform and affect the working plane. There is continual interaction between the third and fourth plane.

The fourth plane is the work surface of the process. On this plane the tools of the technologists are manipulated and applied. Problems are analysed, concepts are realised and tested. This is the level of ‘outside the head’. There is continuous interaction between these two planes in a process that advances the project according to the project management and global or strategic plan. It is during this interaction that the political, economic and social influences are built into the product.

This model was presented at a research group meeting and discussed. While the main concepts appeared to be correct, the model was difficult to understand and considered too abstract. An evaluation of this model by a teacher identified a problem with depicting levels as these could indicate a hierarchy of practice with management at the top and the actions at the bottom.

4.3 MODEL IDEA SCREENING

These points were taken into account and two further iterations of the model developed. These were presented to the research group on 20th February 1997. The first of these iterations is presented in Figure 4.5.

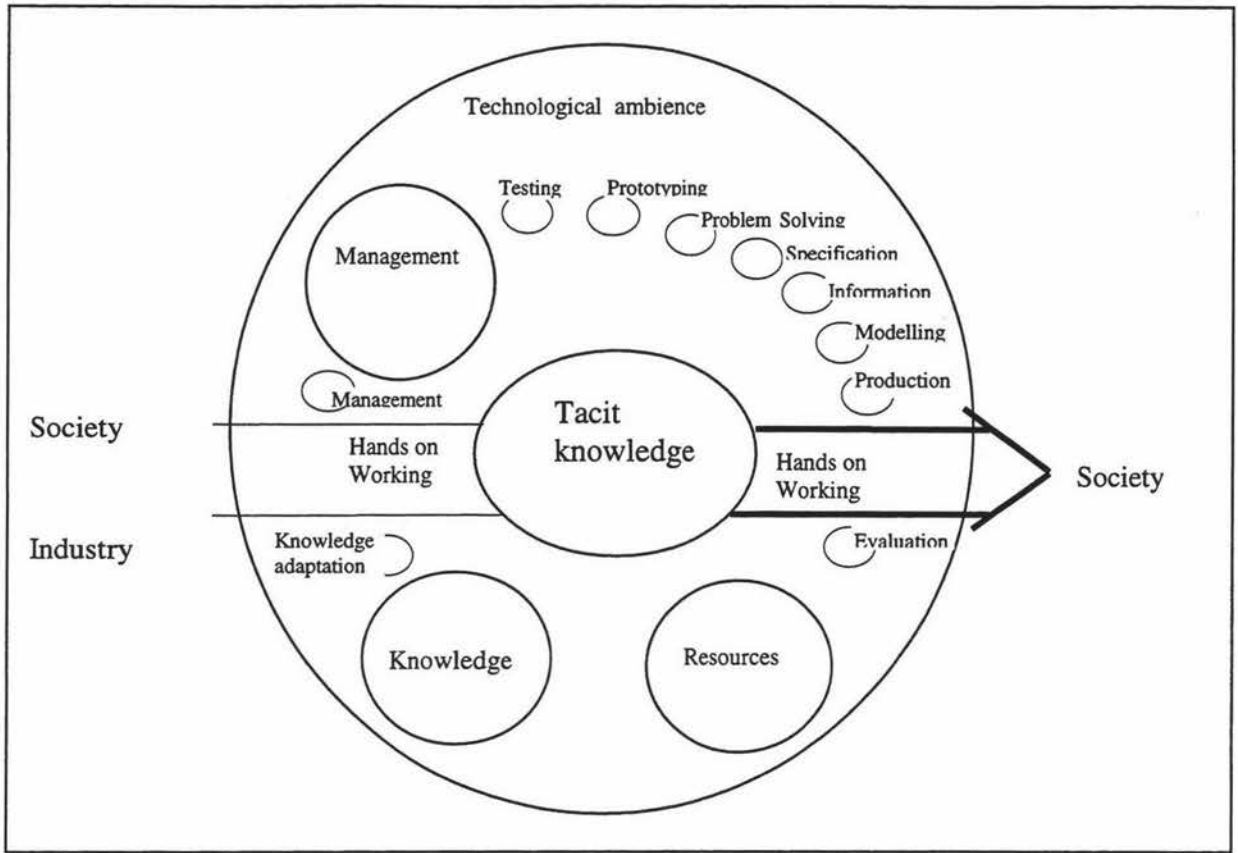


Figure 4.5 Model Of Technology Practice 2nd Iteration

This model attempted to place each area in which technologists operate on the same level with the tools and techniques displayed in a separate diagram. The research group felt this model did not convey all the elements of technology practice. A brainstorming session followed in which the important aspects of practice were considered and how they could be depicted. It was suggested the working plane be separated and looked at in more detail.

The global perspective and context of practice were considered important, as was the need to reflect the way technologists worked. From the observations of technology practice and the Bachelor of Technology degree structure (section 4.2.1), it seemed clear the model would be required to communicate the need to:

- Organise and manage the whole development process.
- Acquire information and knowledge necessary to achieve a solution.
- Select and use appropriate resources.

In doing these actions and the practical action of developing the product, technologists use-

- Tools and techniques appropriately and skilfully.

The ideas from the brainstorming session and the need to include these concepts were developed into the third version of the model. This model structure and its basic elements were considered by the product development technologists as offering the best prospect for identifying and communicating the elements of technology practice. This third model idea was taken to the next step and developed into the final model concept.

4.4 MODEL CONCEPT DEVELOPMENT

Through discussions with the product development technologists it was decided the global plane should be divided into two areas; the wider societal and cultural influences, and the contextual or work environment influences on practice.

4.4.1 Society

Each distinct culture has an associated set of values and worldview that is reflected in the technological practice of the individuals from that culture and usually embedded in the products produced (Pacey, 1983). This was recognised by the product development technologists in the development of new products. It was clear from observing their practice that target user groups were consulted throughout the process in an effort to reduce the influence of the product developers' personal concepts and assumptions on the final product. This was particularly important when the product was being developed for users from a different culture or country. An example of this was observed in the development by product development technologists, of a board game designed to teach Te Reo Maori.

Observations of student projects highlighted the importance of laws and regulations in the development of new products. These exemplified the wider societal influence on technologists' practice. Other influences observed and discussed with the product development technologists were the economic system involved in financing development projects and the market economic system.

Pacey (1983) described these influences on practice as three aspects of technology practice – cultural aspects, organisational aspects and technical aspects. These three groupings provide a useful way of analysing the factors that arise from society and influence the practice of technologists. Table 4.1 provides examples of the cultural, organisational and technical considerations observed as important in the development of products by technology students.

Table 4.1 Examples Of Societal Influences On Technology Practice

Cultural	Organisational	Technical
Differences between ethnic groups	Capitalist economic system	Available materials and their selection
Beliefs in progress	Patent system	Empirical approaches
Education	Venture capital	Systematic process
Urbanisation	Consumer law	Rigorous and fair testing
Mass consumer society	Safety regulations	Optimisation and efficiency
Conception of beauty and form	Professional engineers' associations	Methodology
Attitudes to creativity and risk	Product quality regulations	Quality assurance
		Computers

For each aspect there exists a formidable body of knowledge, some of which was available in books and journals, but much was unspoken or tacit knowledge absorbed by students from the community of practice and wider societal norms. Product development technologists, developing solutions to problems, used their understanding and knowledge of these three aspects to identify and define the problem and develop appropriate solutions for identified groups of users.

4.4.2 Work Environment

Staudenmaier, (1985) described the work environment as a pervading atmosphere or ambience, that surrounds technology practice. There is a tension between what the technologist would like to do and have, and what is permissible or available in the particular environment in which the practice is taking place. As with the society element, Pacey's (1983) diagram of technology practice can be used to analyse the work environment element.

The attitudes to innovation, creativity and risk taking are examples of cultural influences, or perhaps in the case of the work environment, the influence of the community of practice. Within the work environments at Massey University and sponsoring companies, there were many constraints which students and staff had to work within. However, an atmosphere of creativity and encouragement to think outside the square (Akin and Akin, 1996) was deliberately fostered. For students working on industry projects, there were differences in business cultures between companies.

The ways companies organised, structured and managed their development projects were also different. Often these reflected the attitudes in the wider community. Finally, examples of the technical issues that influenced student work environments were the amount and type of equipment available to develop and produce products, the materials and components available, and the expertise and accumulated knowledge available.

Nonaka and Konno (1998) used the Japanese term *ba* to convey the idea of place or context in which technology practice occurs. They described how this 'place' reflected the culture of the wider community that surrounds it. Figure 4.6 depicts how the aspects identified by Pacey permeate the 'place' where practice is occurring, thereby influence the decisions and creativity of the people involved. Each work environment will be different in the way it interprets societal influences.

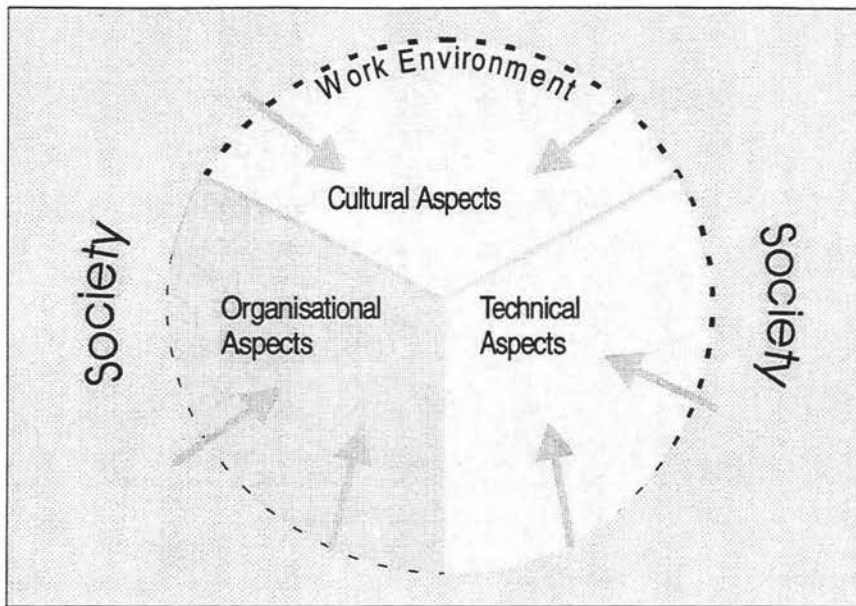


Figure 4.6 The Influence of Pacey's Three Aspects on the Work Environment

de Vries (1997) identified a series of influences such as: technological, market, political, judicial, and aesthetic, which arise from society and the work environment.

The importance of the work environment is evident in studies of industry and the way in which contexts and atmospheres can encourage creativity and knowledge creation. (Leonard and Sensiper, 1998; Nonaka and Konno, 1998; Nonaka, Takeuchi and Umemoto, 1996). It will be important in any model of total technology practice to recognise the influence of both the societal and work elements on the decisions and choices made in the development of products.

4.4.3 Purposeful Action

The purposeful nature of technology noted in discussions with technologists and illustrated by the arrow in Savage's diagram was included in the model. The technologists and students carried out their practice within the 'pervading atmosphere' of the Department of Consumer Technology and the sponsoring company, with the expectation from themselves and others that an appropriate solution would be developed that satisfies all or many of the requirements identified in the need.

Much of the product development course involved students developing and applying effective project skills to enable them to develop appropriate products in planned and

effective ways. Discussion with product development technologists (Section 4.2) identified technology as a goal orientated practice that required decisions to be made that ensured progression along the purposeful action arrow.

Total technology practice involves the recognition of societal influences and the strengths and constraints of the work environment on choices made as the product is developed. Figure 4.7 illustrates the society, work environment and purposeful action elements that promote constrain and define technological products.

Practice occurs within the three elements depicted in Figure 4.7 *society* within which practice is taking place, *work environment* that defines the working context and the *purposeful action* which achieves the goal of technology practice itself. These provide the pervading atmosphere in which practice takes place.

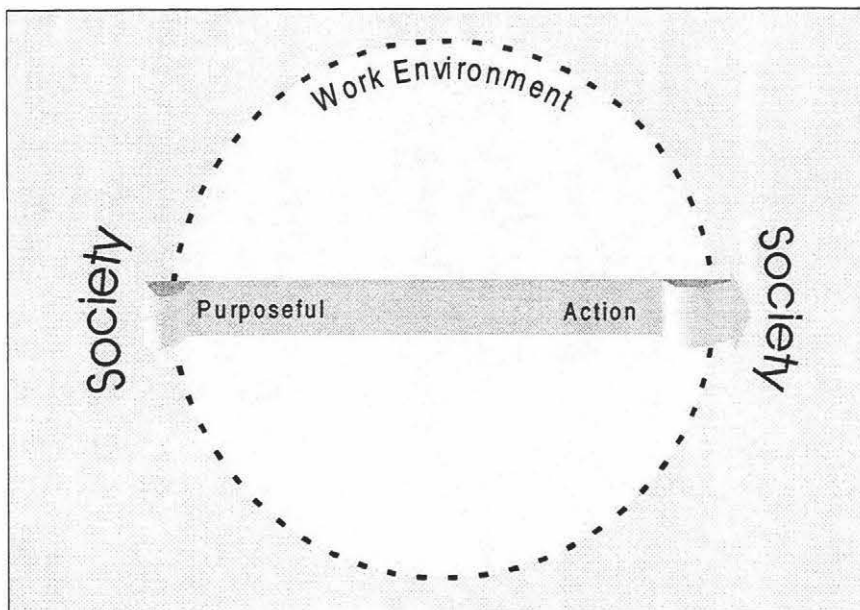


Figure 4.7 The Atmosphere That Pervades Technology Practice

In its broadest interpretation, the purposeful action element of total technology involves the actions of the technologist from recognising and defining the problem through the development of solutions to the use and disposal of the product. It may also involve the actions of an engineer involved in the development of a highly specialised, narrowly focused component with specifications already defined, and limited consideration of issues involved in use and disposal as the product it is part of a larger system.

The technologist or technology team now became the central focus of the model. Four further elements centre on the technologists themselves.

4.4.4 Organisation

This element of total technology practice involves deciding on and organising the technological process for example in developing new products. Having decided on the process, the technologist must then manage the project. The process of product development in industry has developed over time and been the subject of research since the 1960's (Earle, 1997).

Observations of the product development degree course indicated the importance of developing students' ability to organise and manage systematic processes in the development of new products. Management papers were taught in the second, third and fourth years of the degree course (Massey University Calendar, 1999). A sample of the objectives for these papers were:

- To develop students' skills in the area of scheduling, product costing and people management.
- To commence an awareness of the impact people have on organisations and their structure.
- To introduce students to the principles and practice of design management functions, project planning, project monitoring techniques, technology management and the role and responsibilities of management and product developers for successful product development.

Besides organising the process to be followed, technologists must also organise time, people, resources, and relevant information. Figure 4.8 focuses on the technologist at the centre of the process and identifies the organisational aspect of total technology practice.

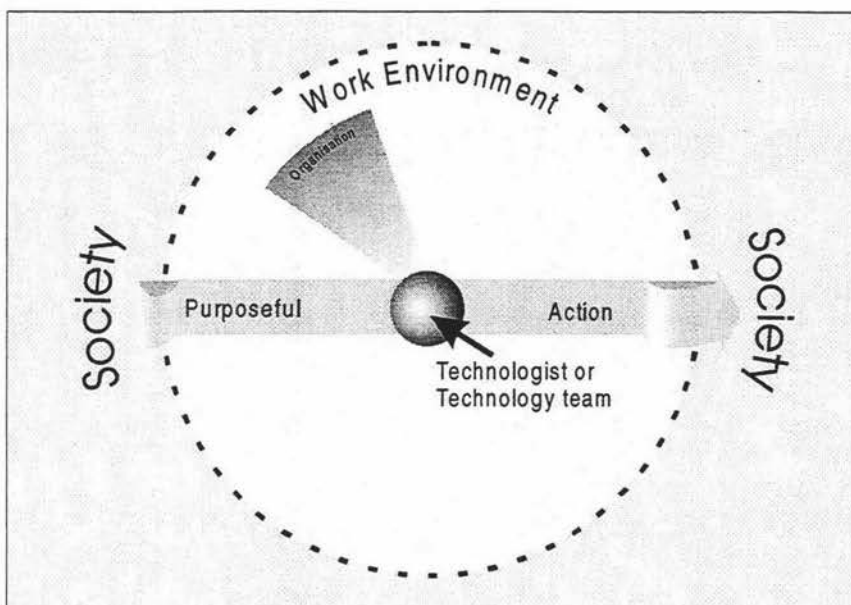


Figure 4.8 Organisation in Technology Practice

This aspect of practice is important in developing the students' ability to manage and organise their practice to achieve their technological goals. The organisation of the technological process of identifying an appropriate need or opportunity through to the development and use of a solution is what is required for purposeful action to occur. All aspects of organisation can be grouped in this area, from students organising their time, to organising other people and the raw material required for the product.

4.4.5 Information

Technologists use and adapt information from a great number of sources. Some of this information is considered technological in origin, while other information either comes from life experience or through adaptation of knowledge from a range of other disciplines, particularly science, mathematics and social science. It was clear from observations and discussions that a technologist's ability depended on a depth of knowledge in related subject areas and an ability to organise this knowledge and information in a technological framework of principles and abstractions. Technologists also developed knowledge of information sources such as handbooks like '*Perry's Hand Book of Chemical Engineering*', and computer databases.

The Bachelor of Technology (Product Development) paper schedule listed papers in Chemistry, Physics, Computing, Calculus, and Statistics in the first year. This was

followed by papers in Industrial and Materials Chemistry, Physics of Consumer Products and Technological Mathematics. These papers provided a depth of knowledge in related subject areas and a framework for organising this knowledge so it can inform technology practice.

All aspects of information gathering, selection, analysis and application were important in total technology practice. Figure 4.9 adds the element of information to total technology practice. Students undertaking industry projects gathered and processed information from a wide range of sources and applied it to the development of their product.

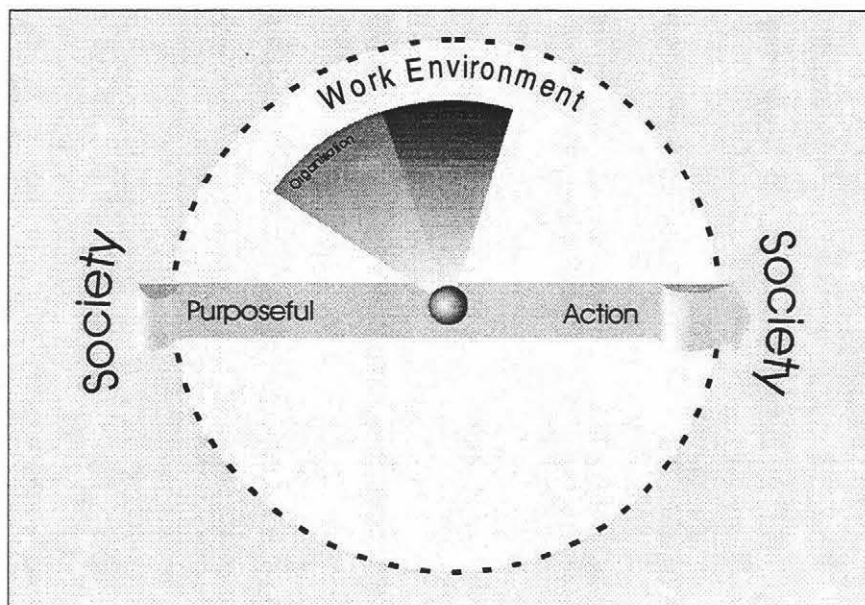


Figure 4.9 Information in Technology Practice

4.4.6 Resources

Resources are an essential part of technology practice and always involve costs of some sort. For intangible products these are predominantly time and information equipment such as computers. For more tangible products, materials, components and production equipment are involved.

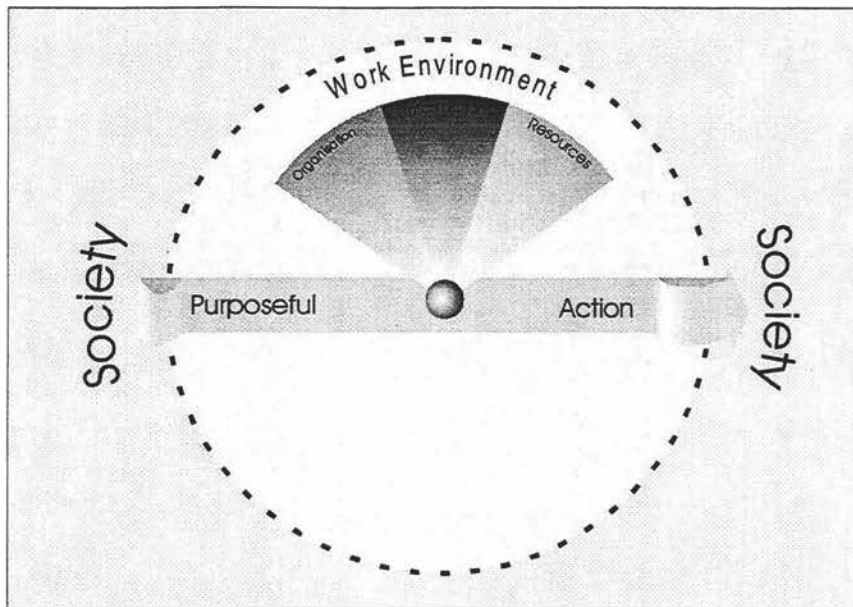


Figure 4.10 Resources in Technology Practice

Figure 4.10 adds the element of *resources* to total technology practice. Resources were utilised or altered in the process of developing products. The resources used by the product development technologists and students can be divided into categories.

- Consumables for example, materials like plastic and metals, and components such as electric motors, wheels and electric switches used in tangible products.
- Energy - used throughout processing or production of products and in many cases the operation of the product itself.
- Services - such as water and the infrastructure of services involved in producing, using and disposing of products.
- Capital – this included investment capital in the factory building and equipment needed, and the working capital to employ people and pay the-day-to-day expenses in the sponsoring companies.
- People - the most important resource in any technology project, for their knowledge, ability, networking, team skills, and motivation.
- Information - an increasingly important resource required for good decision making. For example: information from consumers, financial information, resource information, information on statutory requirements and ethical issues.

- Time - a resource that technologists must use as effectively as possible. For example: concurrent development of various aspects of development.

Each resource required the development of specific knowledge, both of a theoretical type and of practical application and use (tacit knowledge).

4.4.7 Techniques

The techniques themselves were not rules set in concrete, but rather a combination of knowledge and praxis that must be adapted and applied in a thoughtful reflective way, then evaluated for suitability and results. The skill of the technologist was in the appropriate application of techniques (Robertson, 1996).

Figure 4.12 adds *techniques* as an aspect of total technology practice. These techniques are selected and used depending on the context and the specific problem being addressed.

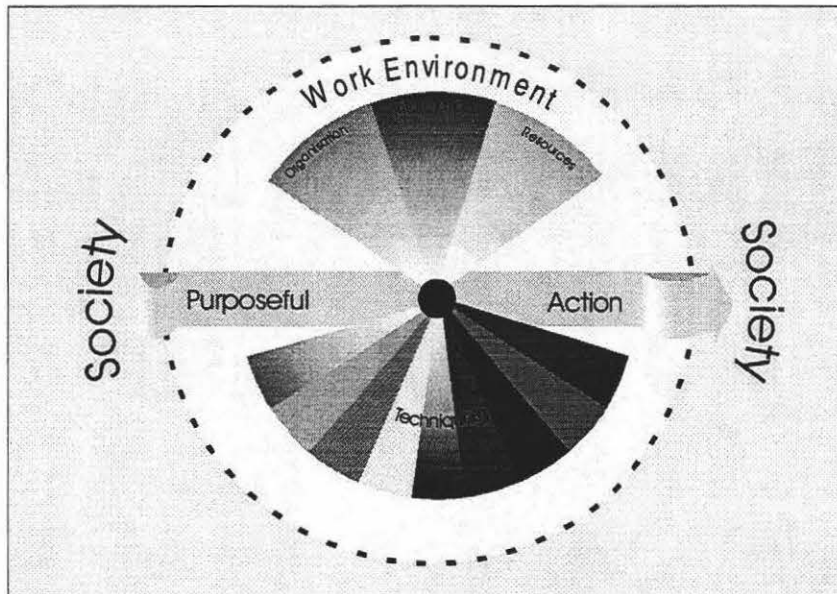


Figure 4.11 Tools and Techniques in Technology Practice

The techniques used by the product development technologists and taught as part of the product development course were categorised into different types.

- Information techniques - involving gathering and analysing information.

- Modelling/prototyping techniques - representing ideas, testing variations and optimising before committing to the final concept. Modelling techniques ranged from simple sketch drawings through to complex mathematical models.
- Testing techniques - important for quantifying variables and changes and reducing risk factors by working from knowledge derived from testing. The technologists and fourth year students dealt with real world situations, where the effects of variables on outcomes could not always be adequately calculated from theoretical knowledge. Testing of outcomes was very important in order to identify the problems at each stage of the process.
- Specifying techniques - the use of matrixes and statistics to develop product design specifications and production specifications. Specifications were important in directing the technology practice by setting targets. Targets must be correct and achievable within the specific work environments.
- Problem solving techniques - idea generation and idea screening for encouraging creativity and directing the process towards the goal of developing a product. Examples of idea generation techniques were brainstorming and analogy techniques.
- Evaluation techniques – to ensure each decision made in the product’s development was the most appropriate. The product development technologists also evaluated their own practice. For example the techniques and process used were recorded in technology journals which were then used to reflect on the success of failure of the techniques or process and how it might be altered or improved next time.
- Production techniques - system analysis and pilot plant testing used in the complex process of moving from producing ‘one-off’ to producing large numbers of product.
- Management techniques - important in organising practice. Such techniques as cash flow budgets and critical path analysis were used.
- Knowledge adaptation techniques - used to utilise knowledge generated in other disciplines. This knowledge was often reorganised or recontextualised for the specific problem worked on.
- Commercialisation techniques - used to move the product from the development stage to the context of use. Techniques were physical techniques such as transport and storage and social techniques involved with marketing.

The choice of technique and when and how it should be used varied according to the particular problem, the experience and preferences of the technologist, and the

surrounding work environment. It was not sufficient to know the techniques in a theoretical sense, students were expected to develop tacit knowledge of their application and use.

Knowledge of techniques and how and when they were used was one of the more important elements of practice developed in the product development students. Students were expected to develop the conceptual knowledge associated with a range of techniques, along with the procedural knowledge of their use and appropriate application. There was no set order to the use of the techniques, as it depended on what was to be achieved. The same technique may be used many times and for different purposes. Students needed opportunities to build their tacit knowledge of a wide range of techniques in order to build their capability in product development.

4.4.8 Knowledge Development

Each element of technology practice described above contributed to the development of the model of total technology practice. This model can only be at best, a generalisation of what is a complex human activity. Technologists decided the most appropriate process to follow, and the way compromises and values would be built into the product as it was developed. In doing this they organised, gathered necessary information, and selected and used resources, based on their experience, knowledge both tacit and explicit and the tools and techniques developed over time by the community of product development technologists.

Figure 4.12 shows how the organisation, information, resources and techniques link to the technologist. As the technologist's knowledge expands through experience, a greater conceptual and procedural knowledge of these elements appeared to develop.

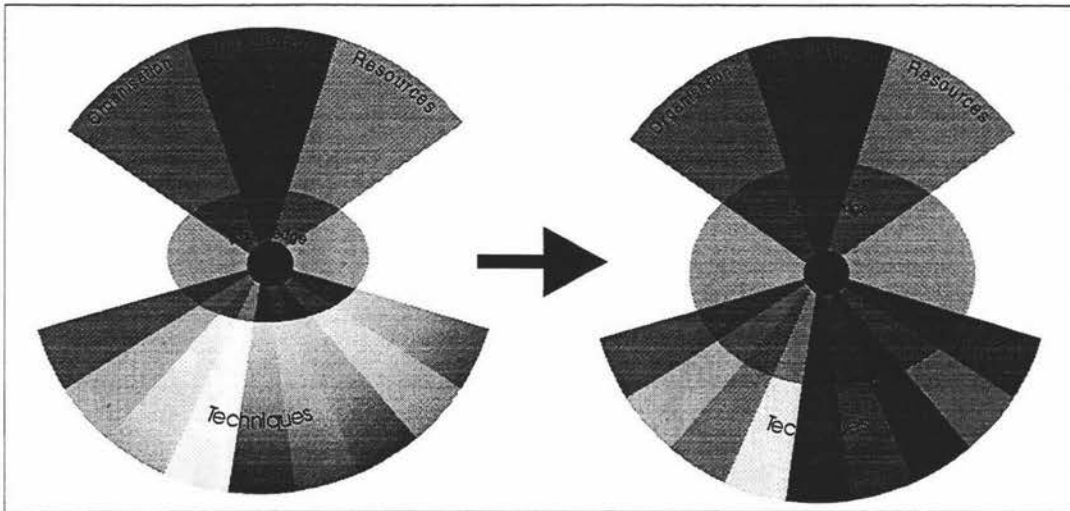


Figure 4.12 Development of Technological Knowledge

4.5 CONCLUSION

The technologist or technology team achieve their goal by working along the purposeful action arrow, from the identification of the problem to the use and disposal of the product. As they do this, the nature of the techniques, organisation, information and resources changed. At the beginning of the process they identified the problem, usually gathering information from people with the problem, or who might use the product. As the technologists move onto developing concepts and testing prototypes the techniques, organisation, information and resources used are different.

