http://researchcommons.waikato.ac.nz/

Research Commons at the University of Waikato

Copyright Statement:

The digital copy of this thesis is protected by the Copyright Act 1994 (New Zealand).

The thesis may be consulted by you, provided you comply with the provisions of the Act and the following conditions of use:

- Any use you make of these documents or images must be for research or private study purposes only, and you may not make them available to any other person.
- Authors control the copyright of their thesis. You will recognise the author's right to be identified as the author of the thesis, and due acknowledgement will be made to the author where appropriate.
- You will obtain the author's permission before publishing any material from the thesis.

BECOMING EFFECTIVE TECHNOLOGY TEACHERS: ENHANCING ASSESSMENT PRACTICES IN PRIMARY CLASSROOMS

A thesis
submitted in fulfilment
of the requirements for the Degree
of
Doctor of Philosophy
At the
University of Waikato

by
JUDITH PATRICIA MORELAND

University of Waikato
2003

ABSTRACT

This thesis explores primary school teachers' technology pedagogical content knowledge and how this impacts on teaching practices in technology education, particularly formative interactions. Based in the interpretist paradigm and using case study methods, the two-year journeys of eight co-educational teachers from two primary schools and their technology education perceptions and practices are described. The first year (1998) explores existing teacher knowledge and practices and student learning. The second year (1999) traces the impact of a professional development programme aimed at enhancing teachers' technology pedagogical content knowledge in relationship to formative assessment. The significant impact of a planning framework containing the categories of technological practice, conceptual aspects, procedural aspects, societal aspects and technical aspects is examined.

Findings from the first year reveal that existing school subcultures, school policies and teacher subject expertise influence teacher classroom practices in technology. Planning, teaching and assessment were often related to social and managerial aspects rather than procedural and conceptual technological aspects. Hence, learning and formative assessment interactions focussed on these aspects rather than student understandings in technology. The second year explores the development of teachers' technological knowledge through a collaborative, ongoing teacher development programme. The development and use of a planning framework exerted considerable influence on teachers' constructing appropriate knowledge and understandings and on developing a technological knowledge base robust and distinct from previous knowledge bases. A complex mix of specialist knowledge is required for teachers to become competent, confident teachers of technology. It is important to decide on appropriate student learning outcomes and to transform teacher technological understandings to those suitable for students.

Further, the study shows that improvement in classroom formative interactions, especially the provision of descriptive feedback, makes a strong contribution to enhancing learning. It confirms that enhancing teacher pedagogical content knowledge impacts on their ability to provide descriptive feedback. Embedding

formative assessment in technology and undertaking it in a sociocultural, transactional, conversational and future-oriented way strengthens student technological learning. Student gains are made in technology when teachers focus descriptive feedback on specific technological goals, particular technological qualities of student work and the provision of advice on how to improve technologically. This study provides empirical evidence that teacher perceptions and practices in technology and technology education impact on the technological learning of students. The assumption that students' learning of technology can be enhanced through enhancing teachers' pedagogical content knowledge and formative assessment practices is justified.

ACKNOWLEDGEMENTS

I thank my supervisors Alister Jones and Margaret Carr for their invaluable guidance and assistance over many years. I appreciated their encouragement and patience. They introduced me to new ideas and helped me shape this technology education story.

This thesis is more than an analysis of the collective journeys the teachers, students and I undertook, as I did not work alone. A team was involved. I acknowledge the input of Alister Jones and Ann Northover, two members of the research team. Much of our debate helped form the nucleus of ideas that underpin this thesis. Alister's and Ann's contributions assisted me to gain insights in teaching, learning and assessing technology. Our long, complex discussions helped develop the understandings and knowledge I gained throughout the study. Alister and Ann Northover are acknowledged for their contribution to the research as fellow research team members.

I gratefully acknowledge that this thesis could not have been undertaken without the teachers and students. I thank them for their willingness to be involved for the two years of this research and for their unceasing generous goodwill.