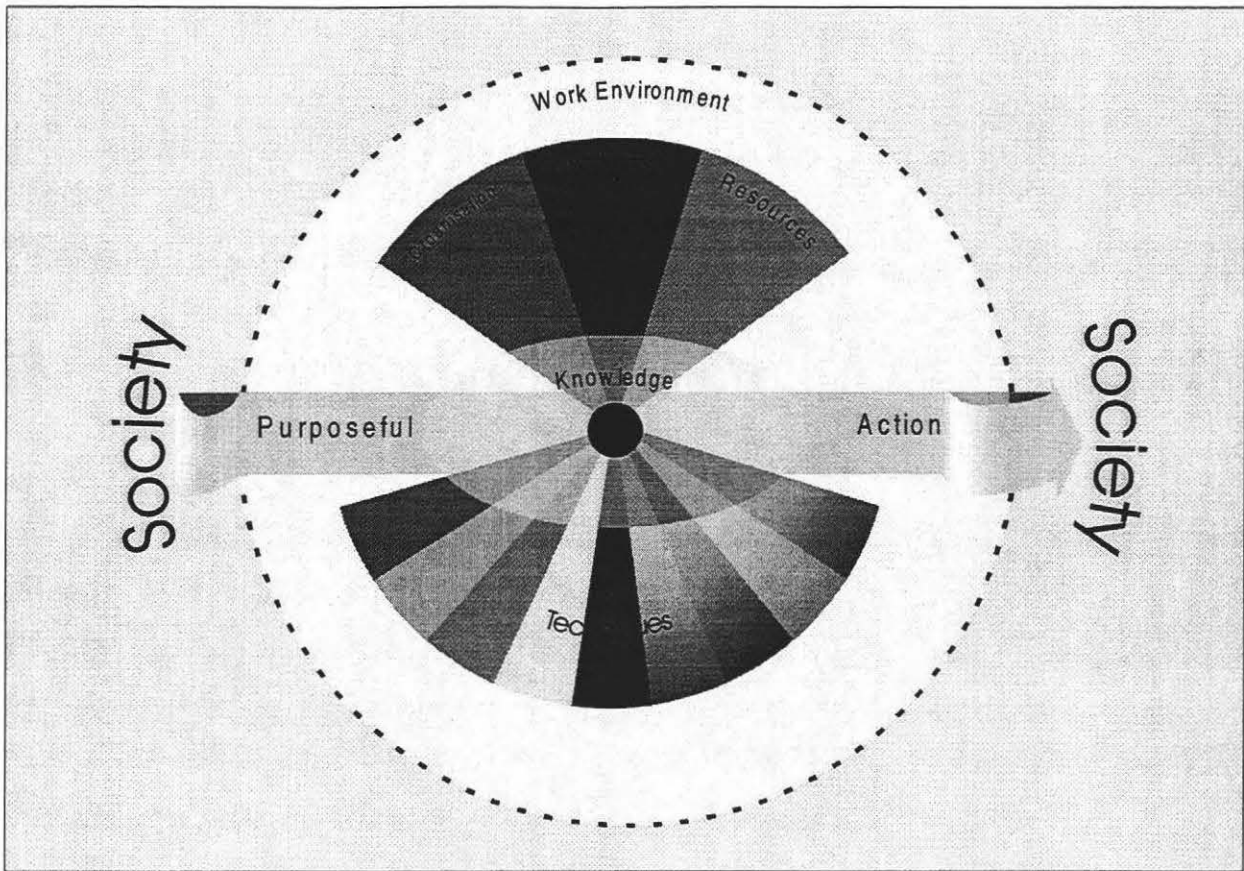


Figure 4.13 Model of Total Technology Practice

Together all these elements appeared to present a balanced understanding of total technology practice. This balance was maintained in the development of technological knowledge. It was felt this model represented technology practice well, however this required validation by a wider and more diverse group of technologists. The results of the validation research are reported in Chapter 5.

CHAPTER 5. MODEL VERIFICATION BY TECHNOLOGISTS

5.1 INTRODUCTION

The model and its detail had been developed by a small group of product development technologists in the Department of Consumer Technology, Massey University. This chapter reports the results of three techniques used to verify that the model accurately represented in general, the elements and concepts of technology practice. The first section of the chapter discusses a case study of a technological development that occurred between 1967 and 1980 in New Zealand. The second section reports the comments of a group of eight technologists who formed an expert panel to evaluate the model and identify techniques used for gathering information. The third section applies the model elements to development of a packaging unit for technology education.

5.2 CASE STUDY: NEW ZEALAND PHARMACEUTICALS LTD.

New Zealand Pharmaceuticals Ltd is a company successfully adding value to by-products of the New Zealand meat industry. It is situated in the Manawatu, a short distance from Massey University. This company was chosen for the case study as its development could be traced from the initial identification of the need and associated social considerations through all stages of development to the final factory development, which currently employs people and adds considerable value to what used to be a by-product.

The research involved in developing and optimising the process used in this company was undertaken by technologists at Massey University. This involved the development of a new process for extracting cholic and deoxycholic acid from animal bile. The development of this uniquely New Zealand processing company allowed all the elements identified in the model of total technology practice to be identified and their interaction demonstrated.

The results of this study are reported in the form of comments made by Professor Earle and a table that provides a holistic perspective and summarises the detail of the case study.

Earle R. (1997) confirmed the elements within the model as an adequate means of grouping the technology practice involved in this commercial development. The study identified knowledge and organisation as important elements of practice.

“In technology there is not only a need for knowledge, there has to be organisation to ensure that the aims are achieved”.

The case study identified the need for resources.

“Added to knowledge and organisation, there have to be physical resources”.

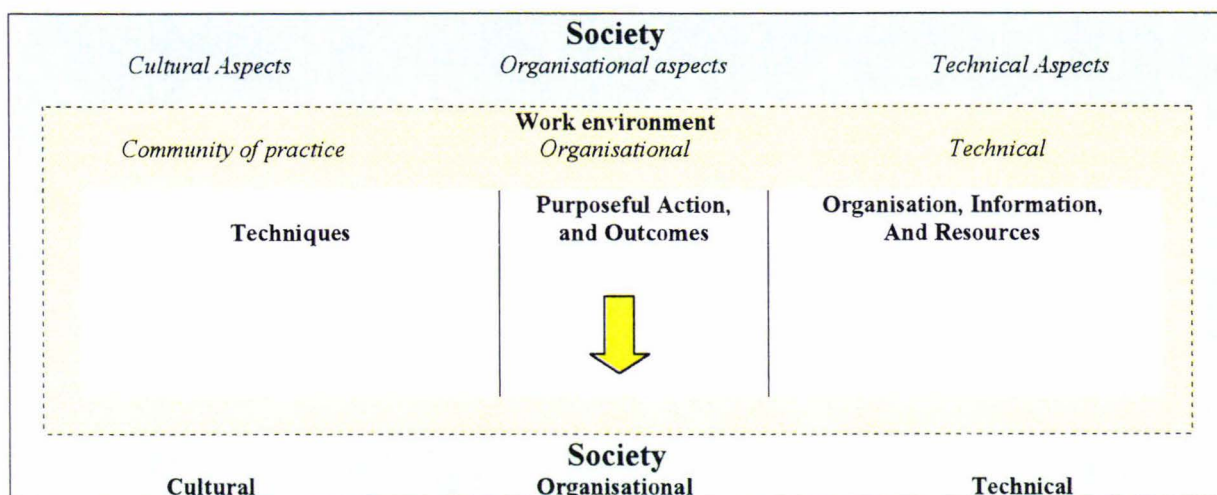
The resources identified were animal bile (raw materials), working space, energy, capital, and, equipment.

The case study identified other inputs as:

“Information, testing, specifications, modelling, prototyping, evaluation, optimisation, production, experimentation and adaptation”.

Testing, specifications, modelling and prototyping were identified as technique areas in the case study. Optimisation and adaptation were obviously important driving influences and were seen as part of the values and culture of the technologist’s community of practice associated with the work environment.

A further in-depth interview with Professor Earle was undertaken to develop a detailed analysis of the development and to identify the social and work environment elements that influenced the technology practice. The results of this interview and the previous interviews were recorded in the form of a table that reflected the model elements and their interaction. This table is an adaptation of the graphical model of total technology developed with the product development technologists. This graphical model was converted to a vertical table to allow the inclusion of detail for each element of practice. Table 5.1 is the structure used in this table.

Table 5.1 The Model Of Total Technology Practice Reorganised As A Vertical Table

This table reflects the model described in Section 4.5. Society surrounds and influences practice and can be discussed under the headings of cultural, organisational and technical aspects. This is demonstrated in the table by an intrusion into the white space that represents the technology practice. The work environment element also surrounds practice. The dotted line separating these two elements illustrated the way the work environment was permeated by society. The process followed was represented in the purposeful action element through the middle and the organisation, information and resources elements in the right hand column and the techniques used in the left-hand column.

The table begins by identifying the cultural, organisational and technical aspects in society that influenced the identification of the need in the first place and the subsequent development of the innovation. The work environment influences were identified in a similar way, substituting the term *community of practice* for *cultural aspects* in society. The influence of society and the work environment on technology practice was illustrated by these elements intruding into the white space representing the elements of practice that centre on the technologists. Figure 5.2 summarises the case study and illustrates how the elements of practice identified in the model can be used to describe the total technology practice involved in the development of New Zealand Pharmaceuticals Ltd.

Table 5.2 Case Study: New Zealand Pharmaceuticals







<i>Cultural Aspects</i>	Society <i>Organisational aspects</i>	<i>Technical Aspects</i>
Attitudes to physical, biological and cultural environment Stable political and financial systems Wealth creation and generation Attitudes to innovation Attitudes to waste disposal	Meat industry organisation International pharmaceutical organisation Foreign exchange behaviour Infrastructure – rail system, energy, financial resources N. Z. Company law N.Z. Environmental law Government encouragement Education system	Massey University equipment and technical knowledge Scientific and technical literature Agriculture Production Council Department of Scientific and Industrial Research Industrial skills including: high quality, cheap stainless steel fabrication skills and expertise (resulting from the dairy industry)
Work environment		
<i>Community of practice</i>	<i>Organisational</i>	<i>Technical</i>
Adding value to a low priced bulk export by further processing Price stability and expanded marketing Demonstration of a technological approach to economic development Opportunity for further research.	Company structure Financial structure University structure	Knowledge, equipment and space provided by Department of Biotechnology, Massey University. Knowledge, business skills provided by Tasman Vaccine Laboratories Ltd.
Techniques	Purposeful Action, and Outcomes	Organisation, Information, And Resources
Overseas contacts and observation Technology transfer from other countries	1967 Identify the range of by-products from the meat industry for further processing 	<i>Information</i> By products from the meat industry Initial chemical, processing and marketing information on these. Potential yields and financial viability World pharmaceutical markets and processing. Quality and quantity of raw materials
Literature search – Chemistry and Pharmaceutical publications.	Beginning of technical investigation  Potential products identified  Product Idea Screening	<i>Organisation</i> Financial and entrepreneurial aspects Research – literature, overseas contacts Academic research Financial resources Physical resources of space and equipment
Research projects on – Insulin Sutures Bile acids – steroid production Using scientific techniques	 Focus down to most likely products 	<i>Resources</i> Technological knowledge of people involved (Massey staff, TVL chemists) Financial and Entrepreneurial knowledge of people involved (TVL management). Government R&D grants (\$)
Yield analysis Management and financial techniques	Feasibility Study 1968 	National Development Conference
Market research techniques	Market Exploration 1969 Identify the product most likely to succeed in the market environment	Market opportunity identified Insulin production dominated by overseas companies Steroid production less dominated
Decision making techniques		

Table 5.2 Case Study: New Zealand Pharmaceuticals (Continued)

Techniques	Purposeful Action, and Outcomes	Organisation, Information And Resources
Management Go, No-Go Decision		
<p>Flow process charts developed. Unit operations identified Testing and problem-solving unit operations Optimising – recovering and reusing expensive constituents; increasing yield, reducing costs. Testing techniques for product standards</p> <p>Materials and equipment testing for pilot plant</p> <p>Techniques to research scaling up problems</p>	<p>Cholic and Deoxycholic Acid production selected ↓ Biotech team active research ↓ Pilot plant construction</p>	<p><i>Information</i> Standards – European and customer (Pharmacopoeia contains standards and standard tests) Issues involved in scaling up Optimisation of yields Composition and variation of raw materials Environmental law and waste stream composition.</p> <p><i>Organisation</i> Hire skilled people Further research projects and grants R & D grants Lotteries funding for equipment Raw material supply Building of pilot plant</p>
<p>Pharmaceuticals Investigation Co. Established - A co-operative of all meat companies in N.Z with the purpose of securing raw material supply.</p>	<p>↓ 1970</p>	
<p>Technical problem solving Yield tests Management and financial techniques Decision making techniques</p>	<p>Pilot plant trials Technical feasibility report. ↓ Financial feasibility report. ↓ Pilot plant opened</p>	<p><i>Resources</i> Raw Material – NZ meat processors Finance –TVL 40%, Meat Co. 60% Expertise – Massey, TVL Equipment – Massey Facilities – Massey (old dairy factory)</p> <p>NZP Company structure established</p>
Management Go, No-Go Decision		
<p>Financial control techniques Engineering and construction techniques Total Quality Assurance (TQA) Including additional unit operations to meet customer standards (fatty acid removal)</p> <p>Factory scale problem solving techniques – resulting from larger scale and longer operating time.</p> <p>Techniques for continual optimisation of process</p> <p>Research on additional products New factory commissioned</p>	<p>1973 Commercialisation ↓ Fatty acid levels too high ↓ 1974 Factory constructed</p> <p>Contract to sell total production to Collectorgane (Marketing arm of Roussell UCLAF)</p> <p>↓ 1975</p> <p>↓ 1977 First dividend</p> <p>↓ 1979</p>	<p><i>Resources</i> 14 acres of land by the main trunk rail line and Manawatu river. Skilled engineers and construction expertise. Raw material Plant and equipment Fatty acid problem</p> <p><i>Organisation</i> Construction of the factory Money for construction, day to day expenses Factory staff Marketing and Sales Transportation Finance and foreign exchange Renegotiations with customer (Collectorgane)</p> <p><i>Information</i> Market information Production information</p>
<p>A new profitable industry</p>	<p>A profitable company</p>	<p>A profitable, stable export company, exporting high value products from low value by-products</p>
Society		
<p>Cultural Additional jobs Increased wealth for the country Demonstration of technological capability Higher educational opportunities</p>	<p>Organisational Increased control over export earnings Diversified products Targeted marketing</p>	<p>Technical Increased knowledge base within New Zealand</p>

The New Zealand Pharmaceuticals development diagram illustrates the elements of technology practice and how they contribute and inter-link in the development of new production processes. It demonstrates how innovation took place within a societal context and the interaction between society and the technological development.

5.3 EXPERT PANEL: VALIDATION OF MODEL AND TECHNIQUES

The technologists who participated in the expert panel discussion represented a wide range of expertise as listed in Table 5.3. Where statements from these technologists are used in the text, they will be referenced for example, as ET1 for the Process Engineering technologist.

Table 5.3 Composition Of Expert Panel

Expert Technologist 1	Process Engineering
Expert Technologist 2	Production Engineering
Expert Technologist 3	Biotechnology
Expert Technologist 4	Product Development, Food Technology
Expert Technologist 5	Control Technology,
Expert Technologist 6	Production Systems and Management
Expert Technologist 7	Electronics
Expert Technologist 8	Meat Technology, Production and Process Technology

Table 5.4 lists the activities and outcomes used to structure the expert panel discussion. These were displayed at various stages of the discussion using an Overhead Projector. Each element of the model was discussed and verified as important in technology practice.

Table 5.4 Expert Panel Discussion Planner

Activity
Introduction
Research overview
Discussion on the general model
Focused discussion on elements of practice
Discussion concepts
Categories for information collection and analysis techniques
Other generalised technique categories.

5.3.1 Society

The use of the word society and the way it surrounded all practice was discussed in detail. ET1 suggested the term community be used rather than society. Concern was expressed that too much emphasis was placed on society in technology education thus

reducing the time available for technology practice. It was agreed, however, that societal influences were important in developing new products.

“Being aware of the culture and the influence of different cultures which helps application of certain technologies might be important” (ET6).

There was general agreement with this comment.

5.3.2 Work Environment

There was agreement that technology took place within a context that influenced practice, and that these influences are important to consider in technology practice.

“Those social conditions are key elements in any successful technological development. I’m quite happy with the technical ambience” (ET2).

“That’s one of the key elements – differentiation of good technologists is that they do have to understand the human aspects, they do have to understand the social science aspects” (ET4).

5.3.3 Purposeful Action

This element of the model prompted considerable discussion from the expert technologists. There was general discussion and some confusion on what this section of the model meant. The need for the model to itemise the process involved was generally agreed on.

“...it will be really helpful if we have a few points in a line that identify the different parts of the process” (ET7).

“It is vital in my view to have these flows through here [the purposeful action arrow] so when you train the teachers if you don’t show those signs they are not going to pick them up” (ET1).

It was felt that teachers did not have the experience in technology practice that would allow them to develop the process without a clear methodological structure within the model.

“You have got to start there because one word we haven’t used is experience. A lot of the iterative nature is ‘I have not got that quite right’, ‘I will have to go back and do it again’ - it’s the experience that tells you you haven’t quite got it right yet” (ET3).

“it [experience] teaches you how to approach the same or similar problems that come up again” (ET4).

For these reasons it was felt the model should contain the main stages of the process used by technologists.

“...teachers can't guide students. They don't have the ability [training and knowledge] to think through the whole process”(ET4).

“There is a need to provide teachers with cookbook processes, which are technological”(ET8).

Discussion followed on how this process should be described and what points needed to be identified. The beginning of the process was seen as important.

“Community values – goals [at the start or left side]- to community enhancement on the right” (ET1)

It was emphasised that identifying and defining the problem or opportunity on the left hand side was important (ET8&2)

“Good technologists don't rush in and gather information and run about – [what] they do do, [is] the definition of what their problem is” (ET4).

“Need to have on the left – Identifying the problem, ‘What transformation we are trying to undertake. First find out what that is, and then information about it” (ET2).

From this point the panel identified the general process.

“The sequence is – they identify the problem; find opportunities; they analyse them; they do something about it - do the transformation [and]; produce something at the end. That is the real role of the technologist” (ET2).

The panel concluded this could be summed up in the sequence of analysis, synthesis and implementation, and that the Product Development process was a version of this generic process.

5.3.4 Organisation

Little time was spent discussing this element as all agreed it was an important part of practice.

“Organisation is about the structures and the processes. The tools and techniques to get the job done” (ET2).

5.3.5 Knowledge

There was some discussion on what constituted this element of practice. During the industrial revolution,

“the technologist was empirical and didn’t worry about the technicalities [they] just got out there and built it rather than get the laws” (ET1).

Modern technology was seen as a balance between understanding and applying fundamental laws and working empirically to solve problems.

“whilst there are certain times where you are empirical and you go out and experiment, there are other times when you actually go from a fundamental understanding and try to drive forward and apply laws. We have to get the balance between both those two elements, it is not one or the other” (ET1).

5.3.6 Resources

There was little discussion on this element of practice as resources were seen as fundamental in technology, particularly properties of raw materials and their processing.

5.3.7 Techniques

It was agreed that technologists used tools and techniques in their practice, although it seemed that few had considered categorising these. ET2 proposed the techniques be arranged in a different way.

“lets look at the techniques for analysis, lets look at the techniques for synthesis and lets look at the techniques for making it happen” (ET2).

As an example, the technologists were asked to write down the techniques for information gathering using the headings of analysis, synthesis and implementation. After some confusion the request was rephrased and they were asked to think of an example of technology practice they were involved with and write down the techniques that were used. The results of this exercise are contained in Appendix 2.

These results were summarised and combined into a single table detailing the information gathering tools and techniques identified by the technologists (Table 5.5). The first section of the table provided details of the source of information and a limited number of information collection and analysis techniques. The second section summarises the general techniques identified by the expert technologists.

These results confirm many of the toolkit concepts developed by the product development technologists in Chapter 4. However, an important addition identified by this group of technologists was the people information sources used by many of them in their practice. This appears to support Fleck's (1998) concept of informal knowledge embodied in verbal interaction. Research on the relationship between information and personal knowledge in new product development found the most frequently accessed sources of information focused on local sources and verbal communication (Court, 1997).

5.4 PACKAGING TECHNOLOGY TEACHING UNIT

Following the suggestion from the expert panel, a packaging example was developed to illustrate the model and its representation of technology practice. The model concepts and their application in school technology education were discussed with a packaging technologist at Massey University (Gawith and Robertson, 1999). The outcomes from the discussion were used to develop an example of a packaging unit suitable for schools. The example was based on the scenario that students had been asked to develop the packaging for a birthday cake product for children whose families were dependent on the local city food bank. The technology practice and concepts developed in this example were checked with the packaging technologist to ensure it reflected the techniques, organisation, information and resources commonly used by packaging technologists. The example was summarised in a table with the same structure as that used for the case study, described in Section 5.2. This example identified the cultural, organisational and technical aspects of New Zealand society relevant to packaging technology practice and the actions commonly undertaken by technologists as they develop packaging products. This example became a component of an expanded model of total technology practice.

5.5 EXPANDED MODEL OF TOTAL TECHNOLOGY PRACTICE

The expert panel technologists identified the need to provide more detail of the process followed by technologists and examples of how the elements of practice could be applied in teaching. Two further diagrams were developed and combined with the

graphical model and the packaging example described above to compile an expanded model of total technology practice that could be presented to teachers for evaluation.

A simple technology practice planning sheet was developed, based on the design of the graphical model. This planning sheet retained the horizontal configuration, but (when printed on A3 paper) provided space under each element for teachers to write details of the concepts to be considered and the techniques and skills that might be used. In order to give teachers guidance on the systematic process involved in the purposeful action element, an example based on the product development process was developed.

This example described the detail involved in the purposeful action element and stresses the need for technologists to organise and control the process rather than follow steps without thought or consideration. The product development technologists observed in Chapter 4 organised and controlled their purposeful action by identifying the important actions and decisions they would need to make in order to develop the product. Having decided these, they identified the outcomes they would need in order to make the decisions and take the actions. Finally, they planned the activities they would need to undertake, based on the management actions and decisions and outcomes required. A generalised product development process was used to guide the decision making and ensure all important actions were considered.

These two diagrams along with the graphical model and packaging example are included in Figures 5.1, 5.2, 5.3 and Table 5.6 at the end of this chapter. Together these three figures and the packaging example table comprised the expanded model of total technology practice and were presented to teachers for evaluation. The expanded model illustrated the knowledge and actions associated with each element and indicated how this could be applied in technology education.

5.6 CONCLUSION

The case study illustrated how organisation, information, resources and techniques are used by technologists within a societal and working context to systematically develop solutions. The seven elements of technology practice were further verified by the expert

panel discussion. The importance of using a systematic approach was confirmed from the interview results and verified the model's depiction of purposeful action.

Detailed knowledge and actions involved with each element were not fully identified. However, sufficient information was gathered to indicate the structure of each element. The results of the case study, expert panel discussion and packaging example were combined and summarised in a form that could be used by teachers in school technology education classrooms.

From the expert panel research results it appeared the seven elements identified in the model represent a simplified conception of total technology practice. There was general agreement the model conceptualised the interaction between these elements. However, it was felt the steps of the process need identifying for the teachers and students and the elements associated with the technologist needed to move along the purposeful arrow to illustrate how the organisation, information, resources and techniques changed as the product or process is developed. It was suggested an example be developed to demonstrate the model and how it could be used in teaching.

These suggestions were acted on and a resource representing an expanded version of the model of total technology practice developed. This resource included overheads of the graphic model that allowed the elements of practice, centred on the technologist, to move along the purposeful action arrow. It also included the planning sheet (Figure 5.2), the product development process (Figure 5.3) and the packaging example table (Table 5.3). This resource was used to demonstrate the expanded model to teachers before they completed the survey evaluation on the model.

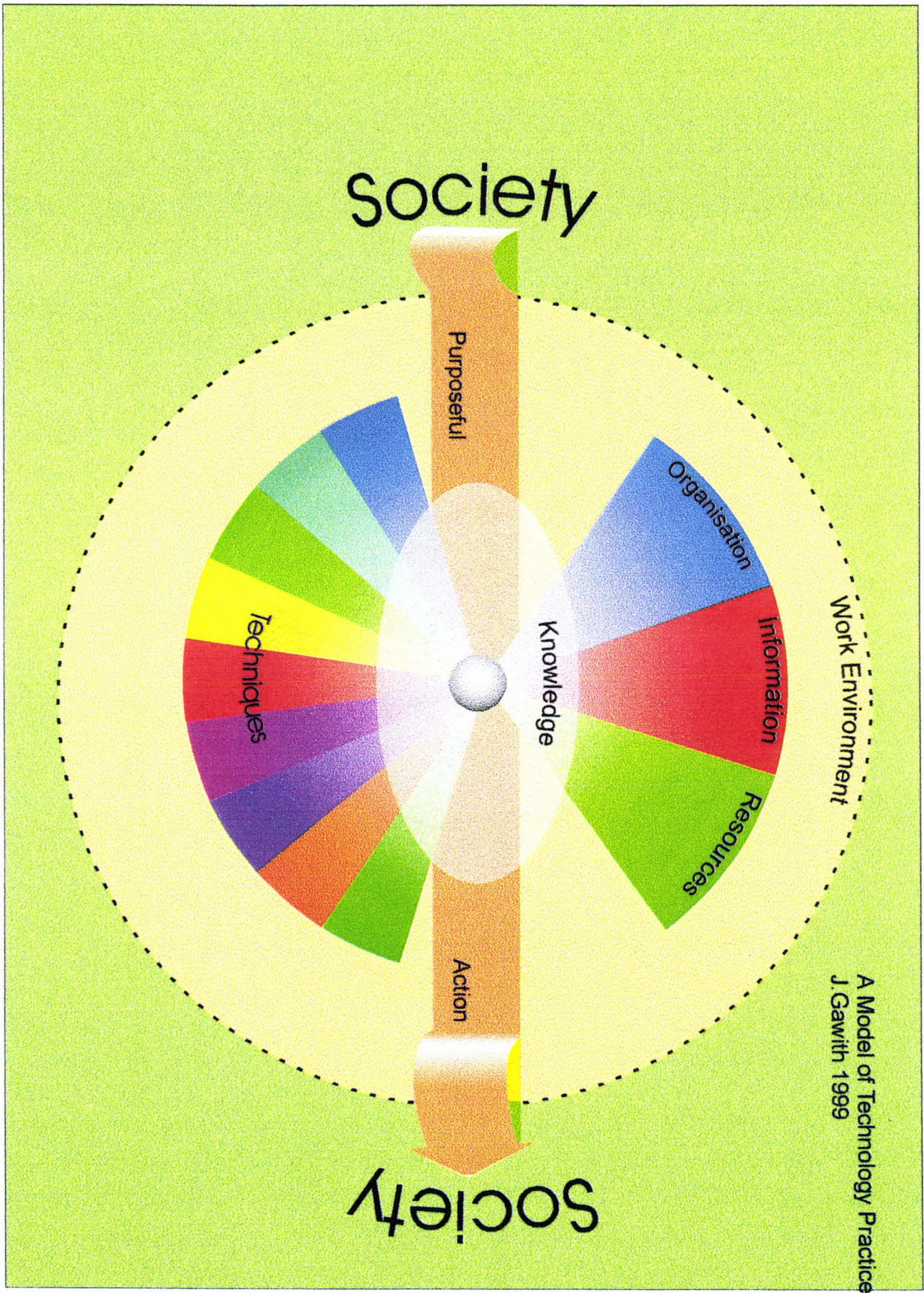


Figure 5.1 Model Of Technology Practice

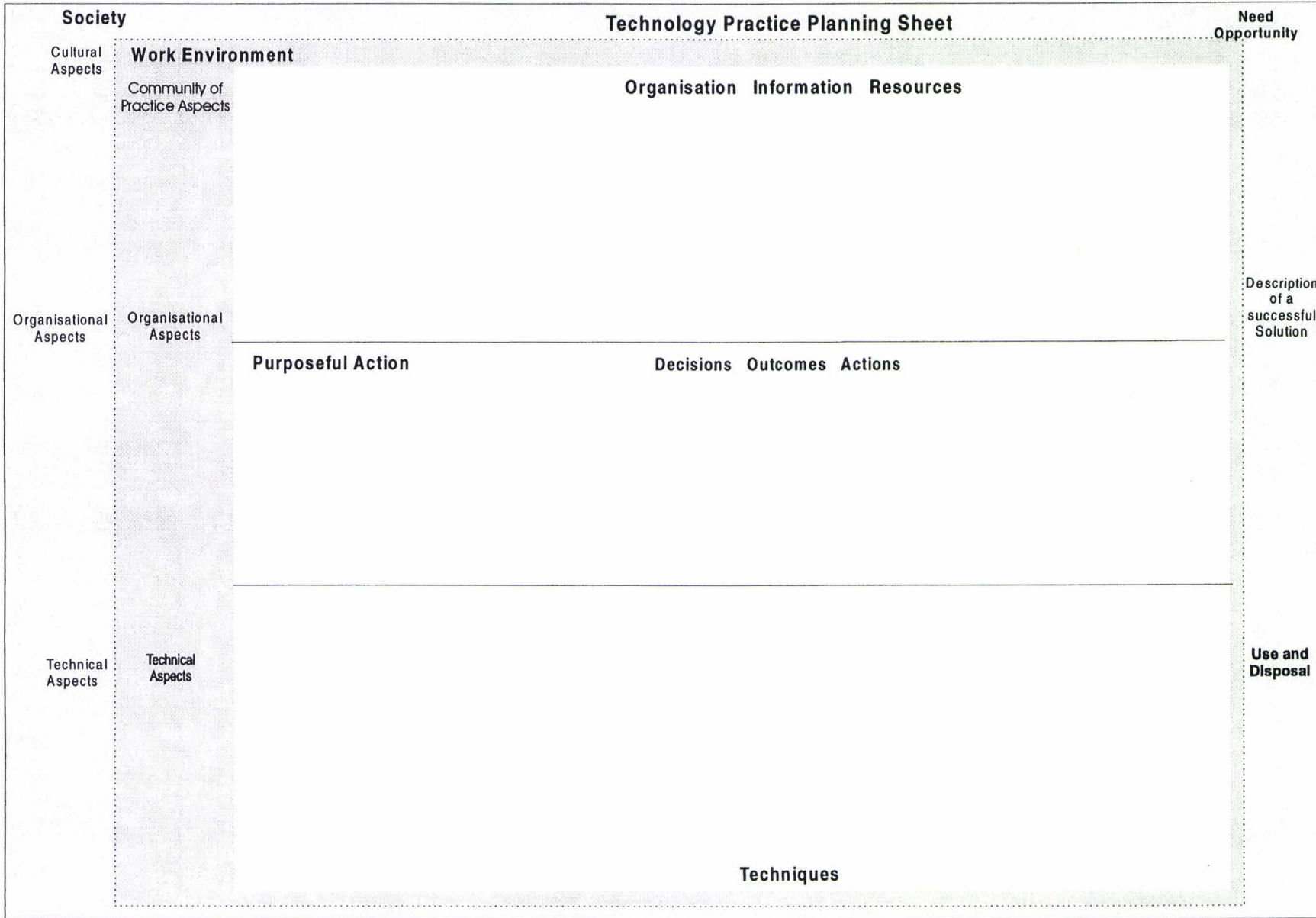


Figure 5.2 Total Technology Practice Planning Sheet

Management actions and Decisions

Decide an appropriate statement of position and how the need/opportunity will be organised and controlled

Decide strengths and constraints of the ambience

Go/No-go Decision

Decide on the compatibility of the project aim with position statement and technological ambience

Critically analyse the product concept and user group

Evaluate the technical feasibility of the product

Go/No-go Decision

Evaluate the market success of the product

Evaluate the safety of the production process and the product

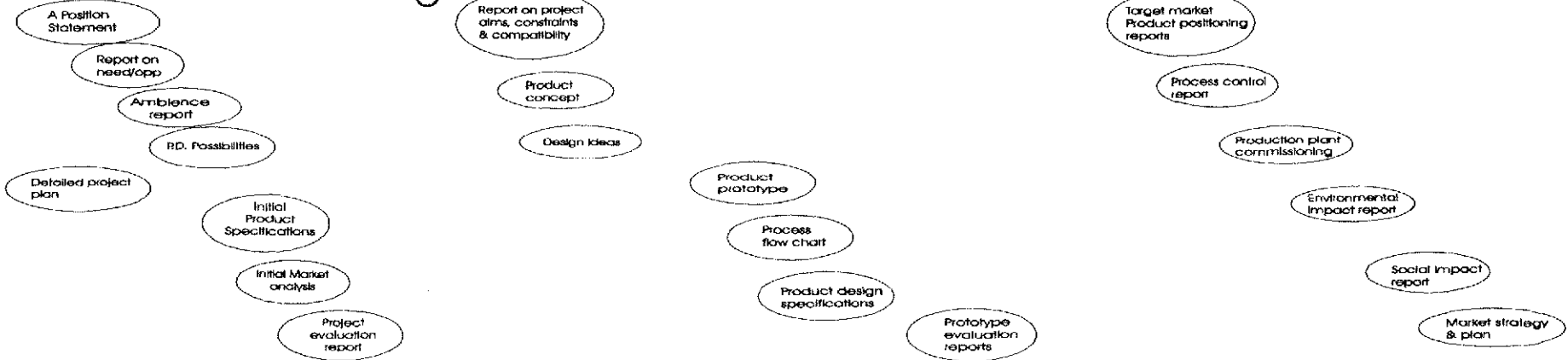
Evaluate quality procedures

Assess financial, environmental & social implications of producing and using the product

Assess the market strategy for the product

Acceptance of Product

Outcomes



Activities

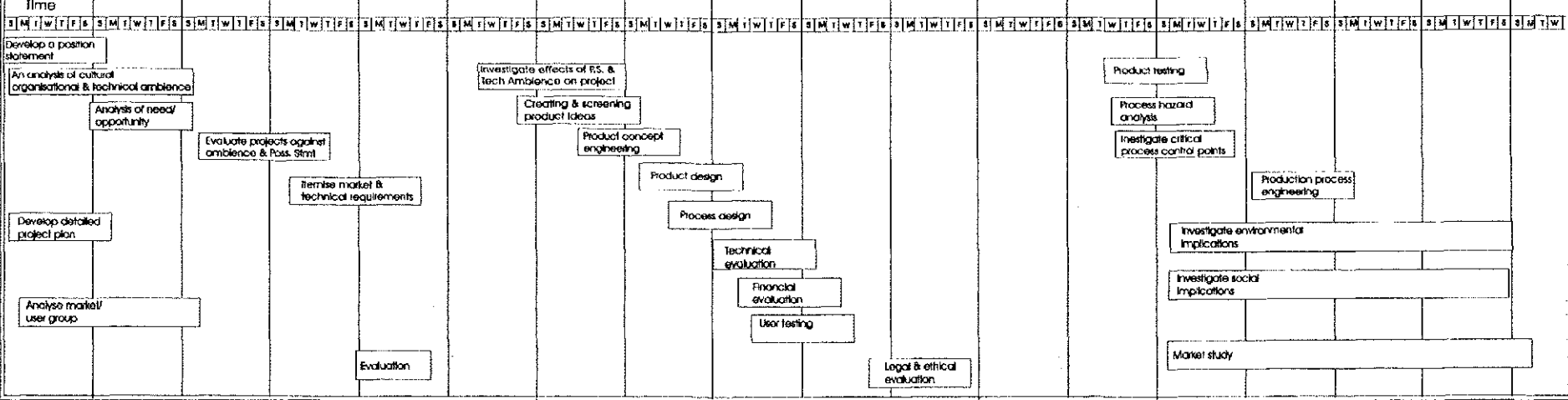


Figure 5.3 Product Development Process Example

Table 5.6 Packaging Technology Planning Sheet















Society		
<i>Cultural Aspects</i>	<i>Organisational aspects</i>	
Attitudes to packaging Expectations of food products Concepts associated with birthdays Attitudes to waste Environmental concerns	Laws and regulations The total packaging system and the accepted conventions involved in this.	
Technical Aspects		
Knowledge of packaging systems and packaging materials. The tools and machines used in packaging.		
Work environment		
<i>Community of practice</i>	<i>Organisational</i>	<i>Technical</i>
'Code of Practice for Packaging Consumer Goods' Attitudes to creativity and risk taking.	Limitations of school timetables Classroom structures that promote creativity and goal orientated work	The equipment within the school The materials that can be used
Techniques	Purposeful Action- Decisions, Outcomes and Action	Organisation, Information, and Resources
Information gathering techniques • Questioning • Surveys • Observation • Library search	Collation of criteria and constraints 	<i>Organise</i> time, paper and equipment for gathering and recording information. Decide on the <i>information</i> needed Determine what <i>resources</i> might be required and gather knowledge on these
Talk to knowledgeable people Read about the topic Question and observe Packaging functions and environment grid	Identify the problem 	<i>Organise</i> the collection, recording and analysis of information – organise to talk to a knowledgeable person.
Management Go, No-Go Decision		
Flow chart		
Lists Tables User questioning	Identify criteria 	<i>Information</i> on what the birthday children and their care givers want <i>Organise</i> to collect this information
Values and ethical codes	Consider values position 	<i>Information</i> on transportation and distribution system.
Code of practice	Preliminary Specifications 	<i>Information</i> – technical information
Evaluation techniques – discussion grids	Idea s and Concept generation 	<i>Organise</i> people, time and resources <i>Information</i> required <i>Resources</i> - Gain knowledge about materials
Lists Tables Diagrams		
Sketches, Drawings, Lists Brainstorming Analogies Modelling Material testing		

Table 5.4 Packaging Technology Planning Sheet (Continued)

Techniques	Purposeful Action – Decisions, Outcomes and Actions	Organisation, Information and Resources
Compression testing Moisture testing Shelf life testing User test	Concept testing 	Organise testing Resources – acquire resources needed Information collection, recording and analysis
Screening matrix	Concept screening 	Organise people, time and resources Information on processing techniques Resources – acquire resources needed and gain knowledge about materials
3D models Processes – cutting, forming, joining Optimising	Prototype development 	Organise testing Resources – acquire resources needed Information collection, recording and analysis
Compression testing Moisture testing Shelf life testing User testing	Prototype evaluation 	Evaluate against social position
Trial runs Use test	Consumer test, transport test  Final specifications	Organise for tests to be carried out and information collection
Management Go, No-Go Decision		
Scheduling techniques Quality control techniques	Produce the packaging  Pack the product  Distribute the product	Organise for the materials, equipment and people. Information on quality
Birthday cakes reaching the children in good condition The children are excited by the package and the caregivers have all the information they need		
<i>Cultural</i> Children from poor families feel more a part of society.	Society <i>Organisational</i> Greater understanding of packaging regulations.	<i>Technical</i> Increased knowledge New techniques and skills learned

CHAPTER 6. MODEL EVALUATION BY TEACHERS

6.1 INTRODUCTION

Teachers evaluated the model concepts as they were developed and verified by the technologists. The product development process emphasises the importance of evaluating concepts with the users. The very early model concepts were evaluated by a technology education teacher adviser and were reported in Section 4.2. The third model iteration described in Section 4.5 underwent preliminary user testing with three groups of technology teachers and was used for the first focus group with teacher facilitators. The favourable reactions and comments from these teachers were noted and provided confidence for the continued development of the model. The expanded model described at the end of chapter 5 was evaluated by the second focus group of secondary school teachers and used to demonstrate the model to teachers participating in the user survey. The comments from the three groups of teachers

6.2 MODEL PRESENTATION

The third model iteration was presented to three groups of teachers and at a conference (Gawith 1997a). The comments on the model were generally positive. From their comments, teachers appeared to understand the elements involved in technology practice and liked the way the model presented a balanced view of practice and demonstrated the growth of knowledge in each element. Particular interest was expressed in the technique categories and more details were requested for these. Concern was expressed by the Auckland group that commercialisation was not included as a technique category.

The outcomes from these presentations were that the model was a useful aid for understanding technology practice and that these teachers could use the model to help plan and structure their teaching in technology education.

6.3 FOCUS GROUPS

The first focus groups involved a group of eight teacher facilitators (TF), involved in running professional development courses in technology education, mainly at the primary and intermediate level. The second focus group involved four teachers (T) from secondary schools, two of whom were science teachers. The discussions were guided by, but not restricted to, the following five questions:

1. Is there a potential use for such a resource?
2. Who would use this resource?
3. What criteria or attributes would you as teacher educators, have for such a resource?
4. What other resources have you seen or used that you consider to be successful and that demonstrate best practice?
5. Are there any other comments or issues concerning these resources that you would like to discuss?

The following points emerged from the Focus Group discussions.

6.3.1 Model Use In Schools

When asked if they (Teacher Facilitators) would use this resource, most agreed they would. However, there was less certainty that teachers would use it.

“I think it would need more than just dropping it in a school considering where the schools are at the moment. In a couple of years time that might have changed” (TF6).

Many resources are developed for use in schools and many of them are “just left on shelf and not used” TF6.

6.3.2 Relationship With the Technology Curriculum

There was debate as to how closely the resource should relate to the curriculum document and how much it should reflect practice in industry.

Several teacher facilitators indicated the resource should reflect solely the technology curriculum statement.

“I’m saying it should be more focused [on the curriculum document]” (TF1).

“If you go along and do some more esoteric thing that technologists do that’s not reflected in our curriculum or not appropriate to children you are wasting your time I think” (TF1).

“If you don’t reflect the document you don’t pick up the central concepts” (TF4).

Others disagreed that the curriculum should be the sole focus and indicated the resource should also reflect practice in the private and public sector.

“What you are going to end up [with], if you take it from that aspect is school technology [as opposed to technology practice outside schools]. I would like to see school technology as reflecting to some degree what happens in industrial technology. ... I think everyone has got to get to the stage where they can take on the concepts of technology practice in the wider world and apply it with knowledge to schools otherwise we are going to be poles apart. You must have the philosophical understanding of what is going on out there [private and public sector practice] in order to put it in here [schools]” (TF5).

There was general agreement with this view and that the model should be related to the curriculum statement.

“No philosophical problem with that. But must relate back to the curriculum” (TF1).

This discussion highlighted the focus by many teacher facilitators, on the technology curriculum statement, and the need for school resources to relate closely to the official Ministry of Education document.

6.3.3 Progression In School Curriculum

There was discussion on student knowledge and skill progression in technology and how the model provided a structure for this to be managed in the classroom. Some teacher facilitators indicated the curriculum provided a structure for progression and it was not necessary for the model to demonstrate progression.

“Take giving information – [the curriculum] talks about immediate environments, local environments and then moves out into the market and consumer preference. That’s the sort of transition [progression]... so you use some of the structures and ideas in here [the curriculum document], you have a transition. What teachers need is some techniques they can use with little children for gathering information in the immediate environment. What are

some of the strategies technologists might be using that could be applied?” (TF1).

Other teacher facilitators saw value in expanding perceptions of progression in technology to include concepts and skills and saw the model as drawing these out.

“ what’s going on in a way is what is in the science document – the investment in skills. There they put them in four categories - This is what scientists do. The rest of it is just organisational strategies to try and sort out the world ... the guts of it is – ‘this is what scientists do’ the [model] is what technologists do but we bury them all away in here [the curriculum statement] but what you put up in the overhead relates to [what technologists do]. ... You are looking at what is the progression. There is a sequential model isn’t there and that’s the sort of thing you are trying to do” (TF3).

There was general agreement on this and the need for students to learn to choose appropriate techniques to apply.

“If I was a teacher in the classroom it [the model] would need to relate to the curriculum” If I had a range of techniques that could apply to roughly those sorts of areas and I knew that these are the sorts of strategies technologists use and can be applied in kids’ personal immediate environment type question, that would be very helpful” (TF1).

6.3.4 Visual Attributes

A number of teacher facilitators indicated it was important for the model to be very visual and for the final resource to contain considerable visual material.

“Do you imagine you will put together a resource that is quite visual?” Visual material [is a] very valuable, budget, resource for use in schools and there is nothing much there in technology yet” (TF4).

Examples given were videos and picture packs.

This indicated the need for the model to contain much visual material, particularly for use in the junior school.

6.3.5 Model Application

For teachers to have an understanding that helped them interpret the curriculum was seen as important. It was generally indicated the model would help teachers in this regard.

“Don’t worry too much about getting it too defined for children as teachers will adapt the resource for their own situation anyway” (TF3).

The core concepts need to be identified.

“In its simplest way, what you are trying to do here is elevate it [technology practice] beyond just a good activity. You’re on the right track. Its almost like you are talking about a supplement to the curriculum” (TF3).

There was general agreement from the rest of the group, with some teacher facilitators highlighting the need to understand the important core concepts and skills within technology practice in a way that allows these to be transferred to other contexts.

“It is intuitively what we do. Many of the techniques are out there already, but unless you make it explicit for the children it’s like it is invisible to them.. they can’t apply it unless they recognise it” (TF2).

“But unless you make it explicit - sometimes to the children it’s like showing them a lump of coal with this wonderful rich language in it. [If] you can’t work on the language and make it explicit to the children - it just washes over them. ... You can’t apply it to the next thing unless you know “ (TF2)

Secondary Teachers (T): The secondary teachers had the advantage of commenting on the expanded model of technology practice and highlighted the importance of systematic process and developing knowledge of concepts and techniques. They also recognised the importance of appropriate application of techniques.

“students need learned techniques that they can apply to solving a particular problem or developing the solution” (T1).

“The techniques are an important part of the knowledge. They have to recognise techniques and when to apply them in technological practice” (T1).

The implication of the working environment was also recognised by the secondary teachers as important.

“and the initial problem choice is obviously done within the context of what techniques and materials etc, are available within the institution” (T3).

“In that way I can see this working - take this step by step ... does this apply (*“and there’s a ‘why’ there as well” ST 2*)... it’s a process” (T1).

The secondary teachers noted the influence of society and the working environment on practice and the need for planning and using a systematic approach, but recognised that students found this difficult.

“My reaction is very positive but it takes mature minds. We struggle with this all the time, [because] students want to get on and do rather than take that preparatory time” (T4).

“This gets away from the design and make thing. This is technological practice involving all the different aspects – totally different from design and make” (T1).

The secondary school teachers appeared to quickly appreciate the elements of the model and considered the implications for secondary school curriculum.

“The whole thing about technology is that it is a very integrated subject. If you are going to bring it in in a meaningful way it forces the whole thing to be looked at [the schools curriculum]. Where the schools are right now, are the seven learning areas, the fact that technology has to draw on this wide range of techniques. They can't be taught in technology per se. What it requires is the whole education thing to be looked at. ... when and who should teach the techniques?” (T3).

“While we may plan, the kids pigeon hole their information and they don't cross over into another subject, the schools pidgin hole the learning itself so the whole thing of technology is struggling to get underway because of that.” (T4).

The secondary teachers saw merit in using the model elements to organise and structure technology in the secondary school.

“The technique tool bar concept is quite appropriate really” (T4).

“[in technology] you've got techniques that have application where as [in mathematics, graphing] is a task that needs completion. Its not seen as part of a whole in the same way that yours is because it [technology techniques] is linked to product development. The other one is linked to thinking or thought development. The concept of the tool bar has really got me. That could be a very good exercise for the staff or the heads of department meeting to just list all the tools or techniques students gather together in that particular area. You could actually make a tool bar and put it on A4 sheets that you could hand to kids and say look here [are some techniques]. ... [You would] need to identify where they learned that technique” (T2).

“I think that is one of the learning difficulties. It's actually a higher level skill to be able to take a concept and adapt it to a different context” (T3).

Both the focus groups recognised the need to identify techniques and link them to technology practice in an explicit way in order to encourage students to transfer knowledge. They recognised the need to develop knowledge and skills in a way that encouraged students to transfer their growing understanding from one technology project to the next.

6.3.6 Other Similar Resources

When asked if they knew of any resources that encouraged children to think about what they were doing and adapt techniques to the context, they were not able to identify any in technology.

6.4 USER SURVEY

A self-administered questionnaire was used to gather opinions on the model from 39 primary, intermediate and secondary school teachers and three tertiary educators. The results of the questionnaire are reported under four headings – Understanding the model, Communicating technological concepts, Application to the curriculum, Use of the model by teachers and students, Use of the model for curriculum planning. The frequency graphs and tables reported in these sections use percentages calculated from the total sample, including missing results. At the end of the questionnaire, respondents were asked for written comments on the model and for suggestions on how it could be improved. The questionnaire along with the complete set of SPSS frequency tables and written comments, are included in Appendices 8, 9 & 10. Respondent questionnaire forms were identified with a three-digit identity number. Where written comments have been reported, these numbers have been referenced (for example *ID* 134) to allow comments to be identified in Appendix 10.

6.4.1 Understanding The Model

Teachers were asked to indicate on the three point scale (Yes, No, Sort of) if they understood the model. 90% responded by marking the 'Yes' box. A similar three point scale was used to assess if teachers understood how the elements of the model interacted with technology practice. The percentage of respondents answering 'Yes' for each element, is recorded in Table 6.1

Table 6.1 Teachers Understanding The Model Elements

Elements of Practice	(%)	(No.)
Knowledge	90	35
Society	87	34
Resources	87	34
Information	85	33
Techniques	85	33
Organisation	82	32
Working Context	77	30
Purposeful Action	74	29

Most teachers indicated they understood how each element was involved in technology practice. When the results were analysed according to the level of teaching, (Primary, Intermediate or Secondary), Secondary teachers were less sure in six out of the eight categories, particularly the concept of 'Purposeful Action'. These results are recorded in Table 6.2.

Table 6.2 Teacher Understanding of Model Elements by School Level

Elements of Practice	Primary (%) n=5	Intermediate (%) n=10	Secondary (%) n=14
Knowledge	80	90	86
Resources	80	90	86
Society	80	100	79
Information	80	90	79
Techniques	80	90	79
Organisation	80	90	71
Working Context	80	80	71
Purposeful Action	80	80	57

The number of respondents in each category were too low to provide reliable statistics on differences between teaching levels. Further research would be required to confirm a significant difference and identify the reasons behind the differences between secondary teachers and primary and intermediate teachers. However, there appears to be less certainty among secondary teachers that they understand how the concepts of organisation, working context and particularly purposeful action interact in technology practice.

6.4.2 Communicating Technological Concepts

Teachers were asked to indicate how useful the model was in communicating the technological concepts that technology practise involved a holistic approach to problem solving, that the process involved was systematic and that the problem solving and

process occurred within a particular context that influenced the practice. The aim of the New Zealand technology curriculum is to enable students to achieve technological literacy. Teachers were asked if the model communicated the concepts involved with technological literacy without defining the term. A five-point scale was used, ranging from 1 (Not Useful) to 5 (Extremely Useful). The results were analysed by adding together the respondents that marked scores four and five, as indicating they found the model useful. The results of these four questions are reported in Figure 6.1.

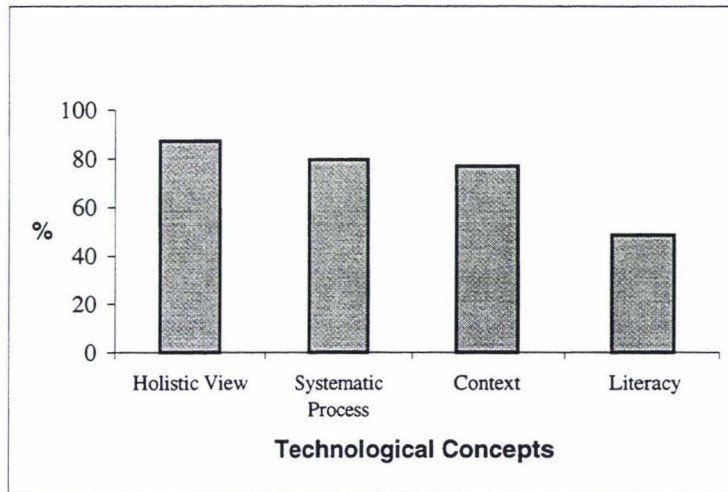


Figure 6.1 Teacher Assessment of the Model's Usefulness in Communicating Technological Concepts

Most teachers indicated they found the model useful in communicating the concepts:

- Technology takes place within a context that will influence the products developed (77%);
- Technology practice is a systematic process (80%), and;
- Technology practice is holistic (87%).

Fewer (49%) indicated the model was useful in communicating technological literacy. This may reflect confusion over the term as much as a judgement of the model. One respondent commented "I don't understand question 13 [technological literacy]" (*ID* 133).

The remaining five written comments on this section indicated the model communicated the concepts clearly, although one commented the terms would have to be thoroughly explained.

6.4.3 Application To The Curriculum

In this section the teachers were asked to rate the model on how well it incorporated the three strands of the curriculum, and how it fitted the learning objectives outlined in the curriculum statement. A five-point scale was used ranging from 1 (Not Well) to 5 (Extremely well). Scores of four and five were taken to indicate the model incorporates the strands and fits the learning objectives well. The combined numbers for scores 4 and 5 were reported in Table 6.3.

Table 6.3 Teacher Assessment Of How Well The Model Incorporates The Curriculum

Curriculum Strands and Learning Objectives	%	(No.)	Mean score	Standard Deviation
Technological knowledge and understanding	82	32	4.3	0.7
Technological capability	85	33	4.2	0.7
Technology and society	80	31	4.3	0.8
Learning objectives	72	28	4.0	0.9

80% to 82% of respondents indicated the model incorporated the technology curriculum strands one and three (knowledge and understanding, and society and technology). A slightly greater number (85%) indicated it incorporated the capability strand. Teachers were less sure the model represented the learning objectives identified in the curriculum statement. This may be a factor of the number of learning objectives at each level of achievement in the curriculum (11 learning objectives at each level).

Teachers generally indicated the model reflected the curriculum document. The majority of the nine written comments on this section related to how the model covered all aspects and showed relationships between the strands and contexts.

“As a planning medium – good. Reminds teachers there are three strands and they are inextricably linked” (ID184).

“Will ensure full coverage if used properly” (ID105)

One teacher expressed doubts as to the compatibility of the model with the curriculum.

“Relates to how technology practice works but not sure about fitting it into curriculum” (ID195)

6.4.4 Use Of The Model By Teachers And Students

This section of the questionnaire attempted to gather teachers' views on the use of the model in school technology. 79.5% of the teachers indicated the model would be used by both teachers and students. A five-point scale from seldom to regularly was used to assess how often teachers thought the model would be used. These results are reported in Figure 6.2.

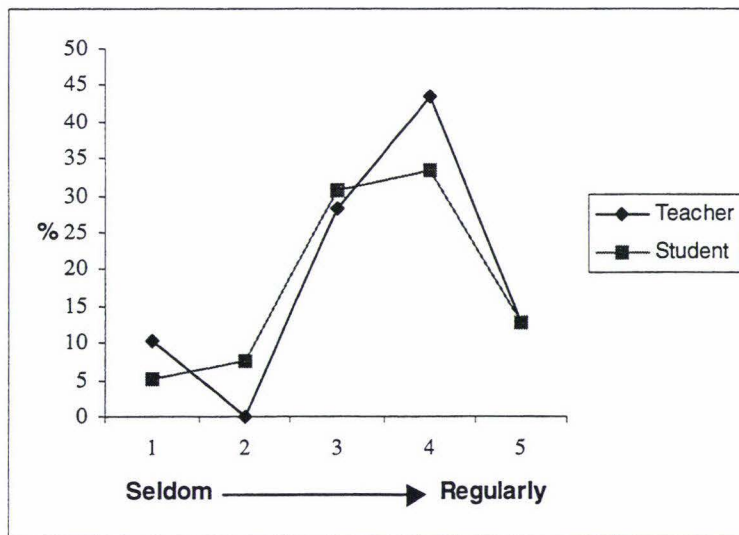


Figure 6.2 Teacher Assessment of How Often the Model Would Be Used

Respondents indicated both teachers and students would use the model about the same amount. Asked when teachers would use the model, respondents indicated most would use it throughout a class project. These results are reported in Figure 6.3.

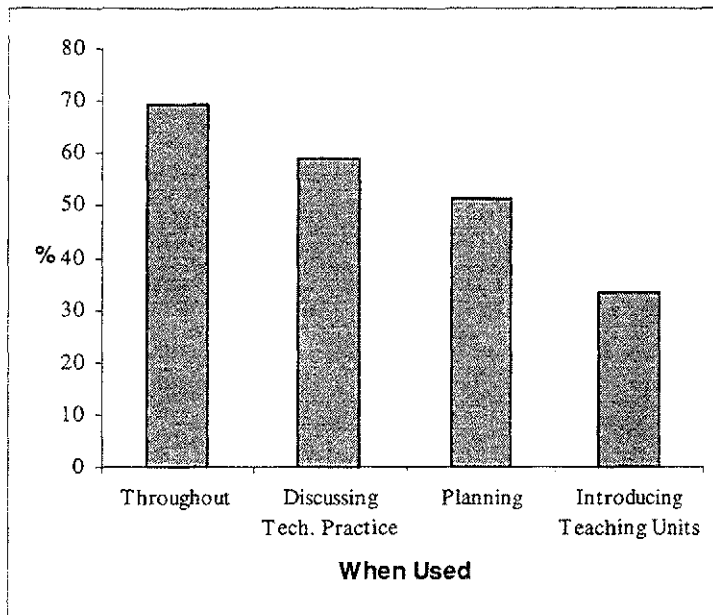


Figure 6.3 When Teachers Would Use the Model

Almost 70% of teachers indicated they would use the model throughout a class project. However, only 33% indicated they would use the model to introduce a technology unit. This may be because of the model's complexity and the need from a teaching perspective to 'set the scene' for the new unit of work.

Other comments on when the model would be used were at the end and the beginning of the next unit to discuss "Where have we come from, now where can we go next" (ID 184).

The teachers were then asked how they would use the model. Four closed categories were used:

- As a lesson planning tool
- As a teaching tool
- As a tool to encourage students to plan their technology project
- As a tool to encourage students to evaluate their practice
- Other

The results are reported in Figure 6.4.

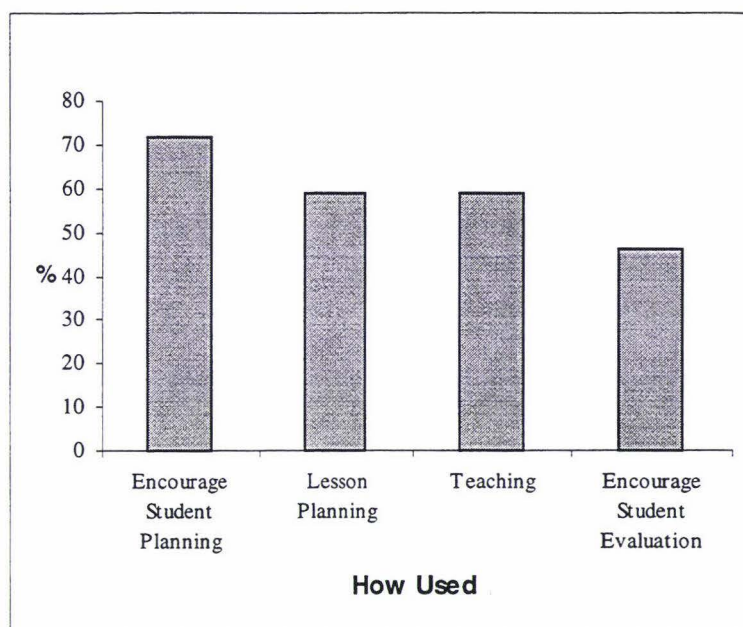


Figure 6.4 How Teachers Would Use the Model

Most teachers saw the main use of the model as a tool for encouraging students to plan their technology projects. When this result was analysed by school level, 86% of secondary teachers would use the model for this purpose. However, this view was not shared by primary teachers, with only one indicating the model would be useful to encourage student planning. Only 60 % of teachers indicated they would use the model as a lesson planning tool and as a teaching tool. Again there appeared to be differences between the school levels with primary teachers indicating strong support in these two uses – 80% and 100% respectively, with intermediate and secondary teachers indicating around 60% for both uses. Less than half (46%) would use the model as a tool to encourage students to evaluate their practice. Other uses for the model were “as a basis of explanation of the technology curriculum introduction into school” (*ID 105*), and as a “check-list in all areas of teaching and working through a technology unit or project” (*ID123*).