I acknowledge my colleagues in the Centre for Science and Technology Education Research. The discussions we have held over the past five and a half years have helped me sharpen my thinking. I particularly thank Bronwen Cowie, Mike Forrett, Megan Chambers and Louise Milne for their friendship and the in-depth discussions we have had related to assessment, young students' learning technology and all facets of technology education. Their ongoing support and encouragement to 'keep going' was appreciated. I also thank Raewyn Oulton for her help with my diagrams.

The provision of sound, timely advice from the Advisory Group, Steve Benson, Bronwen Cowie, Margaret Carr, Mike Forrett, Mary Hill, Louise Milne and Rachel Wood was welcomed and helpful.

The second year of data generation was undertaken with funding support from the Ministry of Education for the Learning in Technology Education (Assessment) Project. I acknowledge this assistance.

I thank my good friends Liz McKinley, Jane and Kevin Burgess and Sheryl and Gary Dawson for their friendship, laughter and for always being there in support.

Finally I wish to thank my family. I cherish the love, unqualified support and ongoing encouragement from Ken, Nikki and David. I thank all my other family for their unfaltering belief that I was always going to complete.

CHAPTER OUTLINE

1. Introduction

1.1 Introduction 1

1.2 Thesis justification 2

1.3 Thesis underpinnings 4

1.3.1 Assessment and effective learning 4

1.3.2 The role of pedagogical content knowledge 5

1.4 This study 6

1.4.1 The contexts for study 6

1.4.2 The researcher 9

1.4.3 The research aims 10

1.4.4 Outline of the thesis 10

2. Assessment and technology education in primary schools 12

2.1 Introduction 12

2.2 Assessment and effective learning 14

2.2.1 Introduction 14

2.2.2 A sociocultural perspective 14

2.2.3 Formative assessment enhances learning 17

2.2.4. Descriptive feedback desired 20

2.2.5 Student ownership of learning and assessment 23

2.2.6 Summary of assessment and effective learning: relevance to this study 27

2.3 The importance of pedagogical content knowledge and significance to formative assessment 27

2.3.1 Pedagogical content knowledge 27

2.3.2 PCK and assessment practices 29

2.3.3 PCK and assessment in technology 31

2.3.4 Summary of PCK, its significance to formative assessment and relevance to this study 34

2.4 Primary school students' learning technology 35

2.4.1 Introduction 35

2.4.2 Iterative nature of undertaking technology tasks 36
2.4.3 Transforming ideas into working realities 39
2.4.4 An environment to foster technological learning 42
2.4.5 Summary of primary students' learning technology and relevance to this study 47
2.5 The research questions 47

3. Methodology 49
3.1 Introduction 49
3.2 Methodological paradigms for research 49
3.3 Interpretive research design 51
3.3.1 Multiple perspectives 52
3.3.2 Multiple data generation methods 53
3.3.3 Data analysis 65
3.3.4 Ethical considerations 67
3.3.5 Ensuring trustworthiness of data generation and analysis 68
3.4 The research design 70
3.4.1 Data collection and timeline 70
3.2.4 Multiple perspectives 71
3.4.3 Multiple data generation methods 75
3.4.4 Management of the data 83
3.4.5 Ethical considerations 84
3.4.6 Strategies to ensure trustworthy data collection and interpretation 85
3.4.7 The analysis and kinds of analysis 87
3.5 Summary of Chapter 3 90

4. Existing perceptions of technology and technology education: findings from 1998 92
4.1 Introduction 92
4.2 Perspectives of technology and technology education 93
4.2.1 Previous experiences in teaching technology 93
4.2.2 Perspectives of technology 98
4.2.3 Technology education perspectives 100

4.3 Technology assessment views and experiences 105
4.3.1 Assessment integral to teaching and learning 105
4.3.2 Influences on assessment 106
4.3.3 Deciding what to assess 108
4.3.4 Comparisons with assessment in reading 109
4.3.5 Student self assessment 111
4.3.6 Reporting to caregivers 111
4.4 Summary of Chapter 4 112

5. Planning, teaching and assessing technology education: 1998 classroom findings 117
5.1 Introduction 117
5.2 1998 planning 117
5.2 1 Overview of each class 118
5.2.2 Teachers' programme planning 118
5.2.3 Summary of planning 123
5.3 Teachers and students in technology classrooms during 1998 124
5.3.1 Understandings of technology 124
5.3.2 Pedagogical aspects 129
5.3.3 Assessment aspects 137
5.3.4 Summary teachers and students in technology classrooms during 1998 148
5.4 Key findings of Chapter 5 151