6.4.5 Use Of The Model For Curriculum Planning

Teachers were then asked how useful the model might be to them:

- for structuring their teaching;
- for providing a structure to facilitate progression;
- as an aid for planning organising, and controlling classroom projects;
- for analysing case studies of technology practice.

A five point scale was used, ranging from 1 (Not Useful) to 5 (Extremely Useful). Scores four and five were taken as indicating usefulness and combined for the percentage reported in Table 6.4.

Table 6.4 Teacher Assessment Of Model's Usefulness For Teaching

Teaching Tasks	Percentage %	(No.)	Mean	Std dev	Missing %	(No.)
For structuring teaching	82	32	4.0	0.8	0	(0)
As and aid for planning, organising and controlling classroom projects	64	25	3.8	1.0	8	(3)
For providing a structure to facilitate progression	54	21	3.7	0.6	8	(3)
For analysing case studies	49	19	3.7	1.2	18	(7)

Teachers saw the model as useful in structuring teaching. Eight of the ten written comments supported this view with comments – “Great to explain at start of topic” (*ID* 110). “Very useful for planning learning experiences, resources, balance” (*ID* 184).

As a structure to facilitate progression in learning, only 43% of secondary teachers indicated the model was useful in this regard, compared with 60% of primary teachers and 80% of intermediate teachers.

Two written comments indicated the respondents were unable to answer these questions without trying the model first. This may account for the high number of respondents who gave no response to some of these questions (seven for analysing case studies).

Teachers were then asked to rate the model's usefulness to students:

- for helping them plan, organise and control their projects;
- for helping students develop a systematic process for their projects;
- for encouraging students to select appropriate information skills and techniques in their project work;
- in assisting students develop reflective abilities in technology practice.

These results are reported in Table 6.5.

Table 6.5 Teacher Assessment Of Model's Usefulness To Students

Learning Tasks	Percentage (No.)		Mean	Std dev	Missing	
	%				%	(No.)
Develop a systematic process for their projects	64	25	3.8	1.0	13	(5)
Help them plan, organise and control their projects	49	19	3.6	0.9	15	(6)
Select appropriate information skills and techniques in their project work	44	17	3.4	1.0	13	(5)
Develop reflective abilities in technology practice	44	17	3.5	0.8	20	(8)

Teachers appeared to find these questions difficult to answer with between 12 and 20% giving no response. The written comments indicated the difficulty of the concepts involved:

“Re question 18, I think the model is quite sophisticated, more sophisticated than equivalent models in other subjects, mainly because of its need to integrate a greater degree of ‘knowledge’. As a result it will need very good case studies to show students its usefulness and why they should invest so much time in it” (ID 133).

“Usefulness lies in providing a framework for teacher-led systematic process at junior secondary school and for student controlled processing at senior secondary school. The development of a ‘toolbar’ appendix would improve its usefulness” (ID 182).

The results indicated the model would be most useful for encouraging use of a systematic process by students. Secondary teachers were more positive than primary and intermediate teachers for this use. No primary teachers thought the model would be useful to students to encourage the selection of appropriate information skills and techniques in their project work.

Teachers were asked if they would use the model of technology practice in their teaching, and again at the end of the questionnaire if the model was a practical tool for teaching technology education in the classroom. They were also asked if they thought their students would find the model fun to use. The responses were recorded on a three point ‘Yes, No, Maybe’ scale and reported in Figure 6.5.

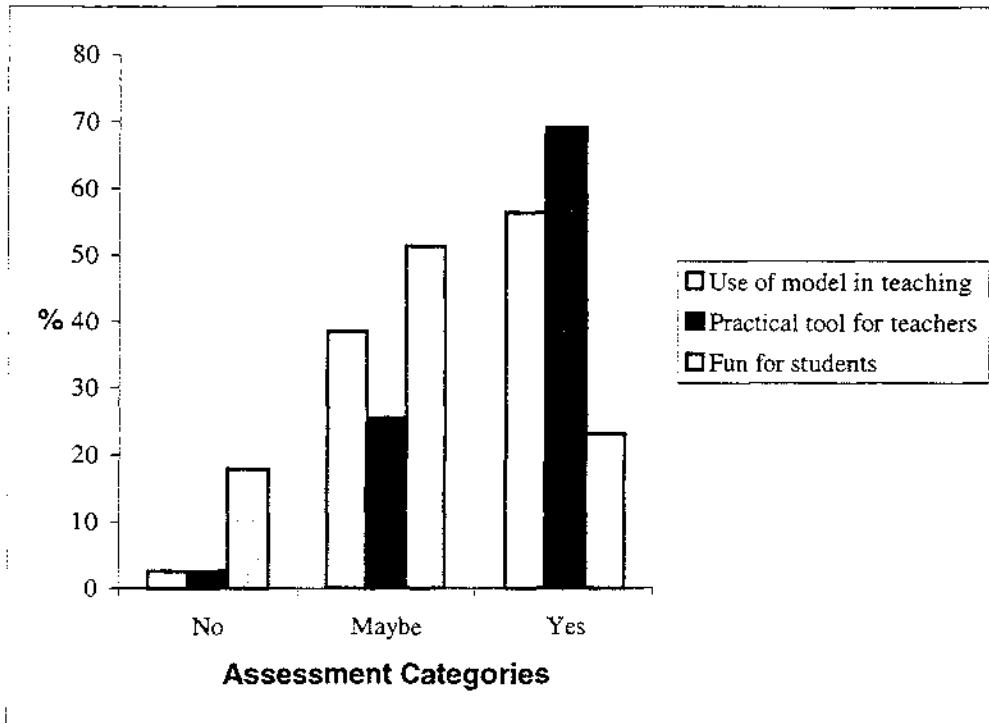


Figure 6.5 Teacher Assessment of the Model's Application

The majority of teachers (69%) indicated the model was a practical tool for teachers to use in technology education. A similar question at the beginning of the survey asking if they would use the model resulted in 56% indicating they would. The difference may have resulted from ideas and thoughts provoked by the intervening questions. Few teachers saw the model as fun for students to use (23%). This confirmed the previous results that less than half the teachers thought the model would be useful to students. This highlights specific student user groups that will require different versions of the model depending on the age of the students.

Teachers were asked to write down the costs that might be involved in the use of the model in terms of teacher time and expenses and resources. Comments were evenly divided between those that thought time would be saved and those that thought it would require more time.

“Once the model is understood it would help with planning time” (*ID 105*).

“At first, time consuming getting used to using the model efficiently but could save planning and organisation later” (*ID 126*).

Others saw a time cost:

“Explanation time and relating work back to the model” (*ID 110*).

“Would need considerable professional development so as teachers fully understand and appreciate the model” (*ID 131*).

Other costs were identified as photocopying. However seven respondents indicated there would be little or no further costs. Two indicated a reduction in costs. Example:

“The model should reduce unnecessary expenses as it sees the pitfalls” (*ID 111*)

Other comments included:

“It’s a good resource to keep pulling the students back as a reference, guideline to help them along the technology process” (*ID 104*)

“To me these [costs] lie in the area of whole school curriculum planning where a model such as this provides a focus for the integration/rationalisation and prioritising of costs/resources needed to introduce technology education into the school programme” (*ID 182*)

6.4.6 Defects In The Model And Improvements

Twenty eight teachers wrote comments on what they saw was wrong with the model. Ten teachers indicated the model was too complex, abstract and difficult to use for children, particularly at the lower primary level. A number of teachers indicated they could not say without using the model.

Other comments included “Availability of a good copy” (*ID104*), and the need for more writing space on the planning sheet.

Teacher suggestions on how the model could be improved covered a wide range. Six teachers suggested more detail or explanation be included on the techniques and process as well as other elements of the model. Two suggested simplifying the terms and conceptual level. One teacher suggested:

“The words could have logos attached to amplify their meaning, fix them in the minds of the users like a toolbar” (*ID 133*).

The survey form provided space for teachers to write any other comments. 11 teachers took this opportunity and samples of the comments specifically related to the model are recorded below.

“Have it produced as a poster and A4 as a resource. Send it to all schools” (ID 104).

“I have found the model extremely valuable – has clarified my thinking and put things in logical and useful boxes” (ID131).

“I like the way the diagram has now been put into a planning sheet – I would use this with teachers and students” (ID168).

“I like the expanding ring of knowledge. Schools have down-graded knowledge aspects of education. Possibly because teachers don’t have much time – too many curriculum for in-depth knowledge of any or many. Children should recognise that they are gaining knowledge in information techniques as well as process” (ID184).

“A good broad outline” (ID189)

“I like it as it covers all areas. The term ‘techniques’ fits after your explanation – that you apply these techniques to technological practice. The model would be very useful for senior school technology classes. I would use it more for planning probably for junior classes, as [these] students would find it more difficult to understand” (ID198).

6.4.7 Discussion and Conclusion

The model appeared to be most useful as a tool for planning and structuring technology practice and teacher unit planning. These results were supported by comment from both Focus Groups and indicate an important focus for further development of the model. The use of the model for teaching technological concepts involved in technology practice also appeared to rate highly with the teachers. It appeared the basic structure of the model is sound and is able to communicate important concepts.

Teachers were less certain how well the model would appeal to students in its current form. It was suggested the model use simpler terms and be more visual with icons used where possible. These results supported comments from the Focus Groups and confirmed the need to adapt the model for use by students, particularly younger students.

The results from the Focus Groups and the teacher survey highlight areas for further development. However, this preliminary research does appear to indicate the model in its present form achieves the objectives of communicating the concepts and elements of

total technology practice. The teachers in the survey indicated the model did relate to the curriculum document reasonably well. However, these results, combined with the concerns expressed by some teacher facilitators indicate the need to make more explicit the model's relationship to the curriculum statement.

The issue raised by the Focus Group for the need to identify clear pathways for progression in school technology will require further research. The model indicated broad categories (the seven elements) for developing knowledge, understanding and skill. However, the detailed pathway for progression has not been addressed. This requirement will need to be considered in further iterations of the model.

The model evaluation by teacher confirmed the general form of the model was acceptable and that it communicated the elements of technology practice. The evaluation of the model for use by students, particularly younger students, indicates further development is required in simplifying its complexity and improving its visual appeal. From a teacher perspective, the results highlight the need for more detail, a clear indication of knowledge and skill development and more obvious links with the curriculum.

Research identifying the model detail design and the structure of technological knowledge involved in practice had been proceeding concurrently with the model concept verification and evaluation. The results of this research are now reported.

CHAPTER 7. FINAL MODEL DETAILED DESIGN

7.1 INTRODUCTION

The second research question required that the techniques, knowledge and actions be identified for each element of technology practice. Once the model concept had been developed, the product development technologists assisted with identifying the detailed content of the elements. The results of this detailed development are reported in section 7.2. Further understanding was gained from the expert panel technologists. Finally six individual in-depth interviews were conducted with technologists from different technological areas. Section 7.3 reports the results of the six interviews with specialist technologists. The final Section (7.4) discusses the common concepts and implications for school technology teaching.

7.2 INITIAL DETAILED DESIGN BY PRODUCT DEVELOPMENT TECHNOLOGISTS

Having identified what appeared to be the important elements of practice, the second research question concerning the knowledge and actions involved with each element was addressed. Teachers involved in evaluating the model indicated the importance of identifying the detailed content of each element of practice, particularly the techniques. The practice of the product development technologists was used to identify and structure the detailed content of each element. The technique element was studied first, followed by organisation, information and resources. The four elements that centred on the technologist

7.2.1 Tool Kits/Techniques

From the earlier research the tools or techniques used by technologists appeared to be the most important element to develop detail. The use of the term 'Tool Kit' was later replaced by the term 'Technique'. Discussions and brainstorming sessions with product development technologists identified eleven important tool kit categories listed in Table 7.1.

Table 7.1 Tool Kit Categories

Consumer information	Technical information
Modelling	Prototyping
Testing	Specifications
Problem solving	Evaluation
Management	Production
Knowledge adaptation	

From this initial list of tool or technique categories, further brainstorming sessions with the product development technologists identified lists of specific techniques for each 'Tool Kit' or technique area. Within each area list, further subdivisions were identified. For example, the consumer and technical information areas were divided into collection and analysis tools, and modelling was divided into abstract and physical techniques. The subdivisions in each technique area were intended to highlight the important applications technologists used techniques for, when developing products.

The results of these brainstorming sessions are presented in the form of a table (Table 7.2).

Table. 7.2 Detailed Tool Kits For Product Development

CONSUMER INFORMATION TOOL KIT		
<p>Collection tools</p> <p><i>Primary Research</i></p> <p>Information from respondents</p> <p>Interviewing</p> <p>Panels and focus groups</p> <p>Observation</p> <p>Experimentation</p> <p><i>Secondary Research</i></p> <p>Statistical sources</p> <p>Literature</p> <p>Company information</p> <p>Purchased information</p>		<p>Analysis tools</p> <p>Information summarising</p> <p>Tabulation</p> <p>Single variable analysis</p> <p>Discriminant and factor analysis</p> <p>Multidimensional scaling and conjoint analysis</p> <p>Forecasting</p>
TECHNICAL INFORMATION TOOL KIT		
<p>Collection Tools</p> <p><i>Information search</i></p> <p>Scientific literature</p> <p>Commercial sources</p> <p>Patent literature</p> <p>Statutory regulations</p> <p><i>Experimental research</i></p> <p>Ad hoc experiments</p> <p>Classical experiments</p> <p>Experimental designs</p>		<p>Analysis tools</p> <p>Information summarising</p> <p>Data tabulation</p> <p>Single variable analysis</p> <p>Multivariate analysis</p>
MODELLING TOOL KIT		
<p>Abstract models</p> <p><i>Verbal</i></p> <p>Product concept</p> <p>Process description</p> <p><i>Drawings and sketches</i></p> <p>Product sketches</p> <p>Process flow charts</p> <p>Detailed product drawings</p> <p>Detailed equipment drawings</p> <p><i>Mathematical</i></p> <p>Mass and energy balances</p> <p>Unit operations simulation</p> <p>Process simulation models</p> <p><i>Technical</i></p> <p>Chemical and biochemical reactions</p> <p>Microbiological systems</p>		<p>Physical modelling tools</p> <p>Product mock-ups</p> <p>Complex 3-D models</p> <p>Ergonomic models</p> <p>Process plant mock-ups</p> <p>Pilot plant</p>
PROTOTYPING TOOL KIT		
<p>Product Design</p> <p>Raw materials and process selection</p> <p>Basic design</p> <p>Auxiliary design</p> <p>Packaging design</p> <p>Aesthetic design</p>	<p>Prototype Experimentation</p> <p>Formulation (raw material) experimentation</p> <p>Process variable experimentation</p>	<p>Prototype testing</p> <p>Technical use testing</p> <p>Consumer testing</p> <p>Industrial customer testing</p> <p>Life testing</p> <p>Storage life testing</p>

Table 7.2 Detailed Tool Kits For Product Development (Continued)

TESTING TOOL KIT			
Technical Product Testing Chemical	Consumer Product Testing Sensory panels	Safety Product Testing Microbiological contaminants	Process Testing Variation in process variables
Microbiological	Use panels	Chemical contaminants	Control of process variables
Nutritional Physical	Large scale consumer testing	Physical contaminants Process safety – HAACP Structural safety	
Environmental Testing	Social impact testing		
SPECIFICATIONS TOOL KIT			
Technical Specifications Product design /development specifications Product specifications Process specifications Production specifications Quality assurance plan	Marketing Specifications Marketing strategy Marketing plan Promotional plan	Business Specifications Business strategy Business plan Product mix strategy Innovation strategy	Overall specifications Total quality management
PROBLEM SOLVING TOOL KIT			
Problem definition Aims and constraints SWOT analysis Problem solving strategy	Idea generation Group idea generation Drawings and sketches Product attribute analysis Product positioning analysis Scenario writing Process analysis	Idea exploration and screening Qualitative analysis Quantitative analysis Investment and risk analysis	Problem solution Comparison methods Final selection methods
EVALUATION TOOL KIT			
Market evaluation Market segmentation and product positioning Product mix audit Promotion mix evaluation Distribution analysis Pricing and demand	Production evaluation Yields analysis Quality variation Energy and water efficiency Labour and supervision	Financial evaluation Costs Revenue Profits Rate of return	Impact evaluation Environmental External societal outcomes Internal (company) societal Outcomes
MANAGEMENT TOOL KITS			
Company management Present plan Future planning Monitoring and Control methods	Project management Project plan Monitoring and Control methods	Personnel management (or human resource management) Personnel planning Personnel recruitment and training Personnel monitoring methods	Information management Information collection Information storage and retrieval Information presentation
PRODUCTION			
Materials Material selection Material procurement	Unit operations Unit operations selection Unit operations optimisation	Total system Combination of unit operations Transport methods Optimising total system	Production control Setting the control systems Optimising the control systems
KNOWLEDGE ADAPTATION TOOL KIT			
Reclassifying Reorganising Reconstruction of knowledge	Re-evaluating Repackaging knowledge Recontextualising scientific knowledge		

The lists of techniques identified by the product development technologists provided the initial structure and content of the technique areas used by technologists. Further research will be required to adapt the structure and techniques described in the table and compile individual technique teaching resources suitable for use in school technology education. In view of the conclusions in Section 6.3.7, this process of adaptation will be required for each level of schooling.

7.2.2 Organisation

The main areas that require organising within technology practice were identified with the help of the product development technologists. These formed the main categories within the organisation.

Process of development involved deciding and developing a systematic approach to the development of a product. The technologist ensures the process proceeds smoothly, without important steps being left out. Two examples of processes used by technologists were product development, and process development.

People involved in the project are organised to work towards a successful outcome. This requires good communication and time management techniques such as critical control networks and Gantt charts.

Information required to achieve successful solutions must be organised and obtained from a variety of sources. This may involve further research or the employment of consultants.

Capital required for the development must be organised and monitored, within the constraints of the work environment. The term capital was used in an economic sense to include finance as well as the plant and equipment required to carry out the development.

Resources required for the product itself required organisation. For example, the raw materials consumed in manufacturing products must be organised and available at the appropriate time.

7.2.3 Resources

The main headings for the Resource element were identified. These comprise:

Consumable raw materials and components refer to the chemical and biological materials and subsystems that are purchased and incorporated into the product.

Energy to operate the production or process equipment and in some cases the product itself.

Capital resources finance, plant and machinery includes the money to finance the purchase of the equipment needed, and the working capital to employ the people and pay the-day-to-day expenses.

People are the most important resource in any technology project is the people; their knowledge, their ability, their networking and team skills, and their motivation.

Information can be seen as a resource, particularly with modern computers and electronic data bases.

Time is seen in industry as important, particularly the time required to develop new products within a competitive consumer market.

7.2.4 Information

The original term used for this element was 'knowledge'. The main headings for this element were identified through discussions with product development technologists and listed in Table 7.3.

Table 7.3 Knowledge Areas Important in Technology

Knowledge of science, mathematics, social sciences.
Knowledge of techniques, testing, modelling, interviewing, manipulating tools materials and data.
Knowledge of procedures, and processes.
Knowledge of generic concepts or ways of thinking.

A list of knowledge types in processing, food and biotechnology was developed from the Bachelor of Technology paper contents, and from discussions with product development technologists. These are listed in Table 7.4.

Table 7.4 Knowledge Involved In Processing Technology Practice

Basic science	Technology	Engineering
Biology	Process Technology	Process engineering
Biochemistry	Chemical technology	Reaction engineering
Chemistry	Clean process technology	Bioprocess engineering
Microbiology	Bioprocess technology	Food process engineering
Nutrition	Food process technology	Packaging engineering
Physics	Food storage technology	
Calculus		Unit operations
Statistics	Environmental chemistry	Separation processes
Computing	Analytical chemistry	Concentration processes
	Technological chemistry	
	Food chemistry	Process plant utilities
	Food structures and functionality	
	Materials	
	Materials in bioprocessing	
	Postharvest horticultural products	
	Industrial microbiology	
	Food microbiology	
	Technological mathematics	
	Food process dynamics and control	
	Water and waste treatment technology	
	Technological biology	
	Plant biotechnology	
	Molecular biotechnology	

These lists provided useful starting points. However, further study will be required to adapt the terms used and the content involved to an appropriate level for use in school technology education.

7.3 INDIVIDUAL INTERVIEWS WITH TECHNOLOGISTS

This section reports six individual interviews with technologists working in different technological areas. The model of technology practice and the elements were explained to the technologists. The interviews were conducted using the following key questions identified in Table 7.5.

Table 7.5 Interview Questions

What is the process used to develop solutions in your area?
Identify the tools and techniques used in your area?
What are the important concepts involved in the practice of technology in your area?
What is involved with organisation in your area?
What is the knowledge involved with this area?

Not all questions were covered in each interview as some initial questions were discussed at length. Each interview was recorded on audiotape, however, only three of these recordings were transcribed. The interviews were analysed using the meaning condensation method described in Section 3.6, into descriptive statements, concepts and techniques. Each interview was analysed, identifying each point or meaning unit, which in turn were compiled into tables (contained in Appendix 2 to 7). These tables were condensed into a descriptive statement of technology practice from each technologist. Lists were compiled of the important concepts involved and the important tools and techniques used in the technology practice for each technological area. The results of this initial analysis were taken back to the technologists for verification and further comment. From these tables, common concepts involved in technology practice across all six areas were identified. Table 7.6 summarises the results of this analysis.

Table 7.6 Descriptive Statements, Concepts And Techniques From Interviews With Technologists

Information and Communication Technology	
<p>Identify the problem as accurately as possible. Think as broadly as possible using your own experience and knowledge. Knowledge of appropriate case studies are important along with knowledge of the basic principles involved. Have an overview at all times but break the problem down to the component level and work from this base – bottom up, top down design. Communicate and gather information from other people, particularly the user.</p>	
<p><i>Concepts involved in the area are:</i></p>	
Entropy	Transmitter
Bits of information	Receiver
Transforms	Transformers
Noise	Filters
Communications channels	Laws of thermodynamics
<p><i>Tools and Techniques involved in the area:</i></p>	
Black box	Modelling
Reducing complex systems to components	Software tools
	Hardware/instruments
Materials Technology	
<p>Technologists are involved in developing real world products and must understand and maintain an overview of the whole process from problem identification to marketing. In materials technology this involves understanding material selection, how materials react in an environment, how these materials are extracted and transformed into products, and the material / human association. This requires knowledge of material properties and fundamental principles.</p>	
<p><i>Concepts involved in the area are:</i></p>	
Optimisation	Product form and function
Material properties	Material transformation
Material selection	Environmental issues in extraction, transformation, use and disposal
Interaction with environment	
<p><i>Tools and Techniques involved in the area:</i></p>	
Decision making techniques	Casting
Material extraction and production	Joining
Material processing	Finishing
Cutting	Material properties
Forming	Material testing
	Material selection
Electronics and Control Technology	
<p>A technologist is a person with practical skills and a broad theoretical knowledge who has the ability to apply theory as a tool among others, for solving problems and developing solutions. Identification of the problem is important in developing a solution, which may involve the development of an instrument. A knowledge of fundamental principles is important in identifying the problem accurately. In developing a solution, technologists often select and/or adapt Micro or Macro Blocks components that already exist.</p>	
<p><i>Concepts involved in the area are:</i></p>	
Modularity	
Can break a complex product/solution down into levels of components. Macro blocks – Micro blocks – components.	
Selection of appropriate Macro blocks / Micro blocks / components	
Instrumentation knowledge and selection of appropriate instruments.	
Reality line in modelling and simulating the real world context	
Noise in electrical circuits	
<p><i>Tools and Techniques involved in the area:</i></p>	
Simulation tools	Experimental design
Equations	Instrumentation
Finite element style techniques	Fault finding process
Computer simulations	

Production and Process Technology											
<p>Technologists understand the fundamental properties of the raw material they use and takes account of natural variation. They take a holistic view of process that accounts for all output streams including wastes. Processes are not considered in isolation but rather seen as interactive with impacts on other things such as the environment, culture and people. Problems are identified using techniques such as 'gap analysis'. Complex processes are broken into component parts. These are arranged to convey a logical sequence.</p>											
<p><i>Concepts involved in the area are:</i></p> <p>An in-depth understanding of the material being processed. Systematically breaking a complex process into component parts – unit operations. Questioning the need for each component and/or improving its efficiency. Knowledge and means for assessing the impact of a process. Modelling/simulating from flow process charts to laboratory simulation, to pilot plant to commercial plants. Scaling up Taking and maintaining a holistic view Accounting for all outcomes from a process – energy and mass balancing.</p>											
<p><i>Tools and Techniques involved in the area:</i></p> <table> <tbody> <tr> <td>Brainstorming; Fishbone diagrams</td> <td>Feasibility studies</td> </tr> <tr> <td>Delphi decision making;</td> <td>Modelling</td> </tr> <tr> <td>Matrix decision making;</td> <td>Flow process charts</td> </tr> <tr> <td>Fore-sighting</td> <td>Laboratory modelling / simulations</td> </tr> <tr> <td>Mass and energy balancing</td> <td>Pilot plants</td> </tr> </tbody> </table>		Brainstorming; Fishbone diagrams	Feasibility studies	Delphi decision making;	Modelling	Matrix decision making;	Flow process charts	Fore-sighting	Laboratory modelling / simulations	Mass and energy balancing	Pilot plants
Brainstorming; Fishbone diagrams	Feasibility studies										
Delphi decision making;	Modelling										
Matrix decision making;	Flow process charts										
Fore-sighting	Laboratory modelling / simulations										
Mass and energy balancing	Pilot plants										
Production Operations Technology											
<p>Technologists are improvement (or change) agents. They have fundamental knowledge, practical ability and skill to answer the questions – What is the problem? What is it we have to change? How are we going to make it happen?</p> <p>They do this through a process of analysis, synthesis, implementation and evaluation. Process management involves people and uses techniques to include these people in the change and stabilisation process.</p>											
<p><i>Concepts involved in the area are:</i></p> <p>Systematic methodology Accurate identification of the problem Identifying the boundaries of the problem and working creatively within these. Recognising flows within a process system – energy, information and resources. Recognising and understanding dependencies Identifying bottlenecks in a process and eliminate or reduce their effect. Defining the boundaries of the problem and working creatively within these</p>											
<p><i>Tools and Techniques involved in the area:</i></p> <table> <tbody> <tr> <td>Current reality tree diagrams</td> <td>Underlying assumption identification</td> </tr> <tr> <td>Linkage diagrams</td> <td>Causality tree diagram</td> </tr> </tbody> </table>		Current reality tree diagrams	Underlying assumption identification	Linkage diagrams	Causality tree diagram						
Current reality tree diagrams	Underlying assumption identification										
Linkage diagrams	Causality tree diagram										
Biotechnology											
<p>Technologists work in rational systematic ways using their knowledge of fundamental theories, raw material and its variation, modern practice, and past experience. Technologists interact with people including those with the problem, but particularly with other knowledgeable colleagues in order to develop and challenge ideas.</p>											
<p><i>Concepts involved in the area are:</i></p> <p>A deep theoretical understanding of the biological raw material and its variation. A theoretical knowledge of the process involved and how it is controlled to compensate for variation in the raw material. Limitations of biological agents Safety for people and environment</p>											
<p><i>Tools and Techniques involved in the area:</i></p> <p>Problem solving techniques Group discussions Use group interaction to force divergent thinking and wider knowledge recall and transfer. Drawing diagrams & Process flow diagrams Laboratory scale model of process to 'bucket' scale to pilot plant</p>											

7.4 COMMON TECHNOLOGICAL CONCEPTS AND IMPLICATIONS FOR TEACHING

The interview results were compared and analysed to identify common themes and concepts from all six technological areas. The results of this analysis and the implications for teaching technology in New Zealand schools are discussed below.

7.4.1 Systematic Process

Technologists follow systematic processes generally involving problem identification, analysis, synthesis and implementation. The product development process was identified as a more specific and detailed version of this general process. The process is adapted depending on the nature and context of each specific problem and is a means of achieving the goal of developing and implementing a solution.

This systematic approach was specifically identified in Materials, Electronics and Control, Production and Process, and Biotechnology interviews and was implied in Information and Communication, and Production Operations. The Materials, and Electronics and Control technologists specifically identified the product development process when developing a product for particular users or user groups.

This appears to be an important concept for school technology practice. The process used is applied and adapted for each situation, using generic patterns such as the product development process as guides.

7.4.2 Understanding The Context And Total System Involved

Often the problem being worked on is part of a much larger system with many subsystems preceding and following the particular problem or opportunity. There are flows through the system such as information, energy, resources, products and people. Technologists require an overall understanding of the system in order to appreciate the context of the problem or opportunity.

This concept was specifically identified in the Biotechnology interview. However, Electronics and Control, Production and Process, and Production Operations interviews indicated a holistic understanding of the context as important.

This total system approach involving the identification of flows through subsystems and links within total systems, is important in enabling students to appreciate the context of the problem and the societal influences to be considered.