6. The professional development programme 156
6.1 Introduction 156
6.2 Key principles for the professional development programme 158
6.2.1 An extended time for trialling ideas 158
6.2.2 Providing support and guidance 159
6.2.3 Building a spirit of co-operative inquiry 161
6.3 The professional development programme 162
6.3.1 Programme structure 163
6.3.2 The workshops 164

6.4 Summary of Chapter 6 192

7. Enhanced classroom practices in technology: 1999 findings 195

7.1 Introduction 195

7.2 Effects of the models on teacher planning 196

7.2.1 1999 technology tasks 196

7.2.2 Using the planning framework 198

7.2.3 Intended lesson sequence planning 201

7.2.4 Assessment considered when planning 202

7.2.5 Burt: changes from 1998 to 1999 205

7.2.6 Summary of the effects of the models on teacher planning 210

7.3 Changes to pedagogical approaches 212

7.3.1 Nature of the task 212

7.3.2 A hands-mind balance 214

7.3.3 Practices in dealing with transfer 214

7.3.4 Approaches to enhance iteration 216

7.3.5 Summary of changes in pedagogical approaches 222

7.4 Enhanced assessment practices 222

7.4.1 Enhanced formative interactions 223

7.4.2 Enhanced summative assessment practices 230

7.4.3 Summary of enhanced assessment practices 234

7.5 Summary of Chapter 7 236

8. Student learning in 1999 239

8.1 Introduction 239

8.2 Students' understandings about the nature of technology 240

8.3 Conceptual and procedural understanding 242

8.3.1 Effective understandings evident in conversations 242

8.3.2 Effective understandings evident in student work 247

8.3.3 Summary of effective conceptual and procedural understanding 261

8.4 Effective ways of working 262

8.4.1 Ability to work iteratively 262

8.4.2 The purpose of the activities 266

8.4.3 Identifying and closing technology gaps 268
8.4.4 Summary of students' effective ways of working 270
8.5 Summary of Chapter 8 271

9. Discussion and implications 274
9.1 Introduction 274
9.2 Primary teachers' 1998 technology teaching and assessment practices 275
9.2.1 Understandings of technology and technology education 275
9.2.2 Difficulties teaching technology education to young students 276
9.2.3 Difficulties with formative and summative assessment 281
9.3 Enhanced teaching and assessment practices and the impact on student learning 286
9.3.1 Enhanced understandings and practices in technology education 288
9.3.2 Enhanced assessment practices 294
9.3.3 Student learning 297
9.3.5 Summary 302
9.4 Implications of the findings 303
9.5 Implications for further research 309

Appendices

Appendix 1 Data collection methods and time-line 311
Appendix 2 The schools and participants teachers' backgrounds 312
Appendix 3 Overview of classes 316
Appendix 4 Teacher interview questions 317
Appendix 5 Sample of field notes 318
Appendix 6 Information to principals 319
Appendix 7 Participant letter of consent 321
Appendix 8 Overview of technology topics 322
Appendix 9 Teachers' lesson sequence outline 323
Appendix 10 Assessment of student achievement in developing fitness equipment 324
Appendix 11 Aims of the professional development programme 325
Appendix 12 Workshop outlines 326

Appendix 13	Technology units taught in 1999	327
Appendix 14	Tina's use of the planning framework for Unit 2 1999	328
Appendix 15	Other planning examples	330
Appendix 16	Aspects for summative assessment	334
Appendix 17	Two written summative assessment examples	335
Appendix 18	Finished products	336

References 338

List of Tables, Figures and Graphs

Tables

Table 3.1	Participant teachers' backgrounds	72
Table 3.2	Participant technology teacher development experiences, attitudes towards technology and the research project	73
Table 5.1	Reasons for topic choice	119
Table 5.2	Altered achievement objectives	120
Table 6.1	Segment of three-perspective structure of individual lessons	166
Table 7.1	Rachel's planning for Unit 2 1999	198
Table 7.2	Rachel's planning and summative assessment	204
Table 7.3	Penny's learning experiences and assessment	204
Table 7.4	Comparing 1998 and 1999 learning outcomes	207
Table 7.5	Burt and student conversations in 1998 and 1999	225
Table 7.6	Summative statements made by Burt in 1998 and 1999	233