7.4.3 Problem Identification

Technology is a problem-focused activity. Identifying the problem or opportunity is the first step. A sound knowledge of fundamental principles from science and engineering were important when identifying problems accurately.

All technologists discussed the need to identify the problem, and indicated the importance of knowledge in this process

The implications for school technology are that students should develop the skills involved with problem identification. The techniques identified by the technologists were:

- Experimentation to identify the problem or opportunity. (Information and Communication)
- Identify the specifications (Electronics)
- Know the environment the material will need to function in (Materials)
- Use past experience and reported studies of similar problems and situations (Biotechnology, Information and Communication)
- Systematically breaking a complex process into component parts (All technological areas)

7.4.4 Breaking A Problem Down

This was a common concept in each area. It involved breaking complex systems or processes into smaller subsystems that could then be worked on or developed. The process of breaking complex systems into smaller units was also important in identifying the problem. The techniques for doing this were also very similar. Areas involved in manufacturing/extraction processes used flow process charts to identify unit operations. In other areas, macro blocks within complex systems were identified, further divided into micro-blocks and finally into components.

This concept was applied in all areas covered by the interviews. The method of categorising the subsystems varied with the context. It appears the knowledge base and information structures reflect the same categories of subsystems. In processes that use raw materials, such as Biotechnology, Food technology, Material extraction, Process technology, the subsystems are called unit operations. Examples of unit operations are mixing, size reduction, separating, transporting, and heat transfer. The chemical and biological reactions which change the raw materials into products are also divided into specific reactions in reaction technology.

In the area of information & communication, subsystems such as transmitters, receivers and communication channels were identified. In materials process and assembly, the subsystems involve cutting, forming, casting, joining, and finishing.

This concept may have considerable relevance for school technology practice. It offers a structure for organising and developing technological knowledge. It also provides an important technique for breaking problems into more specific subsystems.

7.4.5 Organisation Of Knowledge Base

The knowledge base reflects the structure used to break down complex systems and processes. Each area reorganises scientific knowledge and combines it with technological knowledge to establish fundamental principles associated with individual subsystems.

This concept was not stated specifically in the interviews but was implied in the way complex processes were broken into parts, or finite elements, that could be dealt with one at a time (Production and Process technology, Electronics and Control)

This may offer an effective means of developing student's abilities to transfer knowledge and information from other learning areas.

7.4.6 Information Acquisition

A variety of information gathering techniques were used. There appeared to be a strong reliance on past experience and information gathered from other knowledgeable people.

The formal information base is usually organised into the subsystem unit operations or finite blocks identified above.

Several technologists stressed the importance of the users of the product and the people involved in production as information sources.

- Process management involves people and uses techniques to include people in the change and stabilisation process (Productions Operations)
- Processes are not considered in isolation but rather seen as interactive with ... people (Production and Process Technology)
- Gather information from users/people with the problem (Biotechnology)
- Interact and discuss with other knowledgeable colleagues (Biotechnology)
- In materials technology this involves understanding ...the material human association (Materials Technology)

The reliance on people as sources for information has implications for school technology practice. It may be important to develop and practise skills for recalling and using previous experience and for drawing relevant information from other people's experience.

Other sources of information included academic literature and trade catalogues. These findings confirmed the techniques identified by the expert panel technologists reported earlier in this Chapter.

7.4.7 Idea Generation

All technologists identified the importance of idea generation and identified a number of techniques. The need to express ideas in the form of speech, written form, diagrammatic form and graphical form was noted.

- Think as broadly as possible (Information and Communication)
- Brain storming, fish bone diagrams, flow process charting (Production and Process)
- Interaction and discussion with other knowledgeable colleagues, challenge each others ideas, draw diagrams, process flow diagrams (Biotechnology)
- Conflict resolution diagrams, future reality trees (Production Operations)

7.4.8 **Modelling / Simulating / Prototyping**

All technologists stressed the importance of this concept in their area. Three identified progressive modelling/simulating techniques that moved closer to the real world context. Electronics and Control identified a reality line. Production and Process Technology and Biotechnology identified laboratory scale to pilot plant. The tools and techniques identified in this area were:

- Computer software for simulation and analysis (Information and Communication)
- Equations, finite element style techniques, computer simulations (Electronics and Control)
- Flow process charts, laboratory simulation, pilot plants (Production and Process; Biotechnology)
- Future reality tree diagrams (Production Operations)

This concept has considerable implications for school technology practice. The importance of moving concepts from the head to the hand has been discussed by Kimbell (1991). The modelling techniques themselves assist in breaking the problem down into subsystems. Examples of this are flow process charts and diagrams of electronic circuits.

Further concepts involving modelling/simulations are scaling up and using progressive modelling techniques that move closer to the final context of use.

7.4.9 **Selection And Decision Making Involving Conflicting Constraints**

Selection in a situation of conflicting requirements and uncertainty was identified by a number of technologists. Selection of appropriate components was identified as important in Electronics and Control Technology. Selection of materials for a particular product that balanced the requirements of the end user, product developer and the manufacturing process was important in Materials Technology.

Decision making techniques were used to move the process towards a solution within limited time frames. This involves selecting between alternatives, including the selection of components and materials. It also includes the selection of appropriate

techniques, instruments and process, or balancing the conflict between cost and function.

- Selection of the most appropriate instrument to use in fault finding was identified (Electronics and Control).
- The key questions when selecting components – Do you need it? Does it have to move? And does it have to be made out of a different material? (Materials technology)
- Delphi decision making, matrix decision making and foresighting (Production and Process Technology)

Decision making techniques such as a majority vote are often not the most appropriate in technology practice. The use of matrix decision-making techniques in schools will encourage objective consideration of conflicting constraints and provide a means of moving the process on towards a solution.

7.4.10 **Real World Variation And Unknown Variables**

Technology takes place within a real world context and is required to deal with variation and unwanted or unknown variables. All areas identified the need to work with variation and unwanted elements or impurities.

Examples of this were:

- Noise in Information and Communication Technology and in Electronics and Control.
- Impurities in materials (Materials Technology)
- Variation and unwanted components involved in raw materials, particularly biological material (Production and Process; Biotechnology).

Recognition and ability to work with variation and impurities encountered in natural systems and still produce a standard quality product exemplifies modern technology practice (Biotechnology). The ability of students to analyse this variation and adjust processes accordingly will depend on the level of their fundamental knowledge.

7.5 CONCLUSION

The results of the individual interviews with technologists and the detail design carried out with the product development technologists were combined to develop tables identifying the detail of the organisation, information and resources elements of the model and the common techniques used by technologists in their practice. These tables provide a general outline of knowledge, concepts and skills that are common across all the technological areas. Variation on emphasis may apply to particular groups of technological areas as students study at higher levels of the curriculum, but the basic structures are likely to remain. Table 7.7 lists the detail of the organisation, information and resources elements of practice. Table 7.8 lists the common techniques used by technologists.

Table 7.7 Organisation, Information & Resources Elements

Organisation & Management	Information	Resources
<i>The process of development</i>	<i>Context</i>	<i>Raw Materials</i>
Steps in process	Societal norms and concepts	Data
Breaking into steps - Techniques to use	Local community attitudes and beliefs	Information
Product Development methodology	Total system – all the links in the chain	Biological
Analysis, synthesis, implementation	<i>Working Environment</i>	Non biological raw materials
Decision making	Community of practice	<i>Components</i>
Techniques to use	Goals	Industrial materials
Go No-go decisions	Organisational structures	Manufactured components
Outcomes	Technical strengths and constraints	<i>Energy</i>
Outcomes required for good decision making	<i>User</i>	For processing
Actions	Desired product attributes	For transportation
Actions needed to achieve outcomes	<i>Market</i>	<i>Capital</i>
Research - Techniques to use	Size and User groups	Space
Modelling – Techniques to use	<i>Technical</i>	Equipment
Testing – Techniques to use	Processes	Tools and instruments
Evaluation – Techniques to use	Materials – Cutting, Forming, Casting, Joining, Finishing	Working capital (Monney)
Timing	Unit operations	<i>People</i>
Techniques to use	Transportation, Heat transfer, Separating, Size reduction, Mixing	Knowledge
<i>People involved in the project</i>	Components	Energy and enthusiasm
Communication - Techniques to use	Info & Com – Transmitters, Communications channels, Receivers, Amplifiers	Creativity and risk attitude
Decision making – Techniques to use	Electronics – Macro blocks, Micro blocks, components	<i>Infrastructure</i>
Users	Instrument/machine use	Communication
Advisors & Researchers	Material properties	Energy
<i>Information</i>	<i>Raw material</i>	Transport
Collecting – Techniques to use	Availability, Properties, Variation, Environmental impact	
Analysing – Techniques to use	<i>Statutory</i>	
Communicating - Techniques to use	Standards & Regulations	
<i>Resources</i>	Local body planning	
Resource needed in process of development	<i>Formal</i>	
Selection – Techniques to use	Fundamental principles	
Acquirement	Research reports	
Transportation	<i>Methodologies</i>	
Production process	For: Modelling, Simulating., Prototyping	
Acquirement	Testing	
Monitoring for required standard	Fair test	
Product launch & marketing	Researching, Evaluating	
<i>Capital</i>	Managing	
Space	<i>Past Experience</i>	
Equipment	Note books	
Working capital	Case studies	

Table 7.8 Technique Categories

Consumer info. Collection	Technical info. Collection	Modelling Prototyping Simulating	Testing	Problem solving	Evaluation	Instrumentalities	Management	Implementation	Information Adaptation
<p><i>Primary sources</i> Talk to users Interview users Survey users Observe</p> <p><i>Secondary sources</i> Published statistics Literature</p> <p><i>Analysis</i> Summarising Tabulating Graphing Statistical analysis</p>	<p><i>Information Search</i> Talk to experts Scientific info. Patents Govt regulations Commercial information Component information</p> <p><i>Experimental research</i> Ad hoc experiments Experimental design Raw material variation Risk analysis</p> <p><i>Analysis</i> Summarising Tabulating Graphing Statistical analysis</p>	<p><i>Abstract Verbal</i> Describing</p> <p><i>Graphical</i> Sketches Product drawings Flow charts Diagrams</p> <p><i>Mathematical</i> Equations Budgets Financial Mass balances Energy balance Computer Simulation software</p> <p><i>Physical</i> 3D models Mock ups Ergonomic models Pilot plants</p>	<p><i>Product Testing</i> Technical testing Concept testing Material testing Nutritional testing Use and disposal testing</p> <p><i>Safety Testing</i> Testing for contaminants Process safety HAACP Structural safety</p> <p><i>User Testing</i> Sensory panels Shelf life testing User acceptance</p> <p><i>Process Testing</i> Bench scale experiment Yield tests Variables control testing Optimisation testing</p> <p><i>Environmental Testing</i></p> <p><i>Social Impact Testing</i></p>	<p><i>Problem Definition</i> Identify problem boundaries Compare with case studies Discuss with people Recall personal experience</p> <p><i>Problem Analysis</i> Identify subsystems Break problem down Unit operations Macro blocks Procedures</p> <p><i>Idea Generation</i> Brainstorming Mindmapping Drawing and sketching Cause and effect charts Discussion Scenario writing</p> <p><i>Decision making</i> Matrix screening Matrix decision making Feasibility studies Delphi decision making</p>	<p><i>Context</i> Accepted ideas Accepted values Constraints</p> <p><i>Working Environment</i> Strengths Constraints Resources</p> <p><i>Market</i> Who will use the product Review survey</p> <p><i>Production</i> Yield analysis Quality variation Optimisation analysis Production staff evaluation</p> <p><i>Financial</i> Budgets Rates of return Financial risk evaluation</p> <p><i>Marketing</i> <i>Impact</i> Environmental External stake holder groups Internal stake holders</p>	<p><i>Tool use</i> Modelling tools Hand tools</p> <p><i>Machinery use</i> Power tools Machinery</p> <p><i>Equipment use</i> Testing Measuring</p> <p><i>Instrument use</i> Laboratory equipment</p>	<p><i>Context</i> Planning Goal setting Monitoring and control</p> <p><i>Project</i> Pert Charts Flow charts Financial Budgets Cash flows Time Gant Charts</p> <p><i>Personnel</i> Meeting procedures Goal setting Supervision and support Training Monitoring</p> <p><i>Information</i> Collection Storage Retrieval Presentation</p> <p><i>Production</i> Control of variation</p> <p><i>Marketing</i></p>	<p><i>Production</i> Material selection Unit operation selection Optimisation Control systems Optimising control systems <i>Marketing</i> <i>Product Launch</i> Test market Service networks Price Promotion Place</p> <p>Post launch evaluation Use evaluation</p>	<p><i>Reorganising</i></p> <p>Charts Tables</p> <p><i>Reconstruction of</i></p> <p>Recording observations & testing results</p> <p><i>Recontextualisin</i></p> <p>Applying scientific principles in context</p>

Tables 7.7 and 7.8 summarise the outcomes from the detailed model development research into a structure that can be utilised in school technology education. These two tables provide a further level of detail to the elements of technology practice that centre on the technologist. However, not all the detail for each subcategory was identified and further research will be required to identify this and adapt the information in the tables for use in schools. When working within the organisation, information or resources element, technologists will apply techniques from the technique categories identified in Table 7.8.

The basic model can be used to teach the generic concepts and activities of technology practice common to all technological areas identified in the New Zealand curriculum statement. The inclusion of details for each element allows the model to be used to teach technology practice at more advanced levels of the curriculum, building on common structures of concepts and activities involved in technology practice.

The final model details were combined with the expanded model described in section 5.4 to complete the initial prototype of a model of total technology practice. These two tables achieve the second aim of the research - to identify the techniques, knowledge and actions associated with the elements of practice.

The individual interviews with technologists identified common knowledge and concept structures across the various technological areas. The detailed knowledge involved in these structures became more specific and focused depending on the depth of study and complexity of practice in individual technological areas. These results provided a basis for a proposed structure for technological knowledge and concepts discussed in Chapter 8.

CHAPTER 8. DISCUSSION AND CONCLUSION

8.1 INTRODUCTION

This project was a preliminary study that used the first stages of the product development process to investigate the development of a model of total technology practice that communicated the generic elements of practice and the associated knowledge and technological concepts used by practising technologists. The findings of the study are intended to add to the pool of technology perspectives from which a robust and durable essential learning area might emerge (Goodson, 1983; Teagust, 1990)

This project had four aims:

- To identify the generic elements of total technology practice.
- To identify the techniques, knowledge and actions associated with these elements.
- To propose a structure for the technological knowledge and technological concepts involved in total technology practice.
- To develop a model for use in New Zealand schools, that communicates effectively the knowledge and technological concepts of total technology practice.

The study identified a simplified structure of seven elements to describe technology practice and developed a model to communicate these elements and their interrelationship. This model took a holistic, total technology approach in which moral and ethical issues were included as part of technology practice (Mitcham, 1995). Practising technologists identified these elements and verified their accuracy and effectiveness in describing their practice. The initial investigation was carried out without considering the curriculum statement and its achievement objectives in an endeavour to develop the elements of practice from a technologist's perspective. The elements of technology practice that emerged from the present study can be developed within the curriculum framework. Some of these elements are contained in the New

Zealand curriculum statement, such as society and purposeful action. However, the present study identified additional technological concepts and perspectives that are important in developing capability and empowerment in school technology, such as the extensive use of techniques and the importance of organisation.

In the process of identifying the elements of practice, it became clear that technological knowledge was intricately related to technological practice in a way that appears to differentiate technological knowledge from the knowledge of other essential learning areas. Technological techniques and basic knowledge associated with the elements of practice must be applied within a technological context in order for them to be understood and for their important tacit knowledge to develop. Although in theory, the elements of practice can be identified and the associated techniques and knowledge taught, it would be difficult for students to transfer and use this information unless it is associated with practice. Technological knowledge is reflected in action, requiring the technologist to synthesise all their relevant 'knowing' in order to implement the action. Much of the 'knowing' involved and its synthesis cannot be articulated and is therefore tacit knowledge. The present study looked at technological knowledge and its relationship to total technology practice and proposed new constructs for teaching technological knowledge and practice in New Zealand schools.

8.2 MODELS OF TECHNOLOGY PRACTICE

The literature provides a number of examples of models of technology practice and the technological or design process. The models of process (Roozenburg and Eekels, 1995; Kimbell *et al.*, 1991; Savage, 1991) provided iterative steps for developing solutions but lacked contextual influences on practice. The broader models of technology practice (Eggleston, 1992; Peters, Verhoeven and de Vries, 1989; Pacey, 1983) included contextual aspects such as the society and its organisation. Taken together these models identified steps involved in a process and also general elements of technology practice. However the model developed in the present study drew these elements together and attempted to communicate the actions of technology practice rather than steps in a process, and to place the actions within a context of influences and constraints that are part of real life technology practice. The technology practice

involved in product development described in this study identified elements such as organisation and also the extensive use of techniques not included in many of the models identified in the literature.

It was felt that none of the models addressed or incorporated in a holistic way, all the objectives of the New Zealand technology curriculum. The opportunity existed at Massey University to address these perceived deficiencies and develop a model that reflected the experience and practice of technologists involved in applied technological problem solving in a modern New Zealand industry context.

8.3 GENERIC ELEMENTS OF TOTAL TECHNOLOGY PRACTICE

The model of practice developed from this research identified seven elements of technological practice that technologists or groups of technologists bring to the development of technological solutions:

- Knowledge of their own concepts, and appreciation of others concepts of societal norms and cultural perspectives.
- Knowledge and understanding of the strengths and constraints of the working environment.
- The purposeful nature of action required to develop appropriate solutions and the procedural and conceptual knowledge involved in achieving a solution.
- Knowledge and ability to organise and manage an effective development process.
- Knowledge and an understanding of how to access and utilise information.
- Knowledge of resources, their selection and use.
- Knowledge of a wide range of techniques and skills.

These generic elements appeared to be fundamental actions practised by technologists when developing effective and appropriate solutions.

Total technology practice involves the whole process from identifying the problem or opportunity through analysis, synthesis, and implementation, to use and disposal. It involves identifying societal aspects and working within this context and the strengths and constraints of the work environment to produce a product. Technologists involved in this research identified the ability to work within an environment of conflicting

requirements and uncertainty as an important element of their technological practice. They identified the need to move the process forward to a solution and described a number of techniques used to gather information and make decisions within an environment of conflicting constraints. The elements of technology practice identified in this research were verified by technologists as generic across the range of technological areas and able to accommodate and structure the actions involved in complex technological problem solving.

Compton and Harwood (1999) defined technological practice in the following way:

“Technological Practice refers to the way in which a person or group develops technological solutions.

The perspectives of the person or group, along with different knowledge and skills, the society and environment, and the nature of the technological development itself, are all factors which work together to determine the nature of the technological practice”. (p9)

The results of the present study indicate the nature of technological practice across the various technological areas does not change significantly. If this is the general case, a more generic approach to technology practice can be developed in schools rather than the many versions influenced by a multitude of ‘factors’ indicated in the above definition. Also, the present study identifies the elements of technology practice and a structure for their interaction, both of which are not clear in the above definition.

8.4 THE TECHNIQUES, KNOWLEDGE AND ACTIONS INVOLVED IN THE ELEMENTS

The literature on technology education identified the need for students to develop an organised body of conceptual and procedural knowledge in order to be effective problem solvers in technology (McCormick, 1997; Glaser, 1993). This was confirmed by the individual interviews with technologists reported in this study. These technologists identified a wide range of techniques and conceptual knowledge used in their practice. Many of the techniques were common across the technological areas. The practice of product development technologists and students reported in this research identified the importance of procedural knowledge and the way much of this knowledge was tacit and developed through application and experience. This

observation was supported by the literature (McCormick, 1997) and confirmed the need to develop knowledge of 'when' and 'how' to apply techniques and concepts appropriately.

The elements of practice identified in this research provide an ordered and generic conceptual framework for the development of knowledge important in technology practice. Lewis (1991) identified the importance of such a framework for technology education. Results from this research indicated the knowledge and practice were common across most of the technological areas at basic levels of implementation and became progressively more specific to groups of areas and then specific technological areas as implementation occurred at advanced levels. These findings have significance for the organisation and structure of the technology curriculum in schools and may provide an effective means of making explicit the development of technological capability through the curriculum levels of achievement. These findings may also provide a structure for students to relate individual technology projects, and transfer and apply knowledge from previous experience in technology education. Tables 7.7 and 7.8 list the detailed content of the organisation, information, resources and technique elements identified in this research.

8.4.1 Social / Cultural Context

Technologists bring their own concept of societal norms and cultural perspectives to their practice (MacKenzie and Wajcman, 1993; Pacey, 1983). The examples and detailed content of the model described in this research reflect a modern New Zealand perspective on technology practice and may also reflect technology practice in many other Western countries. It is likely that the seven elements of the model could also be used to reflect an indigenous perspective of technology. The model may provide a generic framework for different ethnic worldviews of technology practice. If this were the case, a common structure to technology practice might assist students appreciate different cultural perspectives of practice and help them reflect on the current cultural norms and perspectives reflected in their practice. Further research would be required to confirm the model's effectiveness for this use.

8.4.2 The Model's Relationship To The New Zealand Curriculum

The teacher facilitator focus group stressed the importance of relating the model of total technology practice to the New Zealand technology curriculum statement. Although the teacher survey indicated the respondents felt the model related well to the curriculum statement, the focus group concerns need to be addressed.

The model format used for the New Zealand Pharmaceuticals case study and the packaging teaching unit was used to relate the three strands and learning objectives from the New Zealand curriculum statement to the elements of practice identified in this research. Table 8.1 records this relationship and demonstrates how the curriculum strands and learning objectives interact as technology practice progresses from identifying the problem to the development of a solution.

Table 8.1 The Model and the Technology Curriculum




Society		
<p>The societal context of the problem investigated –Strand A <i>Technology and Society</i> This will provide an opportunity to discuss “beliefs, values, and ethics of individuals and groups [and how they might promote or constrain” this technological development. Also how past solutions to the problem have impacted on the people involved. Expectations of users can be discussed. In the process of these discussions the aspects of practice relating to this problem or opportunity can be listed using Pacey’s headings.</p>		
<i>Cultural Aspects</i>	<i>Organisational aspects</i>	<i>Technical Aspects</i>
Attitudes Expectations Concepts associated Environmental concerns	Laws and regulations The total system and accepted conventions involved in this area.	Knowledge of technical systems. Resources. The tools and machines used.
Working environment		
<p>Strand B <i>Technological Capability</i> Discuss the strengths and constraints of the working environment and how these might impact on the development of a solution. Strand C <i>Technological Knowledge and Understanding</i> – how concepts and solutions could be communicated and the factors they could be evaluated against.</p>		
<i>Community of practice</i>	<i>Organisational</i>	<i>Technical</i>
“Code of Practice” Attitudes to creativity and risk taking.	Limitations of school timetables Classroom structures that promote creativity and goal orientated work	The equipment within the school The materials that can be used
Techniques	Purposeful Action- Decisions, Outcomes and Actions	Organisation, Information, and Resources
Strand A&B The distinctive features and common principles of how technologists work.	Strand B The application of knowledge and ideas to develop technological solutions	Strand A&B Adapt and apply knowledge and strategies Strand A The nature of technological practice
Information gathering techniques • Questioning • Surveys • Observation • Library search	Collation of criteria and constraints 	<i>Organise</i> time, paper and equipment for gathering and recording information. Decide on the <i>information</i> needed Determine what <i>resources</i> might be required and gather knowledge on these
Talk to knowledgeable people Read about the topic Question and observe Identify the functional groups involved in the product	Identify the problem 	<i>Organise</i> the collection, recording and analysis of information – organise to talk to knowledgeable people.
Discuss and reflect on the techniques and process used and new knowledge developed. Record these for future use within the community of practice.		
Management Go, No-Go Decision		
<p>Strand A & C Evaluate problem and preliminary specifications against the beliefs, values, and ethics of the technologist, users and stakeholders. Reassess the problem against the strengths and constraints of the working environment</p>		
Lists Tables User questioning	Identify criteria 	<i>Information</i> Find out what the product users want in the solution. <i>Organise</i> to collect this information

Table 8.1 The Model and the Technology Curriculum

<p>Lists Tables Diagrams</p> <p>Sketches, Drawings, Lists Brainstorming Analogies Modelling Material testing</p> <p>Strand B (AO 6a) Test ideas and strategies to select a solution</p> <p>Materials testing Testing environmental effects User testing</p> <p>Screening matrix</p> <p>3D models Processing subsystems – separating, mixing, size reduction, etc. Production subsystems - cutting, forming, joining etc. Optimising</p> <p>Technical testing Environmental testing Financial viability User testing</p> <p>Trial runs Use test</p>	<p>Preliminary Specifications</p> <p>↓</p> <p>Ideas and Concept generation</p> <p>↓</p> <p>Concept testing</p> <p>↓</p> <p>Concept screening</p> <p>↓</p> <p>Product concept specifications</p> <p>Prototype development</p> <p>Several iterations</p> <p>↓</p> <p>Prototype evaluation</p> <p>↓</p> <p>Consumer test,</p> <p>Final specifications</p>	<p><i>Information</i> – technical information</p> <p><i>Organise</i> Achievement Objective 6b <i>Information</i> Strand A Technological knowledge and understanding <i>Resources</i> - Gain knowledge about materials <i>Organise</i> testing <i>Resources</i> – acquire resources needed <i>Information</i> collection, recording and analysis</p> <p><i>Organise</i> people, time and resources <i>Information</i> on processing/production techniques <i>Resources</i> – acquire resources needed and gain knowledge about materials <i>Organise</i> testing <i>Resources</i> – acquire resources needed <i>Information</i> collection, recording and analysis</p> <p><i>Evaluate</i> against school environment. <i>Evaluate</i> against moral and ethical position</p> <p><i>Organise</i> for tests to be carried out and information collection</p>
<p>Discuss and reflect on the techniques and process used and new knowledge developed. Record these for future use within the community of practice.</p>		
<p style="text-align: center;">Management Go, No-Go Decision</p> <p>Strand A & C Evaluate the specifications and prototype against the beliefs, values, and ethics of the technologist, users and stakeholders. Evaluate the financial viability and ability to produce the product.</p>		
<p>Quality assurance techniques</p> <p>Scheduling techniques Team work techniques</p> <p>Market research techniques Organisational techniques</p>	<p>Produce the product</p> <p>↓</p> <p>Pack the product</p> <p>↓</p> <p>Distribute the product</p>	<p><i>Organise</i> material, equipment and people. <i>Information</i> on quality assurance</p> <p><i>Information</i> on packaging regulations</p> <p><i>Information</i> on how people buy and sell products. <i>Resources</i> used to get goods to the market place.</p>
<p>Discuss and reflect on the process, techniques used in developing this product Make explicit the knowledge developed by discussing and recording new knowledge both tacit and formal.</p>		
<p style="text-align: center;">Society</p>		

8.5 TECHNOLOGICAL KNOWLEDGE

Technology has been described as a form of knowledge that is dependent on technical skill and tacit knowledge (Mitcham, 1994). The knowledge is in the action (Schön, 1987) and is fundamentally tacit in nature (Leonard and Sensiper, 1998; Nonaka, Takeuchi & Umemoto, 1996). The knowledge has been codified into an extensive body of literature that Fleck (1998) called 'formal knowledge' and described as one of six components of technological knowledge.

8.5.1 Knowledge Of Subsystems

One of the most powerful techniques used by modern technologists involves the ability to break complex problems into smaller more manageable parts (Pursell, 1994). McCormick (1997) expressed the need for students to be taught *how* to do this. The present study identified a mechanism used by technologists for reducing complex problems into manageable parts.

Technological knowledge is organised and structured in ways that reflect application in a practical context (Glaser, 1993; Layton, 1993). The technologists involved in this study appeared to construct their knowledge around the subsystems involved in their practice. In this way their accumulated tacit knowledge and codified or formal knowledge was organised in the most effective structure for problem solving and application. The knowledge structure was used to frame the problem in a way that allowed systematic investigation and experimentation. The subsystem constructs used by these technologists have been developed through experience over time and formalised within communities of practice. This confirms Schön's (1987) observation that professionals develop the ability to 'see', in unfamiliar or poorly understood problems, similarities and principles from previous experience and knowledge.

The acquisition of an appropriate knowledge base is an important requirement for effective problem solving (McCormick, 1997; Hennessy and McCormick, 1994; Glaser, 1993). The technologists interviewed in the present research confirmed this, and identified knowledge of fundamental principles as essential in technology problem solving. These interviews also confirmed that much of the practice of technology involved knowledge from experience and in many cases involved the

selection of available solutions rather than reinventing solutions to problems that have already been adequately resolved. This confirmed Court's (1997) conclusion that much mechanical design relied very little on problem solving techniques, but rather on the depth of knowledge and experience of the engineer.

The subsystems appeared to provide the structure for organising *all* the associated knowledge involved in synthesising 'knowing' and implementing the solution. This included knowledge of human, ethical and environmental considerations, related to the subsystem or product. Information from other subject areas was also reorganised and combined with technological information using the accepted subsystem structure, confirming Layton's (1993) conclusions that scientific knowledge is repackaged, reconstructed and recontextualised when used to inform technology practice.

The seven technological areas identified in the curriculum statement may be combined into three groupings according to the subsystems associated with technology practice. In this way, the knowledge structures involved in technological areas associated with process technology such as biotechnology, food technology and materials extraction and processing, all share unit operations as the primary structure of knowledge. Examples of basic unit operations identified in this research were separation, mixing, size reduction, heat transfer, transport, and fluid flows. Each unit operation represents an identifiable process sub-system involving inputs, a change outputs and also the related process of chemical and biological reactions. The technologists in this research used common methods across these subsystems to measure and track the material and energy involved in process subsystems. Examples of these methods were materials balances and energy balances that are applied to each sub-system and used to select and optimise the process (Gawith 1997b).