Figures

Figure 2.1	Literature organisation framework	13
Figure 3.1	Research phases (1998 & 1999)	70
Figure 3.2	Framework for considering factors affecting classroom based assessment	88
Figure 6.1	Research phases (1998 & 1999)	156
Figure 6.2	Timeline for workshops and intervening classroom practice 1999	163
Figure 6.3	Planning for learning and assessment in technology	168
Figure 6.4	First planning framework	169
Figure 6.5	Aspects to consider when planning	170
Figure 6.6	Process of identifying learning outcomes	171
Figure 7.1	Research phases (1998 & 1999)	195
Figure 7.2	Where are we at with bird feeders?	217
Figure 7.3	Making your hanging structure	217
Figure 7.4	Planning for maths containers	218
Figure 7.5	Student evaluation worksheet	218

Figure 7.6	Storage containers evaluation	229
Figure 7.7	Sensational cereal boxes self evaluation	229
Figure 8.1	Class discussion	243
Figure 8.2	Ongoing conversation	244
Figure 8.3	Mask making conversation	245
Figure 8.4	Heather's second idea	248
Figure 8.5	My maths storage container	249
Figure 8.6	My bird feeder evaluation	257
Figure 8.7	Amy's evaluation	258
Figure 8.8	Tic Tac Toe – the evaluation	259

Graphs

Graph 6.1	Teacher level of understanding after Workshop 1 and 1st classroom practice	178
Graph 6.2	Teacher level of understanding after Workshop 2 and 2nd classroom practice	187

1. INTRODUCTION

1.1 Introduction

Looking back, the 1994 arrival into my primary school classroom of the *Technology in the New Zealand Curriculum Draft* (Ministry of Education, 1993a) was a defining moment. An extraordinary document had fallen into my hands. Here was a curriculum document openly encouraging children's involvement with creating, exploring and critiquing real technological artefacts and systems, affording them opportunities to learn about the very essence of our being, that of being technological. As a teacher I now had legitimate freedom and authorisation to encourage students to examine the influence and impact of technological development and change. My students could become involved with practical pursuits as I had a curriculum to vindicate the educational worth of such activity. Powerful learning is accomplished through children using hands and minds, through the integration of intellectual and practical abilities. This new curriculum area was not only sanctioning practical learning, but also encouraging it.

Of course implementation has not been plain sailing. Though the draft statement was replaced by *Technology Education in the New Zealand Curriculum* (Ministry of Education, 1995) and subsequently mandated in 1999, successful implementation of technology education in New Zealand schools has been intensely challenging, exciting and complex. Always there has been the inventive of stepping into new, uncharted waters. Rules have had to be made along the way since curricula, manuals and lessons from other countries involved with technology education have not always transferred unencumbered to the New Zealand landscape.

Nationally and internationally there is a dearth of data derived from studying technology in everyday classrooms. I wanted to be involved with research improving ways technology could be taught, not just surveying current states. Consequently, at the heart of this study is an underpinning ideal of developing and enhancing classroom learning. This thesis is an attempt to reduce some of our

knowledge gaps related to teaching technology in New Zealand schools and to provide New Zealand research-based guidance.

This thesis is about the in-depth telling of the journeys of a small group of teachers. It is the story of eight New Zealand co-educational primary school (Years 1-6) teachers undertaking the teaching of technology education in their classrooms throughout 1998 and 1999. Although nine teachers were involved in 1998 the number reduced to eight in 1999 as one teacher moved to another teaching position too distant to remain involved. The story is more than a chronicle of their collective journeys for it also traces my involvement with them during the two years and the impact we all had on student learning.

Three aspects are dealt with in this introductory chapter. Section 1.2 provides the thesis justification, section 1.3 describes the thesis underpinnings, and section 1.4 outlines the study.

1.2 Thesis justification

The view that improvement in classroom formative assessment makes a strong contribution to improving learning (Black & Wiliam, 1998a; Crooks, 1988) is emphasised. When I began this study in 1998 there was little New Zealand research-based assessment guidance related to improving teachers' formative interactions with their technology students. Earlier research in teacher development in technology education suggests that assessment is the least understood area and especially problematic (Jones, with Hawe & Mather, 1994; Moreland, 1998). Research (Moreland, 1998) also indicates that even with professional development teachers still experience difficulties in carrying out appropriate assessment in technology. A study of assessment in technology would therefore assist to close these gaps.

Although much has been written about assessment in technology, very few empirical studies have been undertaken (Kimbell, 1994). This has translated into a lack of understanding about student learning and how to assess this in general technology classrooms. This is highlighted in the National Education Monitoring

Project (NEMP) report on technology education (Flockton & Crooks, 1996a) where technology tasks do not have the performance indicators outlined. Instead the technology curriculum provided the framework. For example the Knowledge and Understanding category specifies technological principles, properties of substances, tools and devices, systems, environments and interactions between technology and society (p.11). The lack of clear indicators meant that teacher evaluators found it difficult to assess student performance. In contrast, the NEMP Reading and Speaking Report (Flockton & Crooks, 1996b) undertaken at the same time as technology, provides many such indicators. For example the 'Skills and Processes' category itemised 14 aspects, including making use of semantic, syntactic, visual and grapho-phonic cues in text; making self corrections, adjusting reading speed to complexity and purpose, skim reading, reading aloud, retelling and summarising, and comprehending literal meaning (p.11). To enhance understanding about student technological learning and assessment, this study therefore focusses on classroom interactions, the connections between assessment and learning, and the premise that classroom assessment enhances learning (Black & Wiliam, 1998a; Brown, 1990b; Gipps, 1994; Glaser, 1990; Resnick & Resnick, 1992; Wiggins, 1993).

In formative assessment the use of descriptive feedback most likely promotes effective learning (Hargreaves, McCallum & Gipps, 2000; Tunstall & Gipps, 1996). In order to give descriptive feedback teachers require extensive pedagogical content knowledge (Shulman, 1987). Jones, Mather and Carr (1994) note that technology teachers position assessment procedures within other existing subject subcultures, rather than in technology, because of inadequate understandings of technology and technological processes. To assess confidently in technology, teachers need to have a clear understanding of the nature of technology and technological practice in different technological areas, in order to know when to interact with students and to give appropriate advice. Effective assessment is thus dependent upon informed assessors who can interpret observations and student outcomes (Sadler, 1998). To provide descriptive feedback teachers need to be informed about the curriculum, learning goals and how students might progress (Black & Wiliam, 1998a). A further justification for this study is the examination of ways to enhance pedagogical content knowledge

so that descriptive feedback is positioned within the subculture of technology education.

Finally, in order for students to make progress, they need to be involved with the assessment process themselves, identifying their own strengths and weaknesses and acting to improve (Gipps, 2002; Sadler, 1989). To do this effectively they need to share the teacher's view of the subject matter (Wiliam, 1998). A dearth of research of students' technological learning and self-assessment in everyday primary classrooms is evident. Hence as a final justification, this study attempts to examine student perspectives and learning in technology education.

1.3 Thesis underpinnings

1.3.1 Assessment and effective learning

Classroom assessment has been categorised as diagnostic, formative or summative. Summative assessment is assessment carried out at intervals and sums up learning (Harlen, 1998), although Delandshere and Petrosky (1998) and Biggs (1996) additionally propose that summative assessment may include the identification of next learning steps. Information gained is usually recorded and used for the purposes of reporting (Ministry of Education, 1994). Diagnostic assessment is used to find out what students know and can do at the beginning of a course of learning (Harlen, 1998). It may be viewed as integral to formative assessment as it is for this study (Black, 1993). Formative assessment is undertaken during learning and is used to shape or improve student learning (Gipps, 1994; Torrance & Pryor, 1995). Formative assessment advocates claim that it improves learning and that improvement in classroom formative assessment makes a strong contribution to improved learning (Black & Wiliam, 1998a; Crooks, 1988, 2001; Gipps, 1994; Torrance & Pryor, 1995). The findings of this study back these formative assessment claims.