Production technology, associated with materials, involve subsystems such as cutting, forming, casting, extruding, weaving, joining, and finishing. Again technological knowledge is organised around each subsystem so technologists are able to select and problem solve from an applied and appropriate knowledge base. The principles and knowledge of subsystems can cross technological areas. For

example the techniques and knowledge involved in the extrusion of metals and plastics have been applied in the food processing industry for extruding cereals.

In structures the subsystems include pillars, beams and arches. Common concepts across these are stress and strain. In mechanisms, the subsystems include cogs, rods, levers, cams and pulleys. Further research will be required to identify and organise these important subsystem groups.

These basic subsystems appear to provide a structure for technological knowledge development. Initially recognition that systems can be divided into subsystems and named or codified may be the starting point. For example, in the process of cleaning clothes, removing the dirt from the clothes and drying the clothes could both be identified as a unit operation called separation. A variety of separation techniques could then be explored, such as spinning, squeezing, wringing, blowing hot air through the clothes, or letting the sun and wind do the job. Each technique will have advantages and disadvantages. The same unit operation concepts could be applied to sophisticated separation processes involved in the dairy industry for removing water from milk, such as evaporation of milk, and spraydrying of milk.

As the student moves through school and tertiary education further subsystem groups and techniques will be added with a greater depth of knowledge, both formal and tacit. The subsystems groups may also offer a means of reducing the number of technological areas at the senior school level by combining technological areas according to their common subsystems, resulting in more manageable groupings that could be taught and assessed.

8.5.2 Knowledge Development

Codified or explicit knowledge must be tacitly understood in order to be used in technology practice (Nonaka, Takeuchi & Umemoto, 1996; Polanyi, 1969). Nonaka and Konno (1998) described a spiral process of knowledge development involving internalising, using and developing tacit knowledge, externalising this into explicit knowledge, and finally, combining the explicit knowledge of the group in order to repeat the spiral of knowledge creation. This process of technological knowledge development ensures practice is informed by formal knowledge in ways that are

relevant and applicable to the problem and context. The new knowledge and understandings are 'attached' to the subsystem or problem being worked on. This knowledge may then be made explicit and added to the formal knowledge structure for the subsystem involved.

In this research the technologists identified interaction with people as important in acquiring information and understanding the problem and its context. Interaction and discussion, with knowledgeable colleagues and the people with the problem, was identified as important in developing knowledge and generating concepts for solutions. These findings appear to support the process of knowledge development described by Nonaka *et al.* (1998) and have implications for the teaching of technology education.

The practical application of knowledge and ideas to develop technological solutions is described by the curriculum statement as central to technology education. This research provides a preliminary study of the conceptual and procedural technological knowledge involved in achieving technological capability.

8.6 THE MODEL'S APPLICATION TO TECHNOLOGY TEACHING IN NEW ZEALAND SCHOOLS

The model appeared to have a number of applications to teaching. These included the use of the model as a tool for planning technology. In a school context, the model could be used to structure the development of knowledge and its transfer from other subject areas. It also provides a way of organising and communicating the knowledge and actions involved in technology practice. Teachers involved in this research study indicated the model provided a useful structure for planning teaching units. The seven elements appear to be generic across all the technological areas and may provide a useful common structure for planning and assessment of practice.

Technology education will require a different way of constructing knowledge. Technological knowledge is intricately bound with its application within specific contexts and combines empirical experience with knowledge and skills from a wide

range of subject areas. The knowledge structure can be based around the functional groups defined and accepted by technologists. Within this structure there is potential for structured progression of knowledge development and clear application to the technological world surrounding students.

Such a structure may start with young children recognising subsystems such as cutting and joining when producing an artefact, or separation and mixing when involved in a process. Recognition that actions can be divided into subsystems allows further study of the subsystem and consideration of alternative ways of achieving the result. For example, when joining, students could use glue, staples, or sellotape. These methods could be experimented with and knowledge developed on the various properties of each, how they might function in various environments (such as wet conditions) and how people perceive the look and feel of each method. Now faced with the problem of joining two materials, students have an appropriate knowledge base on which to evaluate the problem and consider possible solutions. It is likely this knowledge structure, developed at lower primary, can be built on in increasing complexity through schooling and form the foundation for senior secondary school and tertiary study in technology.

This knowledge structure along with the elements of technology practice may provide an effective construct for planning progression and assessing technology practice. Further research will be required to test this hypothesis and identify the important subsystems and how they could be developed through the school curriculum.

The elements of technology practice and the concept of subsystems may be a practical and effective structure for studying the way technologists work and how problems have been solved in the past and for present day products. The New Zealand technology curriculum statement places considerable emphasis on exploring technological principles and systems but gives little indication of how this can be done in a structured and progressive way. This study endeavoured to make the knowledge structure associated with technology practice explicit. This knowledge structure extends beyond an empirical approach to practice to include a multidisciplinary methodological approach involved in modern technology practice. If this knowledge is not identified and taught, school technology will be restricted to a

craft approach, which it can be argued, will not empower or equip students for life in a technological world.

8.7 LIMITATIONS OF THIS STUDY

This preliminary study of total technology practice was based on a limited population of technologists working within a University context. The concepts and understandings developed were not generalised with technologists in industry and should be treated as a limited case study. This study identified the general elements of technology practice and the likely way in which technologists structure their knowledge. Further research will be required to construct the detailed knowledge involved in each element and how this can be developed progressively through schooling.

The model evaluation was based on consumer research techniques and while adequate for assessing user responses in terms of concept development, further research will be required to test the effectiveness of the model in schools when used by teachers, and then in the classroom with children.

The model detail and concepts reflected a New Zealand perception of technology practice and cultural norms. This may limit the application of the elements of practice involved in the model to different cultural contexts. Further study will be required to evaluate the effectiveness of the model for portraying different cultural approaches to technology practice.

8.8 CONCLUSION

This project showed that total technology practice could be structured using seven generic elements that together provide a simplified description of technology practice. The elements of practice associated with the human context and goal of technology practice were identified as society, the work environment, and purposeful action. The elements technologists bring to the context were organisation, information, resource use knowledge and skills, and an extensive knowledge of techniques and the skill,

ingenuity and experience to apply and adapt techniques to specific contexts and problems.

These elements and the way they interact can be communicated in the form of a structured model of total technology practice. The study indicated teachers perceived the model as a useful tool for communicating technological practice, knowledge and understanding, and for structuring teaching units in technology education. The model of technology practice with its seven elements provides a generic structure for teaching technology education in New Zealand schools. This structure can be used to combine the eleven achievement objectives, seven technological areas, and nine contexts outlined in the curriculum statement into a generalised concept of technology practice that can be introduced at level one of the curriculum and built up through the following eight levels.

The development of technological knowledge is central to modern technology practice and is based on knowledge of fundamental principles and their practical application. Technological knowledge combines tacit knowledge of application and use with explicit codified knowledge built up by communities of practice and informed by science, mathematics and social science. Technologists structure this knowledge into the subsystems that make up the products and processes of the technological world they study. This structure allows knowledge from a multitude of disciplines and life experience to be transferred and used to inform technology practice.

The New Zealand technology curriculum requires students to achieve technological knowledge and understanding, technological capability, and an understanding of the relationship between technology and society across seven different technological areas and in several different contexts. Without a generic structure of technological knowledge and practice, the student will find it increasingly difficult to relate technology practice between the seven technological areas and transfer understanding from these and from other subjects, as he or she moves up the eight levels of the curriculum. This preliminary study has identified a structure for technology practice and technological knowledge that is common to all seven technological areas and nine contexts identified in the New Zealand technology curriculum.

BIBLIOGRAPHY

- Agassi, J., 1997. Thought, Action and Scientific Technology. *International Journal of Technology and Design Education*, 7; 33-48.
- Akin, O., & Akin, C., 1996. Frames of reference in architectural design: analysing the hyperacclamation (A-h-a!). *Design Studies*, 17 (4); 341-361.
- Anderson, G., 1990. *Fundamentals of Education Research*. The Falmer Press, London.
- Bijker, W. & Law, J., (eds) 1992. *Shaping Technology/ Building Society: studies in sociotechnical change*. MIT press, Massachusetts.
- Burns, J., (ed.) 1997. *Technology in the New Zealand Curriculum – Perspectives on Practice*. Dunmore Press, Palmerston North.
- Burns, J., 1993. *Empowerment through technology education: The need for a historic focus*. Paper presented to NZARE, Hamilton.
- Chant, C., (ed.) 1989. *Science Technology and everyday Life 1870 - 1950*. Routledge, London.
- Cohen, D., 1998. Toward a Knowledge Context: Report on the First Annual U.C. Berkeley Forum on Knowledge and the Firm. *California Management Review*, 40 (3) Spring; 22-39.
- Compton, V. & Harwood, C., 1999. *TEALS Research Project: Starting Points and Future Directions*. Paper presented to the Telecom Technology Education Conference, Auckland.
- Constant II, E., 1980. *The Origins of the Turbojet Revolution*. The John Hopkins University Press, Baltimore.
- Court, A., 1997. The Relationship between Information and Personal Knowledge in New Product Development. *International Journal of Information Management*, 17 (2); 123-138.
- Cowan, R., 1993. How the refrigerator got its hum. In D. MacKenzie & J. Wajcman (eds) 1993. *The Social Shaping of Technology: How the refrigerator got its hum* (6th printing). Open University Press, Milton Keynes, Philadelphia; pp202-218.
- Dehejia, M., 1995. Technology Trends - Towards the Post - Information Age. In *United Nations Industrial Development Organisation: 30 Years Of Industrial Development 1966 – 1996*, International Systems and Communications Ltd., London; pp 232-243.
- Earle, M., 1971. *The Science of Product Development and Its Application to the Food Industry*. Readings in Food Technology, Massey University, Palmerston North.

- Earle, R., 1997. *The Practice of Technology: What technologists do and how they do it*. Paper presented to the Telecom Technology Education Conference, Christchurch.
- Earle, R., 1999. *New Zealand Pharmaceuticals: A Study in Collaborative Industrial Development*. In print.
- Earle, M., & Earle, R., 1999. *Creating New Foods: The Product Developer's Guide*. Chandos Publishing (Oxford) Ltd., Oxford.
- Eggleston, J., 1992. *Teaching Design and Technology*. Open University Press, Buckingham.
- Fleck, J., 1997. Contingent Knowledge and Technology Development. *Technology Analysis & Strategic Management*, 9 (4); 383-397
- Fleck, J., 1998. Expertise: Knowledge, Power and Tradability. In R. Williams, W. Faulkner & J. Fleck, (eds) *Exploring Expertise: Issues and Perspectives*. Macmillan, Basingstoke.
- Gawith, J., 1997a. *The Practice of Technology: What technologists do and how they do it*. Paper presented to the Telecom Technology Education New Zealand conference, Christchurch.
- Gawith, J., 1997b. Teaching Technology: The need for balance. *Network Voice; New Zealand's Magazine for Technology Education*, 1; 30-31.
- Gawith, J., 1996. *Technology Practice*. Unpublished paper, Massey University, Palmerston North.
- Gawith, J. & Robertson, T., 1999. *Wrapping up Packaging Technology*. Paper presented to the Telecom Technology Education New Zealand conference, Auckland.
- Glaser, R., 1993. Education and Thinking: The Role of Knowledge. In R. McCormick, P. Murphy & M. Harrison, *Teaching and Learning Technology*, Addison-Westley, Workingham, England; pp 91-111.
- Goodson, I., 1983. *School Subjects and Curriculum Change*. Croom Helm, London.
- Gordon, W. & Langmaid, R., 1988. *Quantitative Market Research – A Practitioner's And Buyers Guide*. Gower Publishing Co., England.
- Hanson, R., 1997. The Value of a Utilitarian Curriculum: The Case of Technology Education. *International Journal of Technology and Design Education*, 7; 111-119.
- Hennessy, S. & McCormick, R., 1994. The general problem-solving process in technology education. Myth or reality? In F. Banks, *Teaching Technology*, Routledge, London; pp 94-108.

- Hughes, T., 1993. Edison and electric light. In D. MacKenzie & J. Wajcman, (eds) 1993. *The Social Shaping of Technology: How the refrigerator got its hum* (6th printing). Open University Press, Milton Keynes, Philadelphia; pp39-52.
- Johnson, S., 1997. Learning Technology Concepts and Developing Intellectual Skills. *International Journal of Technology and Design Education*, 7; 161-180.
- Jones, A., 1997. Technology Education in the New Zealand Curriculum. In Burns, J., (ed.). *Technology in the New Zealand Curriculum – Perspectives on Practice*. Dunmore Press, Palmerston North; pp 46-59.
- Kemmis, S. & McTaggart, R., 1989. *The Action Research Planner*. 3rd Ed. Deaken University Press, Victoria.
- Kimbell, R., 1991. Tackling technological tasks. In B Woolnough, (ed.). *Practical Science*. Open University Press, Milton Keynes; pp138-151.
- Kimbell, R., Stables, K., Wheeler, T., Wosniak, A. & Kelly, V., 1991. *The Assessment of Performance in Design and Technology*. School Examinations and Assessment Council, London.
- Kotler, P. & Armstrong, G., 1997. *Marketing : an introduction*. Prentice Hall, New Jersey.
- Kvale, S., 1996. *InterViews: An Introduction to Quantitative Research Interviewing*. SAGE Publications, London.
- Layton, D., 1993. *Technology's challenge to science education*. Open University Press, Buckingham.
- Leonard, D. & Sensiper, S., 1998. The Role of Tacit Knowledge In Group Innovation. *California Management Review*, 40 (3) Spring; 112-132.
- Lewis, T., 1991. Introducing technology into school curricula. *Journal of Curriculum Studies*, 23 (2); 141- 154.
- Link, H., 1998. Advances in the Philosophy of Technology: New Structural Characteristics of Technologies. *Society for Philosophy and Technology*, 4 (1) [Online] Available: http://scholar.lib.vt.edu/ejournals/SPT/v4_n1html/LENK.html [1997].
- MacKenzie, D. & Wajcman, J., (eds) 1993. *The Social Shaping of Technology: How the refrigerator got its hum* (6th printing). Open University Press, Milton Keynes, Philadelphia.
- McCormick, R., 1990. Technology and the National Curriculum: the creation of a subject 'by committee? *The Curriculum Journal*, 1 (1); 39- 51.
- McCormick, R., 1997. Conceptual and Procedural Knowledge. *International Journal of Technology and Design Education*, 7;141-159.

- Ministry of Education, 1995. *Technology in the New Zealand Curriculum*. Learning Media, Wellington.
- Mitcham, C., 1994. *Thinking Through Technology: The Path between Engineering and Philosophy*. The University of Chicago Press Ltd., Chicago.
- Mitcham, C., 1995. Notes Towards a Philosophy of Meta-technology. *Society for Philosophy and Technology*. 1 (1&2). [Online] Available: http://scholar.lib.vt.edu/ejournals/SPT/v1_n1html/LENK.html [1995].
- Nonaka, I. & Konno, N., 1998. The Concept of "Ba": Building a Foundation for Knowledge Creation. *California Management Review*, 40 (3) Spring; 40-54.
- Nonaka, I. & Takeuchi, H., 1995. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. Oxford University Press, Oxford.
- Nonaka, I., Takeuchi, H. & Umemoto, K., 1996. A theory of organisational knowledge creation. *International Journal of Technology Management, Special Publication on Unlearning and Learning*, 11, (7/8); 833-845.
- Pacey, A., 1983. *Technology: Practice and Culture, The Culture of Technology*. Blackwell, Oxford.
- Pacey, A., 1992. *The Maze of Ingenuity: Ideas and Idealism in the Development of Technology*. The MIT Press, Cambridge.
- Peters, H., Verhoven, H. & de Vries, M., 1989. Teacher training for school technology at the Dutch Pedagogical Technology College. Cited in: D. Layton, 1993. *Technology's challenge to science education*. Open University Press, Buckingham.
- Polanyi, M., 1969. *The logic of Tacit Inference, Knowing and Being*. Routledge & Kegan Paul, London.
- Pursell, C., 1994. *Whiteheat – People and Technology*. University of California Press, Berkeley.
- Reber, A., 1985. *The Penguin Dictionary of Psychology*. Penguin Books, London.
- Roozenburg, N. & Eekels, J., 1995. *Product Design: Fundamentals and Methods*. John Wiley & Sons, Chichester.
- Ropohl, G., 1997. Knowledge Types in Technology. *International Journal of Technology and Design Education*, 7; 65-72.
- Savage, E., 1991. Determinants of Advanced Technological Content in Technology Education Curriculum. In M. Hacker *et al.* (eds), 1991. *Integrating Advanced Technology into Technology Education*. NATO ASI Series, 78. Springer-Verlag, Berlin; pp 21-39.
- Schön, D., 1983. *The Reflective Practitioner*. Basic Books, New York.

- Schön, D., 1987. *Educating the Reflective Practitioner*. Jossey-Bass Inc., California.
- Senker, J., 1998. The Contribution of Tacit Knowledge to Innovation. In R. Williams, & W. Faulkner, & J. Fleck, *Exploring Expertise: Issues and Perspectives*. Macmillan Press Ltd., London; pp 223-244.
- Simon, H., 1981. *The Sciences of the Artificial*. MIT Press, Cambridge. Cited in C. Mitcham, 1994. *Thinking Through Technology: The Path between Engineering and Philosophy*. The University of Chicago press, Ltd., Chicago.
- Staudenmaier, J., 1985. *Technology's Storytellers Reweaving the Human Fabric*. Massachusetts: MIT Press, Cambridge.
- Teagust, D., 1990. Integration of technology in the school curriculum. *Research in Science Education*, 20; 272-281.
- Teece, D., 1998. Capturing Value from Knowledge Assets: The New Economy, Markets for Know-how, and Intangible Assets. *California Management Review*, 40 (3) Spring; 55-79.
- Ulrich, K. & Eppinger, S., 1995. *Product Design and Development*. McGraw-Hill, Inc., New York.
- Vincenti, W., 1990. *What Engineers Know and How They Know It: Analytical Studies from Aeronautical History*. The John Hopkins University Press, Baltimore.
- Vries, M. de & Tamir, A., 1997. Shaping Concepts of Technology: What Concepts and How to Shape Them. *International Journal of Technology and Design Education*, 7; 2-10.
- Vries, M. de, 1997. Science, Technology and Society: A Methodological Perspective. *International Journal of Technology and Design Education*, 7; 21-32.
- Walker, D., Dagger, B. & Roy, R., 1991. *Creative Techniques in Product and Engineering Design*. Woodhead Publishing Ltd., Cambridge.

APPENDICES

Appendix 1 Expert Panel Data – Information Gathering Techniques

ANALYSIS					
ET5	ET3	ET4	ET8	ET2	ET1 & 6
P & I Diagrams	Import Data – Trade data, market size	Literature – Previous projects, Cookbooks, Journal, Trade Magazine, Textbooks, Catalogues, Patents, Government data Consume lit., Market lit., Technology process, Product, Packaging.	Focus groups	Survey	Library – statistics, theses, journals, books, tech reports
Plot Trend data	Export data	Surveys – Consumer, final industrial, export, target groups, expert groups	Surveys	Case study	www – search, group membership
Interview with plant operators	Chemical abstracts – patents, literature Reviews	Focus groups,	Interviews – Market, staff	Client consultation	Patents
Group Decision		Consumer panels	Personal communication Library	Legislation search	Interviews
Basic equations - applying	Journals	Market Information – Serveys, market size, retail studies, purchase sales data, Coffee/talking, Government		Review of past work	Anecdotal information
	Discussion with knowledgeable people Picking other peoples brains		www	Similar product analysis	Questionnaires, surveys
			Computer based information – Encata etc	Reverse engineering	Supplier catalogues
				Hire an expert/consultation Financial analysis	Plant visits
				Catalogue and product review	Networks - through prof. Societies and less formal
				Data hand books	Legislation /codes
				Read texts Search for papers and reports Ethical issues Library search	Conferences C.P.D. opportunities Popular press Mentors/ consultants

SYNTHESIS

ET5	ET3	ET4	ET8	ET2	ET1 & 6
Dynamic equations – variables and relationships	Feasibility study in terms of tonnage of raw material, etc	Concept testing	Brainstorming	Review of other approaches	Textbooks
Steady state simulations	Feasibility study – paper exercise	Economic evaluation	Delphi decision making	Analyse critical success factors from other solutions	Software
Simulations – comparison with plant data	Flow charts - several		Fishbone – (Ishikawa)	Case studies	Codes of practice
	Yields		Mind mapping – (Buzan)	Simulations	Design aids
	Will it work?		Cause and effect charts	Preliminary specifications	Anecdotal observation
	Will it make a profit		Simulation	Testing	Technical reports
			Madelling	Design techniques eg F.E.A.	Professional body contacts
			F.P.C. (Asme standards)	Extract relevant information and summarise	Networks
				Organisational analysis	www
					Mentors

IMPLEMENTATION

ET5	ET3	ET4	ET8	ET2	ET1 & 6
Test – plant trials	Bench scale experiment to see if flow chart works – yield etc	Experimental design	Review Survey - market, production	Statistical P.C	Legislation / codes
Economic evaluation	Re-check feasibility study on updated costs	Sensory testing	Specification development	Data logging	Textbooks
		Shelf life studies	Product testing	Testing programmes	Good practice guides
			Gantt	“Reliability”	Experienced mentor
			C.P.A.	Material selection	www
				‘Talk’ to subcontractors	
				‘Talk’ to customers	
				Cost analysis	
				Human resources analysis	
				Organisational development study	

Appendix 2 Information and Communication Interview Analysis

Information and Communication
<i>What is the process used to develop solutions in your area?</i>
Problem Identification – Verify the problem is valid Think as broadly as possible Experimenting to get a feel for the issues that might arise Specify as accurately as possible the inputs and outputs and any constraints
<i>Identify the tools and techniques used in your area</i>
Software and hardware Broad thinking – rely on experience and knowledge of subject To teach this – as a supervisor suggest other techniques
<i>What are the important concepts involved in the practice of technology in your area?</i>
Bottom up top down design – components up – global view Yes basic concepts of the discipline itself – entropy, bits of information, transforms, noise, communications channels transmitter, receiver, transformers filters (separating) Noise related to all specialisms in the area. Concept of black box – used if want to keep contents hidden in order to simplify the description Concept of model Laws of thermodynamics
<i>Can you say about organisation</i>
money, equipment, access to information (journals etc) Information from other people Define the problem correctly Good communication with the user
<i>What is the knowledge involved with this area?</i>
!!! Huge knowledge base implicit in the subject. When it comes to application other knowledge is needed ie. Knowledge of the context How is this Knowledge stored? In machine vision – depends to a large extent on what the practitioner carries in their heads. Like Lawyers carry case study knowledge in their heads Knowing that case studies in the past have been solved Knowing these are there and knowing how to look it up Industry standard – constrain practice – N.Z. standard based on international standards
<i>What are the resources involved in the area?</i>
Time People Research hardware Computer software for simulation and analysis
<i>What are the raw materials used?</i>
Mostly intangible. Data generated from objects Input storage and output
The themes were tied together in a descriptive statement
Identify the problem as accurately as possible. Think as broadly as possible using your own experience and knowledge. Knowledge of appropriate case studies are important along with knowledge of the basic principles involved.

Have an overview at all times but break the problem down to the component level and work from this base – bottom up, top down design. Communicate and gather information from other people, particularly the user.

Concepts involved in the area are:

Entropy

Bits of information

Transforms

Noise

Communications channels

Transmitter

Receiver

Transformers

Filters

Laws of thermodynamics

Tools and Techniques involved in the area:

Black box

Reducing complex systems to components

Modelling

Software tools

Hardware/instruments

Appendix 3 Materials Technology Interview Analysis

Materials Technology
<i>What is the process used to develop solutions in your area?</i>
Have an understanding of the market, the customer needs and the quality requirements. Then the process of manufacture, process and assembly. Material selection is considered at many stages of the product development process from identifying the problem and the users of the product through manufacturability to use and disposal. Must consider functional as well as aesthetic properties of material
<i>Identify the tools and techniques used in your area</i>
Decision making technique when dealing with components Do you need it? Does it have to move? Does it have to be made out of a different material? In materials technology there are two areas of techniques, those associated with material production from raw materials; and processing of materials into products. This group can be divided into Cutting, Forming, Casting, Joining, Finishing. Selection of materials involves calculating material strength and product strength. Material properties, particularly strength become more important as context becomes more demanding. (Fundamental theory becomes more important). There are computer programmes and texts to assist in material selection. Problem solving techniques are used a lot.
<i>What are the important concepts involved in the practice of technology in your area?</i>
Optimising, reducing the number of components, selecting the most appropriate material. The physical properties of materials (engineering properties). Understand how materials react in an environment. The final form and function. Knowing how to transform the material Concept of selecting material Environmental issues in extraction, transformation, use and disposal of materials.
<i>What is the knowledge involved with this area?</i>
Need to understand the properties of your materials Fundamental principles
<i>Resources involved</i>
Raw materials Money is important resource
Descriptive Statement
Technologists are involved in developing real world products and must understand and maintain an overview of the whole process from problem identification to marketing. In materials technology this involves understanding how materials react in an environment, how these materials are extracted and transformed into products and the material human association. This requires knowledge of material properties and fundamental principles.
<i>Concepts involved in the area are:</i>
Optimisation Material properties Material selection Interaction with environment Product form and function Material transformation

Environmental issues in extraction, transformation, use and disposal
--

<i>Tools and Techniques involved in the area:</i>

Decision making techniques

Material extraction and production

Material processing

Cutting

Forming

Casting

Joining

Finishing

Material properties

Material selection

Appendix 4 Electronics and Control Interview Analysis

Electronics and Control
<i>What is the process used to develop solutions in your area?</i>
<p>The process depends on the nature of the problem. If the development of an instrument then need to identify the specifications.</p> <p>Uses the product development process. Extensive use of simulation in modern practice.</p> <p>Ensuring you have identified the problem is important. Sometimes people with the problem can't always do this well enough. Use your knowledge of the fundamental principles to identify the problem accurately.</p> <p>Sometime start with equations but more frequently jump to simulation at macro block level. Start at an empirical level</p>
<i>Identify the tools and techniques used in your area</i>
<p>Simulation tools –</p> <p>Equation level – difficult to add real world constraints.</p> <p>Fired element style techniques which brake up into blocks.</p> <p>Real world processes are not linear and most techniques use linear techniques. Models tend to move closer and closer to real world. Reality line. Several stages of simulations that get closer to the real world situation.</p> <p>Use experimental design techniques</p> <p>Fault finding procedures – still a bit of an art form. Are some basic tools</p> <p>Have to have a knowledge of the instrumentation.</p> <p>Selection of appropriate instruments.</p> <p>First thing to look for is dry joints.</p> <p>Generic, standard techniques to find faults.</p>
<i>What are the important concepts involved in the practice of technology in your area?</i>
Noise in electrical circuits
<i>What is the knowledge involved with this area?</i>
Descriptive Statement
<p>A technologist is a person with practical skills and a broad theoretical knowledge who has the ability to apply theory as a tool among others, for solving problems and developing solutions. Identification of the problem is important and may require the development of an instrument or solution to a problem. A knowledge of fundamental principles is important in identifying the problem accurately. In developing a solution, frequently use an empirical approach and simulate concepts at a macro block level.</p>
<i>Concepts involved in the area are:</i>
<p>Can break a complex product/solution down into levels of components. Macro blocks - ?? – components...</p> <p>Instrumentation knowledge and selection of appropriate instruments.</p> <p>Reality line in modelling and simulating the real world context</p> <p>Noise in electrical circuits</p>
<i>Tools and Techniques involved in the area:</i>
<p>Simulation tools</p> <p style="padding-left: 20px;">Equations, Finite element style techniques, Computer simulations</p> <p>Experimental design</p> <p>Instrumentation</p> <p>Fault finding process</p>

Appendix 5 Production and Process Technology Interview Analysis

Production and Process Technology
<i>What is the process used to develop solutions in your area?</i>
<p>Analyse the current position using a step wise process of breaking it down into its component parts – logical sequence of what is happening.</p> <p>Determine where you want to be - the end points.</p> <p>What's happening now where I want to be – Leeds to a gap analyses and by determining that, you can see what needs to be done. There is a process of development by understanding what is currently happening.</p> <p>“Gap analysis”</p> <p>Iterative process</p>
<i>Identify the tools and techniques used in your area</i>
<p>Flow process charting</p> <p>Brainstorming activities, Fish bone diagrams</p> <p>Delphi decision making, Matrix decision making</p> <p>Forsighting – standing in the future and looking back – gap analysis.</p> <p>Mathematical – material (mass) and energy balancing</p> <p>Use this to calculate the viability of a new process – yields, \$values, volumes -idea of the scale of process to achieve a commercially viable process.</p> <p>This requires laboratory scale work</p> <p>Scientific principles</p> <p>Flow process systems to unit operations,</p> <p>New process Laboratory to pilot plant to commercial operation</p> <p>Modelling – spreadsheets etc.</p> <p>Computer modelling often on existing systems –</p> <p>Errors in new process development large, therefore might waste a lot of time developing sophisticated models. Errors can be large 50%.</p> <p>Feasibility study – basic questions. Is this worth doing and proceeding with? Is this not worth progressing with? Do we need more information to clarify?</p> <p>If go or no go even with 50% error factors</p>
<i>What are the important concepts involved in the practice of technology in your area?</i>
<p>Systematically breaking processes down – 1st and most important concept.</p> <p>Deal with variables one at a time</p> <p>Knowing what each impact is going to be</p> <p>Take a complex process and systematically break it into its components so can eliminate and or improve each component</p> <p>To have an in depth understanding of the material they are dealing with</p>
<i>What can you say about organisation?</i>
<p>Project management techniques</p> <p>Identify tasks and the relationship between tasks</p> <p>Takes into account the resources needed</p>
Descriptive Statement
<p>Technologist understands the fundamental properties of the raw material they use and take account of natural variation. They take a holistic view of process that accounts for all output streams including wastes. Processes are not considered in isolation but rather seen as interactive with impacts on other things such as the environment, culture and people. Problems are identified using techniques such as ‘gap analysis. Complex processes are broken into component parts. These are arranged to convey a logical sequence.</p>

Concepts involved in the area are:

An in depth understanding of the material being processed.

Systematically breaking a complex process into component parts – unit operations.

Questioning the need for each component and/or improving its efficiency.

Knowledge and means for assessing the impact of a process.

Modelling/simulating from flow process charts to laboratory simulation, to pilot plant to commercial plants.

Scaling up

Taking and maintaining a holistic view

Accounting for all outcomes from a process – energy and mass balancing.

Tools and Techniques involved in the area:

Brainstorming

Fishbone diagrams

Delphi decision making

Matrix decision making

Forsighting

Mass and Energy balancing

Feasibility studies

Modelling

Flow process charts

Laboratory

Pilot plants

Appendix 6 Production Operations Interview Analysis

Production Operations
<i>What is the process used to develop solutions in your area?</i>
<p>Identifying the problem – What to change? What to change to? How to cause a change?</p> <p>Operation of factory -linkages between the various components influencing the process.</p> <p>Linkages between management, operators etc.</p> <p>Define the core problems –identify clearly</p> <p>Convergent to a process of defining the problem</p> <p>Identify the underlying assumptions come up with ways of changing those assumptions</p> <p>Develop a causality tree to investigate solutions and their impacts on all parts of the operation</p> <p>Looking at the negative outcomes</p> <p>Method of getting buy in from people involved</p> <p>“Change agents”</p> <p>Identifying the obstacles in putting a plan into place</p> <p>Actions to overcome the obstacles</p> <p>A plan of moving people to a new position</p>
<i>Identify the tools and techniques used in your area</i>
<p>Goldrap process</p> <p>Linkage problems</p> <p>Current reality tree technique</p>
<i>What are the important concepts involved in the practice of technology in your area?</i>
<p>Systematic approach</p> <p>Problem identification??</p> <p>Need fundamental knowledge in order to problem solve</p> <p>methodology for what is the problem there is an important first step which is defining the subject mater which is also about defining goals and necessary conditions</p> <p>Putting a box around what it is we are working on and within that being creative.</p> <p>Sometimes You have to be careful about putting a box around and defining the subject matter</p> <p>The actions technologists are involved with are planing</p> <p>Something flows through a system energy information, resources</p> <p>Understanding of dependencies</p> <p>Bottlenecks in a process</p> <p>A network of dependencies</p>
Descriptive Statement
<p>Technologists are improvement or change agents. They have fundamental knowledge, practical ability and skill to answer the questions – What is the problem? What is it we have to change? How are we going to make it happen?</p> <p>They do this through a process of analysis, synthesis, implementation and evaluation.</p> <p>Process management involves people and uses techniques to include these people in the change and stabilisation process.</p>
<i>Concepts involved in the area are:</i>

Systematic methodology

Accurate identification of the problem

Identifying the boundaries of the problem and working creatively within these.

Recognising flows within a process system – energy, information and resources.

Recognising and understanding dependencies

Identifying bottlenecks in a process and eliminate or reduce their effect.

Defining the boundaries of the problem and working creatively within these

Tools and Techniques involved in the area:

Current reality tree diagrams

Linkage diagrams

Underling assumption identification

Causality tree diagram

Appendix 7 Biotechnology Interview Analysis

Biotechnology
<i>What is the process used to develop solutions in your area?</i>
<p>Has his own personal problem solving methodology which is passed onto students by example, case studies and practice.</p> <p>Look at the literature.</p> <p>Interaction and discussion with other knowledgeable colleagues – idea generation.</p> <p>Ways of testing ideas and hypotheses.</p> <p>Gather information from users/people with the problem (this has difficulties as they do not tell you everything)</p> <p>Challenging each others ideas</p> <ol style="list-style-type: none"> 1. observe and record 2. look back on observations 3. Develop as many ideas as you can. 4. challenge each others ideas – setting up dialogue. 5. Propose hypothesis (model) 6. test hypothesis (model) 7 repeat this cycle until a solution is found <p>Problem solving is a process of trying ideas in a rational way, using your knowledge but also learning through experience. Knowledge transfer is important.</p>
<i>Identify the tools and techniques used in your area</i>
<p>Problem solving techniques</p> <p>Group discussions</p> <p>Use group interaction to force divergent thinking and wider knowledge recall and transfer.</p> <p>Drawing diagrams</p> <p>Process flow diagrams</p> <p>Lab scale model of process</p>
<i>What are the important concepts involved in the practice of technology in your area?</i>
<p>Biotechnology concerned with processing biological materials.</p> <p>Controlling this process.</p> <p>Safety of people and environment</p> <p>Limitations of biological agents.</p> <p>Biological raw materials are variable and require control to achieve a constant standard product.</p> <p>Requires a good theoretical understanding of the raw material and the process.</p> <p>Purely empirical approaches cannot maintain constant specifications and allow informed problem solving – risks modern industries cannot take.</p>
<i>What is the knowledge involved with this area?</i>
<p>In modern biotechnology, knowledge is very important.</p> <p>Fundamental theory important to problem solving ability.</p> <p>Knowledge of variation in raw material.</p> <p>Require a deep theoretical understanding of your raw material and your processing</p>
What are the resources involved in the area?
<p>Knowledge, Energy, Money</p> <p>Skilled labour, Water</p> <p>Somewhere to get rid of waste</p> <p>Factories “The thing is with biotechnology is knowledge, that is what counts”.</p>
Descriptive Statement

Technologists work in rational systematic ways using their knowledge of; fundamental theories, raw material and its variation, modern practice, and past experience. Technologists interact with people including those with the problem, but particularly with other knowledgeable colleagues in order to develop and challenge ideas.

Concepts involved in the area are:

A deep theoretical understanding of the biological raw material and its variation.

A theoretical knowledge of the process involved and how it is controlled to compensate for variation in the raw material.

Limitations of biological agents

Safety for people and environment

Tools and Techniques involved in the area:

Appendix 8 Teacher Evaluation Questionnaire

Questionnaire on the Total Technology Practice Model

This research in technology education is intended to gather information on how useful the model of technology practice will be to practising teachers and gather any suggestions for improvements.

Please do **not** put your name on this questionnaire. There will be no attempt made to identify respondents. Your participation in this survey is strictly voluntary and you should feel no compulsion to take part. You are free to not answer any particular question. When you have completed, please place your questionnaire inside the envelope provided. The results of the questionnaires will be compiled, and comments typed by an independent person to ensure anonymity. All questionnaire forms will be destroyed on completion of the research. The results of this research will be reported back to those involved.

The questions are intended to gather your views on the various aspects of the model and I would appreciate your honest and frank opinions. I would also welcome additional comments on the coloured sheet if you have any suggestions.

Most questions require a tick in the appropriate box. Where you are asked to indicate the degree of usefulness tick the most appropriate box on the five-point scale. For example: "*How useful are the University signs for finding the correct lecture room?*"

Not Useful Extremely Useful

1 What level of education do you teach at?

- Primary
 Intermediate
 Secondary
 Tertiary
 Other...

2 Do you understand the model?

- Yes
 No
 Sort of

3 Do you understand how each of the elements identified in the model interact in technology practice?

- | | | | | | | |
|-------------------|--------------------------|-----|--------------------------|----|--------------------------|----------|
| Society | <input type="checkbox"/> | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> | Think so |
| Working Context | <input type="checkbox"/> | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> | Think so |
| Purposeful Action | <input type="checkbox"/> | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> | Think so |
| Organisation | <input type="checkbox"/> | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> | Think so |
| Information | <input type="checkbox"/> | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> | Think so |
| Resources | <input type="checkbox"/> | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> | Think so |
| Techniques | <input type="checkbox"/> | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> | Think so |
| Knowledge | <input type="checkbox"/> | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> | Think so |

4 Would you use the model in your teaching?

- Yes
 No
 May Be

If 'No' please turn to the back page and comment on what is wrong with the model and what improvements you would suggest (questions 26, 27 & 28)

Use of the Model

- 5 Who would use the model?
 The teacher only
 The students only
 Both the teacher and the students
 Other...
- 6 When would you use the model?
 When planning lessons
 When discussing technology practice with students
 When introducing a teaching unit in class
 Throughout a class project
 Other...
- 7 How would you use the model?
 As a lesson planning tool
 As a teaching tool
 As a tool to encourage students to plan their technology project
 As a tool to encourage students to evaluate their practice
 Other...
- 8 How often would you use the model?
 Seldom Regularly
- 9 How often would you expect your students to use the model?
 Seldom Regularly

Communicating the Concepts

- 10 How useful is the model in communicating the concept that technology takes place within a context that will influence the products developed?
 Not Useful Extremely Useful
- 11 How useful is the model in communicating the concept that technology practice is a systematic process?
 Not Useful Extremely Useful
- 12 How useful is the model in communicating a holistic view of practice?
 Not Useful Extremely Useful
- 13 How useful is the model in communicating technological literacy?
 Not Useful Extremely Useful

Teacher Use

- 14 How useful are the elements identified in the model, for structuring the teaching of technology education?
 Not Useful Extremely Useful
- 15 How useful is the model in providing a structure to facilitate progression in

learning?

Not Useful Extremely Useful

- 16 How useful is the model to you, as an aid for planning, organising, and controlling classroom projects?

Not Useful Extremely Useful

- 17 How useful is the model for analysing case studies of technology practice?

Not Useful Extremely Useful

Student Use

- 18 How useful is the model for helping students plan, organise, and control their projects?

Not Useful Extremely Useful

- 19 How useful is the model for helping students develop a systematic process for their projects?

Not Useful Extremely Useful

- 20 How useful is the model for encouraging students to select appropriate information, skills and techniques in their project work?

Not Useful Extremely Useful

- 21 How useful is the model in assisting students develop reflective abilities in technology practice?

Not Useful Extremely Useful

Curriculum

- 22 How well does the model incorporate the following strands of the curriculum?

Technological knowledge and Understanding	Not Well	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Extremely Well
Technological Capability	Not Well	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Extremely Well
Technology and society	Not Well	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Extremely Well

- 23 How well do you think the model fits the learning objectives outlined in the curriculum statement?

Not Well Extremely Well

Practical Application

- 24 Is the model a practical tool for teaching technology education in the classroom?

Yes
 No
 May be

- 25 Do you think your students would find the model fun to use?

Yes
 No
 May be

26 What costs do you see being involved with the use of this model?

In terms of teacher time...

In terms of expense and resources...

27 What do you see is wrong with the model?

28 What improvements would you suggest?

Any other comments:

Thank you for completing this questionnaire.

Please write your comments on this sheet.

Use of the Model

Communication the concept

Teacher Use

Student Use

Curriculum

Practical Application

Thank you for your comments.

Appendix 9 Teacher Evaluation Questionnaire: Statistical Analysis

Frequency Table

Question 3

Do you understand how each of the elements identified in the model interact in technology practice?

Society
Working
Context
Purposeful
Action
Organisation
Information
Resources
Techniques
Knowledge

Yes No Think so

understand model

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	35	89.7	89.7	89.7
	sort of	4	10.3	10.3	100.0
	Total	39	100.0	100.0	

society

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	34	87.2	87.2	87.2
	think so	5	12.8	12.8	100.0
	Total	39	100.0	100.0	

working context

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	30	76.9	76.9	76.9
	no	1	2.6	2.6	79.5
	think so	8	20.5	20.5	100.0
	Total	39	100.0	100.0	

purposeful action

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	29	74.4	76.3	76.3
	no	1	2.6	2.6	78.9
	think so	8	20.5	21.1	100.0
	Total	38	97.4	100.0	
Missing	System	1	2.6		
Total		39	100.0		

organisation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	32	82.1	82.1	82.1
	no	1	2.6	2.6	84.6
	think so	6	15.4	15.4	100.0
	Total	39	100.0	100.0	

Question 3 Continued

information

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	33	84.6	84.6	84.6
	think so	6	15.4	15.4	100.0
	Total	39	100.0	100.0	

resources

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	34	87.2	87.2	87.2
	think so	5	12.8	12.8	100.0
	Total	39	100.0	100.0	

techniques

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	33	84.6	84.6	84.6
	no	1	2.6	2.6	87.2
	think so	5	12.8	12.8	100.0
	Total	39	100.0	100.0	

knowledge

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	35	89.7	89.7	89.7
	think so	4	10.3	10.3	100.0
	Total	39	100.0	100.0	

Question 4

use in teaching

Would you use the model in your teaching?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	22	56.4	57.9	57.9
	no	1	2.6	2.6	60.5
	maybe	15	38.5	39.5	100.0
	Total	38	97.4	100.0	
Missing	System	1	2.6		
Total		39	100.0		

Question 5

who would use

Who would use the model?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	teacher only	6	15.4	15.4	15.4
	students only	2	5.1	5.1	20.5
	both teachers & students	31	79.5	79.5	100.0
	Total	39	100.0	100.0	

Question 6

When would you use the model?

When planning lessons
When discussing technology practice with students
When introducing a teaching unit in class
Throughout a class project

discussions with students

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	23	59.0	100.0	100.0
Missing	System	16	41.0		
Total		39	100.0		

introducing teaching unit

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	13	33.3	100.0	100.0
Missing	System	26	66.7		
Total		39	100.0		

throughout project

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	27	69.2	100.0	100.0
Missing	System	12	30.8		
Total		39	100.0		

other

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2	5.1	100.0	100.0
Missing	System	37	94.9		
Total		39	100.0		

lesson planning tool

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	23	59.0	100.0	100.0
Missing	System	16	41.0		
Total		39	100.0		

Question 7

How would you use the model?

As a lesson planning tool
As a teaching tool
As a tool to encourage students to plan their technology project
As a tool to encourage students to evaluate their practice

teaching tool

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	23	59.0	100.0	100.0
Missing	System	16	41.0		
Total		39	100.0		

encourage planning

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	28	71.8	100.0	100.0
Missing	System	11	28.2		
Total		39	100.0		

Question 7 Continued

How would you use the model?

- As a lesson planning tool
- As a teaching tool
- As a tool to encourage students to plan their technology project
- As a tool to encourage students to evaluate their practice

encourage evaluation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	18	46.2	100.0	100.0
Missing	System	21	53.8		
Total		39	100.0		

other

		Frequency	Percent
Missing	System	39	100.0

Question 8

How often would you use the model?

how often use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	seldom	4	10.3	10.8	10.8
	3	11	28.2	29.7	40.5
	4	17	43.6	45.9	86.5
	regularly	5	12.8	13.5	100.0
	Total	37	94.9	100.0	
Missing	System	2	5.1		
Total		39	100.0		

Question 9

How often would you expect your students to use the model?

how often students use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	seldom	2	5.1	5.7	5.7
	2	3	7.7	8.6	14.3
	3	12	30.8	34.3	48.6
	4	13	33.3	37.1	85.7
	regularly	5	12.8	14.3	100.0
	Total	35	89.7	100.0	
Missing	System	4	10.3		
Total		39	100.0		

Question 11

How useful is the model in communicating the concept that technology takes place within a context that will influence the products developed?

context influences products

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2.6	2.6	2.6
	3	8	20.5	20.5	23.1
	4	21	53.8	53.8	76.9
	extremely useful	9	23.1	23.1	100.0
Total		39	100.0	100.0	

Question 11

How useful is the model in communicating the concept that technology practice is a systematic process?

technology sysematic

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2.6	2.6	2.6
	3	7	17.9	17.9	20.5
	4	18	46.2	46.2	66.7
	extremely useful	13	33.3	33.3	100.0
	Total	39	100.0	100.0	

Question 12

How useful is the model in communicating a holistic view of practice?

communicates holistic view

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2.6	2.6	2.6
	3	4	10.3	10.3	12.8
	4	15	38.5	38.5	51.3
	extremely useful	19	48.7	48.7	100.0
	Total	39	100.0	100.0	

Question 13

How useful is the model in communicating technological literacy?

technological literacy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	6	15.4	16.2	16.2
	3	12	30.8	32.4	48.6
	4	13	33.3	35.1	83.8
	extremely useful	6	15.4	16.2	100.0
	Total	37	94.9	100.0	
Missing	System	2	5.1		
	Total	39	100.0		

Question 14

How useful are the elements identified in the model, for structuring the teaching of technology education?

structuring teaching

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	3	7.7	7.7	7.7
	3	4	10.3	10.3	17.9
	4	21	53.8	53.8	71.8
	extremely useful	11	28.2	28.2	100.0
	Total	39	100.0	100.0	

Question 15

How useful is the model in providing a structure to facilitate progression in learning?

facilitate learning

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2.6	2.8	2.8
	3	14	35.9	38.9	41.7
	4	16	41.0	44.4	86.1
	extremely useful	5	12.8	13.9	100.0
	Total	36	92.3	100.0	
Missing	System	3	7.7		
	Total	39	100.0		

Question 16

How useful is the model to you, as an aid for planning, organising, and controlling classroom projects?

planning aid

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	6	15.4	16.7	16.7
	3	5	12.8	13.9	30.6
	4	14	35.9	38.9	69.4
	extremely useful	11	28.2	30.6	100.0
	Total	36	92.3	100.0	
Missing	System	3	7.7		
Total		39	100.0		

Question 17

How useful is the model for analysing case studies of technology practice?

case studies

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not useful	2	5.1	6.3	6.3
	2	2	5.1	6.3	12.5
	3	9	23.1	28.1	40.6
	4	10	25.6	31.3	71.9
	extremely useful	9	23.1	28.1	100.0
	Total	32	82.1	100.0	
Missing	System	7	17.9		
Total		39	100.0		

Question 18

How useful is the model for helping students plan, organise, and control their projects?

student planning

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not useful	1	2.6	3.0	3.0
	2	2	5.1	6.1	9.1
	3	11	28.2	33.3	42.4
	4	15	38.5	45.5	87.9
	extremely useful	4	10.3	12.1	100.0
	Total	33	84.6	100.0	
Missing	System	6	15.4		
Total		39	100.0		

Question 19

How useful is the model for helping students develop a systematic process for their projects?

student systematic development

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not useful	1	2.6	2.9	2.9
	2	3	7.7	8.8	11.8
	3	5	12.8	14.7	26.5
	4	17	43.6	50.0	76.5
	extremely useful	8	20.5	23.5	100.0
	Total	34	87.2	100.0	
Missing	System	5	12.8		
Total		39	100.0		

Question 20

How useful is the model for encouraging students to select appropriate information, skills and techniques in their project work?

students appropriate information

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	7	17.9	20.6	20.6
	3	10	25.6	29.4	50.0
	4	12	30.8	35.3	85.3
	extremely useful	5	12.8	14.7	100.0
	Total	34	87.2	100.0	
Missing	System	5	12.8		
Total		39	100.0		

Question 21

How useful is the model in assisting students develop reflective abilities in technology practice?

students reflective abilities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	4	10.3	12.9	12.9
	3	10	25.6	32.3	45.2
	4	15	38.5	48.4	93.5
	extremely useful	2	5.1	6.5	100.0
	Total	31	79.5	100.0	
Missing	System	8	20.5		
Total		39	100.0		

Question 22

How well does the model incorporate the following strands of the curriculum?

tech knowledge

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	6	15.4	15.8	15.8
	4	15	38.5	39.5	55.3
	extremely well	17	43.6	44.7	100.0
	Total	38	97.4	100.0	
Missing	System	1	2.6		
Total		39	100.0		

Technological knowledge and Understanding

tech capability

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2.6	2.6	2.6
	3	4	10.3	10.5	13.2
	4	18	46.2	47.4	60.5
	extremely well	15	38.5	39.5	100.0
	Total	38	97.4	100.0	
Missing	System	1	2.6		
Total		39	100.0		

Technological Capability

Question 22 continued

How well does the model incorporate the following strands of the curriculum?

Technology and society

tech & society

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2.6	2.6	2.6
	3	6	15.4	15.8	18.4
	4	13	33.3	34.2	52.6
	extremely well	18	46.2	47.4	100.0
	Total	38	97.4	100.0	
Missing	System	1	2.6		
Total		39	100.0		

Question 23

How well do you think the model fits the learning objectives outlined in the curriculum statement?

Q23

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	2	5.1	5.3	5.3
	3	8	20.5	21.1	26.3
	4	15	38.5	39.5	65.8
	extremely well	13	33.3	34.2	100.0
	Total	38	97.4	100.0	
Missing	System	1	2.6		
Total		39	100.0		

Question 24

Is the model a practical tool for teaching technology education in the classroom?

fun to use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	27	69.2	71.1	71.1
	no	1	2.6	2.6	73.7
	maybe	10	25.6	26.3	100.0
	Total	38	97.4	100.0	
Missing	System	1	2.6		
Total		39	100.0		

Question 25

Do you think your students would find the model fun to use?

Q25

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	9	23.1	24.3	24.3
	no	7	17.9	18.9	43.2
	maybe	20	51.3	54.1	97.3
	9	1	2.6	2.7	100.0
	Total	37	94.9	100.0	
Missing	System	2	5.1		
Total		39	100.0		

Appendix 10 Teacher Questionnaire: Written Responses

Question 26 What costs do you see being involved with the use of this model? Teacher time...

- Expense and resources...**
- 104 Its integral so its not a cost for time. Makes far easier planning - its a good summary.
- 105 It's a good resource to keep pulling the students back as a reference, guideline to help them along the technology process.
Once the model is understood it would help with planning so saving time.
- 110 Explanation time and relating work back to the model.
- 111 Getting to know the model better will take a bit of time at first. There could, and will be, more time needed to set up tests, etc.
- 117 The model should reduce unnecessary expenses as it sees the pitfalls. The model might encourage more expenditure in terms of what you are producing and will help one make use of our resources.
Quite a lengthy amount of time in preparing resources.
- 121 Not all technology areas/teachers have access to computers or in fact the same amount of resources that others might have.
Could take a bit of time if you need to focus on quality. However, it could be simplified to function at certain class levels.
- 126 At first, time consuming getting used to using the model efficiently but could save planning and organisation later. Restricted time in a classroom to get through the technology process as a whole with 28+ children!
- 129 Could save resources cost and management as planning for them thoroughly. Expenses in testing products and materials during the problem solving process.
A lot of explaining.
- 131 Would need considerable professional development so as teachers fully understand and appreciate the model.
- 133 Development of case studies. Incorporating the thinking required to own/apply the model.
- 134 Case studies.
Planning school wide and individual planning unknown amount of time.
- Schools would have to look at having/producing data banks, info, etc. more available.

- 149 Not excessive.
- Not excessive.
- 153 Time involved in introducing the model and familiarising the children with it.
- 157 Unknown but could be useful in focusing.
- 158 Photocopying. Re-organisation of sheet to allow children to have more space to write.
- Photocopying.
- 159 Minimal.
- Massive.
- 161 A little more planning - class time in organising different material.
- No different from present day teaching if boundaries are set before starting.
- 163 Little.
- Little
- 164 Depends on whether used in conjunction with present planning methods or stand alone. With practice time will be less of an issue but time consuming to start with.
- Minimal.
- 169 Preparation, delivery, assessment.
- Photocopying.
- 174 More streamlined. Quicker.
- 179 Initially will take lots of time.
- Lots - to develop teacher P D.
- 182 The costs - it provides an excellent framework for teacher development of tech teaching programmes particularly if "toolbar" concept is appended.
- To me these lie in the area of whole school curriculum planning where a model such as this provides a focus for the integration/rationalisation and prioritising of costs/resources needed to introduce technology education into the school programme.
- 184 Assist/reduce planning time.
- 188 Increases the work load.
- 189 Save time in planning.
- 191 No more than those used now.
- No more than those used now.
- 195 Additional planning along with the unit.
- None.

198 Teachers can use this as a check list if you like for planning - so no costs really in this area.

No costs in terms of expenses and resources - these would be as normal for a class unit.

Question	What do you see is wrong with the model?
27	
104	Availability - of a good quality copy.
105	Difficult to understand without a lot of explanation. has no specifics.
110	Don't know enough about the subject.
111	The end product - this in terms of certain communities needs to go home at the moment. It can't just be a wall chart, etc.
121	Need to use it a bit more to comment.
129	Not practical for planning for a teacher as we have planning sheets that directly follow curriculum strands. But good for children to use.
131	A bit complex for younger children.
133	Too soon to say.
134	The timetable on subject capture that schools currently use (Not the models fault).
149	Workable.
157	Too abstract.
158	More writing space needed.
159	I would change the wording slightly for our children.
161	Community expectations. Time in practical classrooms for using tools.
163	Needs more encouragement for graphic response for those who prefer it.
164	Size of areas and importance of different parts.
168	I would use more to support understanding of tech practice and a basis for development of personal plans and approach.
169	It will need to be simplified in terms of language. Children coming into school (secondary) have appalling language and comprehension skills.
172	Okay for big kids, but I teach 5 and 6 year olds - a bit complicated for them to understand and use.
176	Theoretical. Correct I guess - but I would rarely look at using it.
179	Not sure that it would address the issue that technology must be critiqued as well as practised!
182	
	With added appendices - the "toolbar" of techniques, etc. will provide extra usefulness.
184	Perhaps techniques could have suggestion list of possible useful techniques. I know them, or many. Would every teacher, especially one with no tech ed training.
188	It doesn't suit me as a teaching context - would simply mean more work - doubling up of writing the info recorded here in a more useful format.
189	Needs more curriculum boned areas for lesson planning, eg. technological ???, contexts, achievement objectives.
191	At this stage lack of practise with it!
195	Not suitable for all ages.

198

The model needs explaining. If you are not familiar with the technology curriculum and think in a technological way!, there could be a different interpretation taken from it such as back to technical or skills based. That's just how technical and skills based teachers think! It is easy to understand if you understand what technology is all about!

Question	What improvements would you suggest?
28	Any other comments.
104	I'd like to see the list of techniques that was originally on the model 1997 put back.
105	Have it produced as a poster and A4 as a resource. Send it to <u>all</u> schools.
110	More specific explanation of stages in technology.
110	Not sure.
121	Nothing so far.
126	Possibly adapt some terminology to 'classroom' practice, ie. objectives (a) learning outcomes, (b) learning processes.
131	I have found the model extremely valuable - has clarified my thinking and put things in logical and useful "boxes".
133	The words could have logos attached to amplify their meaning, fix them in the minds of the users like a toolbar. The model on paper is user friendly.
134	None at the moment.
149	The schools may need to throw away current time tables and look at technology being the drives in the T/T and not how can it fit it without changing the current subject contact time.
159	Simpler structure for easy class use.
159	A few examples under each heading.
161	Thank you. Difficult without more class time to improve.
163	I have no problems with the model. However educationalists are expected to cover so many different curriculums it is very hard to cover many of them properly.
164	A child-centred approach to formation.
164	Using each section as an add on to expand the whole process, ie. fill in purpose full action part then look at org. info. res. separately based on middle section then tech based on other two, etc. until the whole thing is built up.
168	?? of possible techniques/technical aspects, etc.
169	I like the way the diagram has now been put into a ??? - I would use this with teachers and students.
172	Smaller paragraphs - more diagrams.
172	Incorporate the design loop.
	At the moment I think and plan in terms of this design loop.

184 See answer for question 27.

I like the expanding ring of knowledge. Schools have down-graded knowledge aspects of education. Possibly because teachers don't have much - too many curriculums for in-depth knowledge of any or many. Children should recognise that they are gaining knowledge in information techniques as well as process.

189 As above.

A good broad outline.

191

A very useful tool to add to my kit!!

195 A model to cover a lower level of thinking.

198 The initial model just touches on the cultural and ethical side of technology - has society and working environment on it. This part is more evident on the planning sheet. Could this be incorporated or words expanded on to emphasise more, eg. like Pacey's model. Depends really on individual interpretation so may not be important.

I like it as it covers all areas. The term techniques fits after your explanation - that you apply these techniques to technological practice. The model would be very useful for senior school technology classes. I would use it more for planning probably for junior classes, as students would find it more difficult to understand.

Use of the Model

- 104 I don't currently use it sufficiently enough because I don't have a good copy to reproduce and use as a teaching tool. But in my lesson preparation assignments I refer to it.
- 105 I would use this as a basis of explanation of the technology curriculum introduction into school. Once I studied it and had a good understanding of the model.
- 121 Definitely a useful tool for making sense of the tech document.
- 123 Because it is comprehensive it can be used by teachers and students as a check-list in all areas of teaching and working through a technology unit or project.
- 129 Made tech easier to understand.
- 131 I would modify the model to suit the age of the children, but would follow the thinking and intention of it. Could use it as a "check-list" against what to do - refer to it as work through the process.
- 133 Re question 9, will be very dependent on question 8. Teacher use will lead to student use. I will need to become clearer in my own understanding.
- 142 The use of the model will need to be taught.
- 157 Not used, so I cannot make a constructive comment.
- 163 It itemises some things I have been needing to develop in the consciousness of both myself and my students.
- 168 I would use this model to document progress with my ??? students - not so sure about primary students.
- 184 Could use at end of a unit - then beginning of next unit with children. Where have we come from, now where can we go next.
- 195 Shows a practical application, etc. what technology practice is and how it works.

Communication the concept

- 104 It's very clear.
- 133 I don't understand question 13.
- 142 All terms will have to be thoroughly explained and perhaps with the use of a case study.
- 149 Easier than anything else presented to me.
- 163 What is important to me is the graphic and how it 'looks' to mean.
- 195 Provides relevant information that can be applied.

Teacher Use

- 104 It's good for teacher training.
- 105 Once understanding is complete, it would be helpful in preparation of technology planning.
- 110 Great to explain at start of topic.
- 121 Planning.
- 123 Stick it on the wall as a reminder and check-list for planning units.
- 133 Re question 16, my technology practice is limited (probably by my current view of technology in schools as a teacher of science) so I am not able to fit the model into a context so readily as some others.
- 158 Unable to answer questions - need to try it first.
- 163 Makes clear use of lineation/delineation of tech practice.
- 184 Very useful for planning learning experiences; resources; balance.
- 195 Higher level primary, secondary teacher facilitator of whole staff.

Student Use

- 104 It's a good summary springboard.
- 105 Difficult for students to grasp.
- 110 Great to refer to.
- 121 Useful.
- 123 Use it as a reference chart to reinforce working through units.
- 131 Think it would be too difficult for children to use independently - would need guidance and discussion. (At primary and intermediate level).
- 133 Re question 18, I think the model is quite sophisticated, more sophisticated than equivalent models in other subjects, mainly because of its need to integrate a greater degree of "knowledge". As a result it will need very good case studies to show students its usefulness and why they should invest so much time in it (maybe this is a reflection of my inexperience).
- 163 Reflects good practice
- 182 Usefulness lies in providing a framework for teacher-led systematic process at junior ?? school and for student controlled processing at senior ?? school. Question 18/21. Model is generalised - the development of a "toolbar" appendix would improve its usefulness here. Question 20/21.
- 184 Students should better understand the whole process of technology.
- 195 Limited.

Curriculum

- 104 Across all the 7 areas.
- 105 Will ensure full coverage if used properly.
- 110 Excellent to show relationship.
- 121 Good to monitor delivery.
- 131 In primary area society is often a difficult strand and connection to project isn't always easily appreciated. Teachers don't understand/know about the way technology influences and is influenced. However model does keep it there before them.
- 163 Direct
- 168 Maybe ??? could be identified in some ways for teacher application.
- 184 As planning medium - good. Remind teachers there are 3 strands and they are inextricably linked.
- 195 Relates to how technology practice works but not sure about fitting it into curriculum.

Practical Application

- 104 Excellent - a very good summary of the process in relation to the NZ Technology Document.
- 163 Unlikely students would want to use it as it is too wordy and centred on 'words'. Still it should help order things given a less sophisticated approach.
- 184 Elsewhere covered I hope.

Appendix 11 Wrapping Up Packaging Technology

TENZ Conference Auckland 1999

JOHN A. GAWITH AND THOMAS R. ROBERTSON

Introduction

Packaging is an integral part of our modern way of life and contributes significantly to our comparatively high standard of living in New Zealand. This paper will look at the history of packaging and the way modern packaging systems have evolved in response to social, political and economic pressure. Packaging is often criticised as a waste of resources and thus, is the subject of much comment from environmentalists. This paper will discuss environmental issues involved with packaging and set the scene for a packaging development project. This project will demonstrate the steps that technologists work through in developing new packaging for products and highlight the knowledge involved and the techniques used by technologists in their practice. The paper will conclude with a brief discussion on how this practice could inform teaching units through the eight levels of the curriculum.

Definition of packaging

The UK Institute of Packaging provides three definitions of packaging:

1. A coordinated system of preparing goods for transport, distribution, storage, retailing and end-use;
2. A means of ensuring safe delivery to the ultimate consumer in a sound condition at minimum cost;
3. A techno-economic function aimed at minimising costs of delivery while maximising sales (and hence profit)

The third definition would include minimising costs of reusing, recycling or disposing while maximising sales.

From a packaging users viewpoint, a distinction is usually made between the various 'levels' of packaging. A *primary package* is one which is in direct contact with the contained product. It provides the initial and usually the major protective barrier. Examples of primary packages include metal cans, glass bottles, and plastic pouches. It is frequently only the primary package that is purchased at retail outlets.

A *secondary package* contains a number of primary packages, for example, a corrugated paperboard box. It is the physical distribution carrier and is sometimes designed so it can be used in retail outlets for the display of primary packages. A *tertiary package* is

made up of secondary packages. A common example is a stretch-wrapped pallet of corrugated paperboard cases. Finally, a *quaternary package* is frequently used to facilitate the handling of tertiary packages in interstate and international trade. The most common example of this type of packaging is the metal shipping container.

Packaging History

Nature provides many examples of packaging ranging from the shell of an egg, the bark on a tree to the skins of animals. The first forms of packaging by humans used leaves such as flax and banana, animal products like leather and animal stomachs. Some of these forms of packaging are still used today. Bickerstaffe and Barrett (1993) described how trade encouraged the use of pottery, glass, metal, leather and wood as food packaging materials. However, much of the food was still spoiled by animals, insects or micro-organisms.

By the eighteenth century, towns were becoming bigger and permanent shops were established in competition with the markets. These shops purchased food items in bulk containers like barrels and sacks. The contents were measured out according to the customers requirements and placed in the customers own containers brought from home. There was no way of controlling the quality of food being sold this way.

“milk was watered down, sand, ashes and sawdust was added to bread, flour to mustard, other leaves to tea, snail’s slime was added to milk and sold as cream.”
(Bickerstaffe and Barrett 1993, p35)

Eventually the English governments enacted legislation to control dishonest merchants. For example, the Adulteration of Food and Drink Act 1860, the 1872 Food and Drugs Act.

Prior to the 1700’s, packaging had been mainly used for short term storage of food and for transporting goods, but as people moved from the country to rapidly growing cities, ways of preserving food became increasingly important. Also at this time large armies and navies had been built up in Europe. In 1795 Napoleon offered a reward for practical methods of preserving food for his large army. Nicolas Appert, a French chef who preserved fruit by heating it in glass bottles won this reward. The Englishman Peter Durand applied this process to metal canisters in 1812. These canisters were lighter and less likely to be broken. Canned foods were used by the British Navy from 1824 and saw a six fold increase in production during the American Civil War.

Meanwhile, in the shops, grocers were still counting or weighing out food items from bulk containers. In 1852 a machine was developed for making paper bags. This meant the grocer could make up portions before the customers arrived and the customer had an easy way of transporting the goods home. In about 1870 the flat bottomed paper bag was developed. This had the additional advantage of being able to be displayed on shelves and benches. Nevertheless, food manufacturers were still supplying the grocers in bulk and relying on the grocer to keep the product fresh and to be honest. Food manufacturers observed the success of the ‘medicine’ industry and the way medical remedies were sold in sealed glass containers with labels that urged consumers to buy the product and instructions on how to administer the medicine (Hine 1995). This marketing concept was used by the American Cereal Company to sell Quaker Oats in

1884. This transformed what many considered was animal feed, into a popular breakfast cereal using packages with printed recipes and attractive images (Hine 1995).

In 1901 the Uneeda biscuit company ran this advertisement in newspapers and magazines:

“When the grocery boy swept out the store, he couldn’t find the lid of the cracker box, so he covered them over with a codfish crate. After he weighed a mackerel and drew a quart of kerosene, he filled an order for a pound of crackers, which was carefully picked from the cracker box under the codfish crate. The customer who bought the crackers said they tasted queer, but the grocer couldn’t help it.”

This advertisement indicates the concern food manufacturers had in the way their products were sold. Such concerns ultimately led to the development of increasingly sophisticated packaging to ensure the food was attractively packaged and in good condition for the consumer. This trend away from bulk supplies to consumer packages meant the grocery stores slowly changed to the format we have today.

Modern context

The same problems the early Egyptians had in storing and transporting their food are still with us today. We have developed sophisticated methods of packaging, transporting and storing food and other products. Without these systems, much food and other product can be lost. In the 1970’s, a study of packaging systems in China found that:

- 17.5% of the country’s cement was lost in transit
- 20% of all glass was damaged before it could be used
- 40% of microscopes were broken before reaching the buyer

(Packaging Today – Australia, 1979)

A similar picture existed in Russia in the early 1980’s (Larionov, 1994). A lack of packaging, distribution and storage facilities resulted in annual losses of:

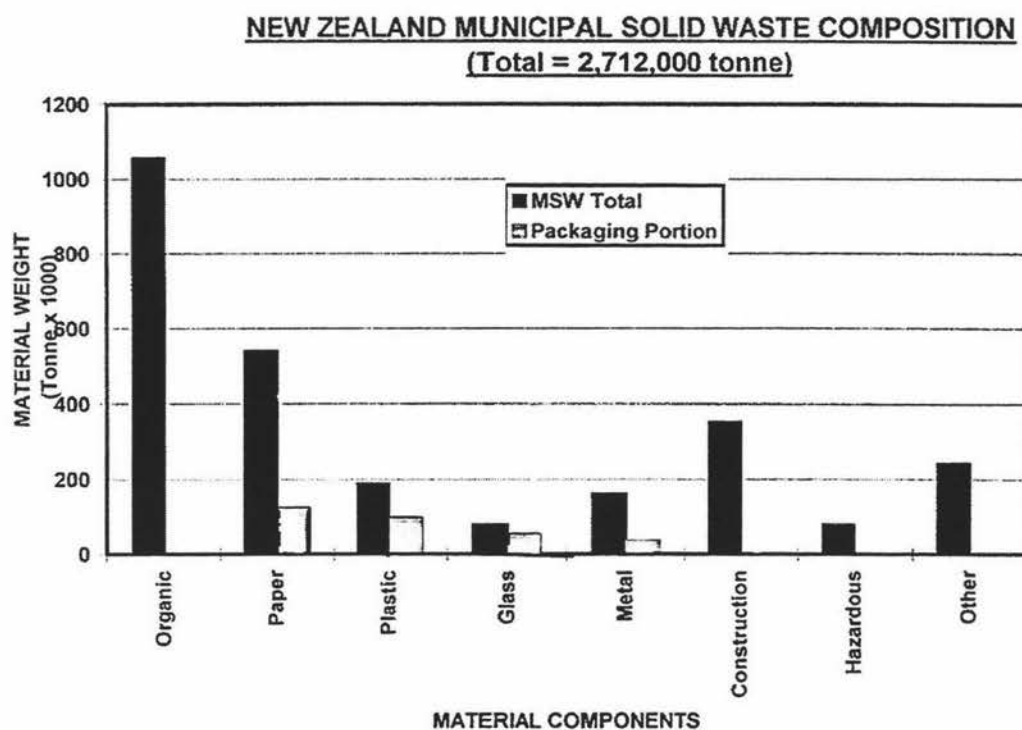
- 45% of fresh vegetables
- 55% of fresh fruit
- 70% of potatoes
- 50% of grain
- one million tons of meat
- one and a half million tons of fish

Where packaging systems and infrastructures are weak, or lacking, large quantities of food and other goods are wasted (Alter 1988; Bickerstaffe and Barrett 1993). As with many issues in technology, there is a trade off involved. If the level of packaging increases, there will be less food wastage, but on the other hand, the resources required for improved packaging will increase and the problems of re-using, recycling or disposing of the packaging also increase.

Gathering accurate information on the cost of disposing of packaging waste is difficult. When questioned, many people estimate packaging as comprising 80 to 90% of their

rubbish. However the packaging proportion of the waste stream on a weight basis is quite small as indicated in Figure 1.

Figure 1 1994 New Zealand Municipal Solid Waste Composition (PIAC 1995)



Nevertheless, we are concerned about the resources used in packaging and how these could be reduced, reused, recycled, recovered, and if necessary disposed of. These expectations and concerns constitute some of the societal, or cultural aspects that influence technologists as they develop new packaging products (Pacey 1992). In New Zealand this has led to the development of a "Code of Practice for Packaging of Consumer Goods" an accord between the total packaging industry and the Government.

Organisational aspects

Most countries have introduced laws and regulations to protect the consumers of goods, particularly food. In New Zealand there are regulations such as the New Zealand Food Regulations of 1984 plus the amendments, Weights and Measures and the Fair Trading act.

Packaging products must also fit into an established organisational structure involving the manufacturer, the transport industry and the retailer. They each have specific requirements and a desire to keep their costs as low as possible.

Technical aspects

The packaging manufacturers fund research and development projects to develop increasingly sophisticated packaging materials. Technologists working on such programmes have reduced the resources used while at the same time improved the effectiveness of packaging. For example, the weight of a glass milk bottle was 570g in 1920 in the 1990's it was 245g, but has now been replaced with a 28g plastic bottle. In 1950 a beer can weighed 91g. The equivalent can weighed 17g in 1990 (Bickerstaffe and Barrett 1993).

Information concerning the technical aspects of packaging systems can be found in reference books and trade journals and include:

1. Packaging material properties
 - Glass
 - Tin plate and Aluminium
 - Paper – solid paperboard and corrugated paperboard
 - Polymers (Plastics)
 - Combinations of materials
2. Packaging Machinery
3. Distribution Systems
 - Primary, secondary and tertiary packaging
 - Transportation
 - Storage
 - Refrigeration
4. Retailing
 - Shelf space
5. Environmental Impacts
 - Municipal Solid Waste Management
 - Recovery
 - Reuse
 - Recycle
 - Disposal

Developing a Packaging Product

For the remainder of this paper, we will look at how packaging technologist might develop a packaging product for a specific situation. It will identify the important elements of technology practice and illustrate how these could be made explicit and taught in schools.

The scenario

Food technologists at school are developing a nutritionally balanced birthday cake product for the inner city food bank to include in their food packs. We have been asked to develop the packaging for this product. Our school is 100 kilometres from the city, and a parent has agreed to transport the cakes on the back of his light truck when he delivers his vegetables to the market.

This development will take place within a New Zealand context, and as a result, the societal values and opinions, organisational structures and technical aspects of our community discussed above will influence the development. The working environment at the school has particular strengths and constraints that will influence what can, and cannot be done. These important aspects of the context and working environment need to be discussed and recorded to ensure the product concepts are realisable and fit within the wider context of use. The first step will involve planning how this product will be developed. The key questions here are: What decisions will need to be made? What information and outcomes will we need to make good decisions? And what actions are needed to get this information and the outcomes?

Purposeful Action - Decisions, Outcomes and Actions

The first decisions to be made are the value positions we should take regarding the packaging – the expectations of the people the cakes are intended for, the resources involved and the environmental impacts.

We will need to know what equipment and resources we have to work with and the criteria and constraints of the various people and groups involved. These will include the food technologists, the transport system, the food bank operating system, the parent who collects the cake and transports it home and finally and most importantly, the child with the birthday.

We need to clearly identify the problem so we know what to do and when we have achieved a solution. Once we have done this, we should make a decision on whether to proceed and try to solve this problem or go back and rethink the previous decisions and outcomes. Technologists call these GO / NO GO decisions.

Once the problem is identified, we develop lists of all the criteria to be met. For example, the size of the primary and secondary package: Does it have to be waterproof? What information is needed on the packaging? What are the likely expectations of the birthday child and how strong does the packaging have to be? The criteria will also include the consequences of the values position taken in the first decision. The main outcome will be a preliminary set of specifications.

With this knowledge we are in a position to generate ideas and concepts for solving the problem. These ideas will be tested to make sure they meet the criteria we set and are practical given the limitations of our working environment. We select the best idea and develop a prototype for testing. The knowledge gained from this will allow the preliminary set of specifications to be further refined and quantified.

After evaluation of prototype performance, we can consider all the previous decisions and outcomes and make a 'GO / NO GO' decision on whether to start production of the packaging product or go back and do more development, prototyping and testing.

Whilst we will stop at this point, the technologist would continue to be involved with the changes that are invariably involved to overcome production problems and ongoing improvements of the package.

The decisions, outcomes and actions must be scheduled into the time available. A common scheduling technique for doing this is a Gantt chart.

Information Gathering

An important question is whether we know enough about packaging to identify the problem clearly? If the answer is no, we need to gather technological information. We could look up the textbooks or we could use the technique many technologists use first - ask someone with the knowledge. In this case I consulted my colleague Tom Robertson, a Food Packaging Technologist, and he provided the following information on packaging.

Packaging Functions

There are four important functions of packaging that have to be considered - containment, protection, convenience and communication.

Containment

This function of packaging is so obvious as to be overlooked by many, but it is probably the basic function of packaging. With the exception of large, discrete products, all other products must be contained before they can be moved from one place to another. The 'package' whether it be a milk carton or a bulk cement rail wagon, must contain the product to function successfully. Without containment, much product would be lost and the environment polluted.

Protection

This is often regarded as the primary function of the package. The package must protect its contents from outside environmental effects, such as water, moisture vapour, gases, odours, micro-organisms, dust, shocks, vibrations, and compressive forces. In many cases the package must protect the environment from the product. This is particularly important for those products such as toxic chemicals which may seriously damage the environment.

In most food products, the protection afforded by the package is an essential part of the preservation process. For example, aseptically packaged milk and fruit juices in cartons only remain aseptic for as long as the package provides protection. Vacuum-packaged meat will not achieve its desired shelf life if the package allows oxygen to enter. In general, once the integrity of the package is breached, the product is no longer preserved.

Since the 1980's the need for tamper-evident packaging has increased. In 1982 six people died from cyanide poisoning in the US following the malicious tampering of Tylenol painkiller capsules. The UK baby food market suffered a dramatic downturn in 1990 after a series of tampering incidents. Child-resistant closures on pharmaceutical and household chemicals are another example of protection, (in this case the child from the product).

Convenience

Modern lifestyles have brought about tremendous change in the packaging required. There are changes in the nature and size of the family, with more women in the

workforce. There is a demand for a wide variety of food and drink that can be consumed outside or away from a table. These changes have all demanded packaging solutions that allow products to be used more conveniently. Convenience also relates to how easy it is to package the product in the first place and then store and distribute it

Communication

There is an old saying that "a package must protect what it sells and sell what it protects." The ability of consumers to instantly recognise products through distinctive branding and labelling enables supermarkets to function on a self-service basis. The use of modern scanning equipment at retail checkouts relies on packages displaying a Universal Product Code (UPC). Products such as food, drinks and pharmaceuticals must by law, display in a prominent position, information on the product. For example, what the product is, who made it, where it came from, how much there is, its ingredients (if it is a foodstuff) how to use the contents, how not to use them, and when to use them by.

Modern warehouses and distribution centres require information on the secondary and tertiary packs in order to keep track of stock. These packages may also display internationally recognised symbols to communicate toxic substances, fragile goods and other handling information.

Packaging Environments

The package has to perform its functions in three different environments. Failure to consider all three environments during package development will result in poorly designed packages, increased costs and consumer complaints.

Physical environment

This is the environment in which physical damage can be caused to the product. It includes shocks from drops, falls and bumps, damage from vibration arising from transportation modes including road, rail, sea and air. Compression and crushing damage arising from the packing operation, stacking in a warehouse and during transportation and in the home environment will also need to be controlled.

Ambient environment

This is the environment that surrounds the package. Damage to the product can be caused as a result of water and moisture vapour, gases (particularly oxygen and carbon dioxide), light (particularly UV radiation), the effects of heat and cold, micro-organisms, rodents, birds and insects. Contaminants in the ambient environment such as exhaust fumes from automobiles, dust and dirt can also find their way into the product unless the package acts as an effective barrier.

Human environment

This is the environment in which the package interacts with people. Designing packages for this environment requires knowledge of the vision and strength capabilities of the people as well as the legislative and regulatory requirements. This environment might require child resistant closures and tamper evident features.

To maximise its convenience functions, the package should be simple to hold, open and use by the consumer. For products which are not totally consumed when the package is first opened, the package should be resealable to retain the quality of the product until completely used.

Product Development Techniques and Project Management

After assimilating this information I talked to Tom again. He suggested we use a matrix or grid technique to structure our thinking. Figure 2 illustrates our results for the primary package. The same grid could be used to identify the requirements of the secondary package.

Figure 2 The Birthday Cake Packaging Functions and Environment Grid .

Functions				Environments	
Containment	Protection	Convenience	Communication		
Contain the cake	Compression of the cake	Easy to pack Easy to store Easy to distribute	Do not crush!		Physical
-	Shelf life- how long? Microbial spoilage Do we need to remove O ₂ and/or add CO ₂ Prevent from drying out	Normal temperatures for distribution – no chilling	Storage time Shelf life information How to store the product		Ambient
Might need to contain the cake after it has been cut	Tamper evidence?	Easy to open Does it need to be re- closed? Easy to store	Birthday cake image Food regulations of 1984 + amendments Branding Bar Coding? How to use	Human	

Not included in this grid are consideration of the environmental impact of the package and the cost. We evaluated our ability to proceed and develop a solution (The Go / No Go decision). The answer was 'Go' so we used the functions and environment grid to generate a list of criteria. We quantified and specified as many criteria as possible to generate preliminary specifications.

Flow diagrams are common technique used by technologists in structuring design project work. Figures 3 illustrates a flow diagram often used by packaging technologists to structure processes and identify the packaging requirements and their links.

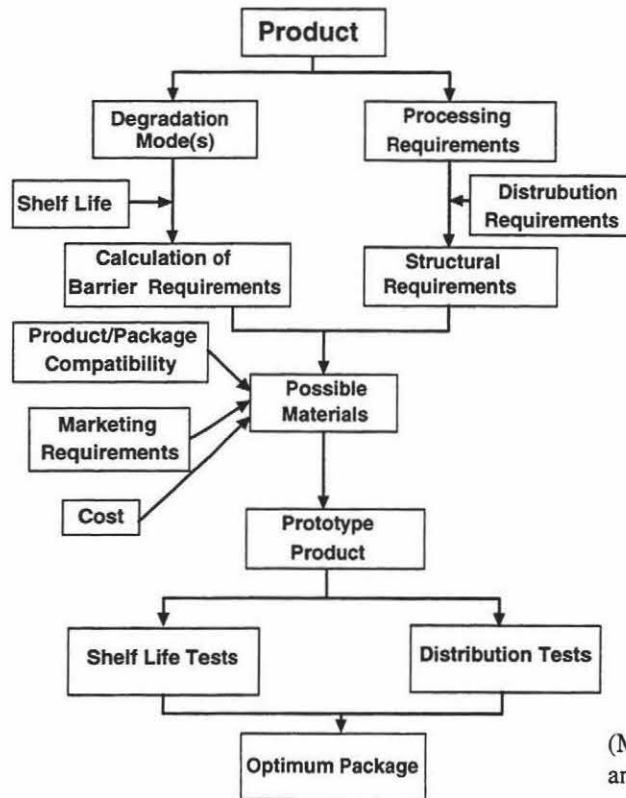


Figure 3 Food Packaging Development Flow Chart

During the problem identification, any ideas for solutions were recorded as we went. They are a useful start for the formal concept generation phase. Creative thinking techniques such as analogy techniques were used. For example, walking around a department store or at home and “seeing” (imagining) our product in all the different packaging displayed there, or; personal identification with the product and linking resulting “emotions” with the new packaging idea (Melis 1991). Other techniques include de Bono’s six thinking hats and brain storming.

The concepts for both the primary and secondary package were screened down to a manageable number. These concepts were modelled, tested and evaluated to decide if the concept would work in practice. The packaging materials and preservation techniques were also tested to gather information on their properties and effectiveness.

The most likely solution was selected using a screening matrix. The important criteria are recorded on one axis and the concepts on the other allowing each concept to be assessed against all the criteria. If a criterion is very important, it can be given additional weighting. This matrix can be set up with a simple ‘yes’ ‘no’ weighting or a more complex 1 to 5 weighting, Figure 4 illustrates the technique and demonstrates how a selection can be made by counting the ticks and subtracting the crosses. Criterion three was most important and had a greater influence on the concept selection.

Figure 4 A Screening Matrix

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
Concept 1	✓	✓	✓✓	X	X
Concept 2	✓	X	✓✓	✓	✓
Concept 3	✓	X	-	✓	✓
Concept 4	✓	✓	X X	✓	✓

From our research and screening, concept 2 was selected for prototype development and testing for shelf life, distribution and structural requirements and other requirements noted in the preliminary specifications. Where necessary, specifications were added or further quantified to form the final specification list. Prototype development continued to ensure the important specifications and requirements were met.

This prototype development phase will conclude with a final 'Go'/'No Go' decision. If the decision is 'no go', we will repeat the steps above and find ways to improve the prototype or develop a new prototype from a different concept.

Our overall methodology is summarised in a recording sheet illustrated in Figure 5. It identifies the important elements of technology practice and the systematic process used in developing the product. The same format can be used to plan a technology project.

Figure 5 Birthday Cake Package Planning and Recording Sheet

<p><i>Cultural Aspects</i> Attitudes to packaging Expectations of food products Concepts associated with birthdays Attitudes to waste Environmental concerns</p>		<p>Society <i>Organisational aspects</i> Laws and regulations The total packaging system and the accepted conventions involved in this.</p>		<p><i>Technical Aspects</i> Knowledge of packaging systems and packaging materials. The tools and machines used in packaging.</p>	
<p style="text-align: center;">Working environment</p>					
<p><i>Community of practice</i> 'Code of Practice for Packaging Consumer Goods' Attitudes to creativity and risk taking.</p>		<p><i>Organisational</i> Limitations of school timetables Classroom structures that promote creativity and goal orientated work</p>		<p><i>Technical</i> The equipment within the school The materials that can be used</p>	
Techniques		Purposeful Action- Decisions, Outcomes and Action		Organisation, Information, and Resources	
<p>Information gathering techniques</p> <ul style="list-style-type: none"> • Questioning • Surveys • Observation • Library search 		<p>Collation of criteria and constraints</p>		<p><i>Organise</i> time, paper and equipment for gathering and recording information. Decide on the <i>information</i> needed Determine what <i>resources</i> might be required and gather knowledge on these</p>	
<p>Talk to knowledgeable people Read about the topic Question and observe Packaging functions and environment grid</p>		<p>Identify the problem</p>		<p><i>Organise</i> the collection, recording and analysis of information – organise to talk to a knowledgeable person.</p>	
<p>Flow chart</p>		Management Go, No-Go Decision			
<p>Lists Tables User questioning</p>		<p>Identify criteria</p>		<p><i>Information</i> on what the birthday children and their care givers want <i>Organise</i> to collect this information</p>	
<p>Values and ethical codes</p>	<p>Code of practice</p>	<p>Consider values position</p>		<p><i>Information</i> on transportation and distribution system.</p>	
<p>Lists Tables Diagrams</p>	<p>Evaluation techniques – discussion grids</p>	<p>Preliminary Specifications</p>		<p><i>Information</i> – technical information</p>	
<p>Sketches, Drawings, Lists Brainstorming Analogies Modelling Material testing</p>		<p>Ideas and Concept generation</p>		<p><i>Organise</i> people, time and resources <i>Information</i> required <i>Resources</i> - Gain knowledge about materials</p>	

Figure 5 Birthday Cake Package Planning and Recording Sheet Continued

Compression testing Moisture testing Shelf life testing User test	Concept testing	Organise testing Resources – acquire resources needed Information collection, recording and analysis
Screening matrix	Concept screening	Organise people, time and resources Information on processing techniques Resources – acquire resources needed and gain knowledge about materials Organise testing Resources – acquire resources needed Information collection, recording and analysis
3D models Processes – cutting, forming, joining Optimising	Prototype development	Information collection, recording and analysis
Compression testing Moisture testing Shelf life testing User testing	Prototype evaluation	Evaluate against social position
Trial runs Use test	Consumer test, transport test	Organise for tests to be carried out and information collection
Final specifications		
Management Go, No-Go Decision		
Produce the packaging		
Pack the product		
Distribute the product		
Birthday cakes reaching the children in good condition The children are excited by the package and the caregivers have all the information they need		
Society		

Application To Other Technology Projects

This method of planning and recording the process just described, encourages young technologist to control the process used. It provides opportunities for reflection on how the project could be done differently next time. Questions such as: Were the techniques used appropriate? What other techniques could we use? Did we organised and managed to project well? Did we use our resources well? What did we learn and how can we improve next time. Because the elements of practice are generic, regardless of the technological area or project being worked on, this model providing a consistent structure on which to build knowledge, understanding, capability and an appreciation of the influences of society on technology and technology on society.

This example can be adapted for all levels of schooling. The main elements of practice identified in the three columns of Figure 5 remain the same regardless of the level technology is taught at. Techniques can be simplified and expectations of children’s

'organisation', 'information' and 'resource' knowledge and skills can be adjusted appropriately. The format allows the teacher to model these elements of practice in an explicit way for their students. The realisation that practice takes place within a social or community context and a particular working environment is important for students to understand, in order to weigh the issues involved and make appropriate choices and decisions.

Children should recognise a common structure to technology practice regardless of the technological area or project they are working on. This allows a progressive curriculum to be developed, linking technology projects with previous experience and extending student's skills and knowledge of technological 'techniques', 'organisation', 'information', 'resources' and 'purposeful action' within a social context and working environment.

References

- Bickerstaffe, J. & Barrett, E. (1993) Packaging's role in society. In Levy, G. (ed) (1993) *Packaging in the Environment*. London: Blackie Academic & Professional.
- Gnanasekharan, V. & Floros, J. (1993) Shelf Life Prediction of Packaged Foods. In Charalambous, (ed) (1993) *Shelf Life Studies of Foods and Beverages*. Elsevier Publishing.
- Hine, T. (1995) *The Total Package: The Evolution and Secret Meaning of Boxes, Bottles, Cans, and Tubes*. Boston: Little Brown and Company.
- Larionov, V.G. (1994) Packaging Personnel Training in the C.I.S. *Packaging Education News*, No. 3.
- Lockhart, H.E. (1995) A paradigm for Packaging. *Packaging Education News*, No8, March.
- Melis, T. (1991) *The Innovative Packager*. Singapore: Octogram Books.
- PIAC (1995) *National Solid Waste Analysis And the Role of Packaging Waste*. Auckland: Packaging Industry Advisory Council.
- Robertson, G.L., (1993) *Food Packaging, Principles and Practice*. N.Y.: Marcel Dekker Inc.
- Soroka, W. (1995) *Fundamentals of Packaging Technology*. Leicestershire: The Institute of Packaging.
- Warburton, D. (1995) Personal Communication.