Formative assessment engages both teachers and students (Black, 1993; Gipps, 1994: Ministry of Education, 1993b). Black and Wiliam (1998a: 7) describe it as "encompassing all those activities undertaken by teachers and/or by their students, which provide information to be used as feedback to modify the teaching and

learning activities in which they are engaged". Feedback is formative when used by students to alter and close gaps between what they know, understand and can do and desired goals (Sadler, 1989). For the purposes of this study formative assessment includes feedback and actions by teachers and/or students to enhance student learning.

Additionally, descriptive feedback is considered vital for improving learning, as it is this feedback that is specifically referenced to student achievement or competence (Hargreaves, et al. 2000). It focusses on valued learning goals (Black & Wiliam, 1993a; Harlen, 1998; Hattie & Jaeger, 1998) and on tasks and their substance (Black & Wiliam, 1998b; Butler, 1987; Crooks, 1988, Driver, 1989). Descriptive feedback is beneficial feedback when it focusses on the strengths and weaknesses of student work, enabling them to take control of their own learning (Butler, 1987; Harlen, 1998; Mavrommatis, 1997, Sadler, 1998; Tunstall & Gipps, 1996). For teachers to give descriptive feedback they require an understanding of skills, knowledge and attitudes thought to be the most important (Crooks, 1998).

1.3.2 The role of pedagogical content knowledge

Ties between teachers' subject knowledge and how that is transformed for teaching and assessment ability have been acknowledged (Bell & Cowie, 1997; Black & Wiliam, 1998a; Black, Harrison, Lee & Wiliam, 2001; Sadler, 1998; Shulman, 1987). Teacher knowledge of disciplines is related to assessment procedures since knowledge of disciplines provides direction to learning (Carr, McGee, Jones, McKinley, Bell, Barr & Simpson, 2000). Close links between teachers' formative assessment practices, the components of a teacher's personal pedagogy and their conception of their role are acknowledged (Black & Wiliam, 1998a; Bell & Cowie, 1997; Sadler, 1998). Shulman (1987) strongly emphasises the need for teachers to build pedagogical content knowledge (PCK). PCK identifies the distinctive bodies of knowledge for teaching. It includes an understanding of what is to be learned and what is to be taught, blends content and pedagogy, and represents how particular topics are organised for learners. Duschl and Gitomer (1997) also declare that formative assessment requires a clear grasp of the subject matter being investigated, a pedagogical sense of the likely understandings students bring to a subject area and a sense of the conceptual area

being explored. Their conclusion is that teacher knowledge of the discipline is related to the use of various assessment processes, since it is crucial for a teacher to have knowledge of the discipline to provide direction for learning. When teachers are unsure of their discipline's structure they are not well equipped to guide learning in it or assess that learning (Black, 1995). Therefore, the development of PCK in technology, the effects on descriptive feedback and subsequently on student learning is examined in this study.

1.4 This study

In this study the development of primary technology teachers' descriptive feedback, which was targeted through the expansion of teachers' technology PCK is considered. Teacher and student perspectives and actions were considered, as were the implications for formative assessment and how technology learning may be enhanced.

1.4.1 The contexts for study

Recognising the socially situated nature of learning means that account needs to be taken of the contexts in which the learning took place (Lave, 1988; Murphy, 1995). Learners think about tasks in relation to what they are doing in the situation (McCormick, 2000), therefore consideration of the applicable contexts for this study is important. The two overarching contexts of technology education and assessment in a primary classroom are outlined.

The context of technology education

It is argued that teachers can only give effective descriptive feedback in particular subject areas if they have a sound understanding of the characteristics of those subject areas. Therefore a description of technology education, as the learning area under consideration, is warranted.

Technology education is one of the seven essential learning areas constituting *The New Zealand Curriculum Framework* (Ministry of Education, 1993b). All learning areas within the framework are organised around eight levels of attainment that specify the learning objectives for students from Junior 1 (Year 1) to Form 7 (Year 13). The general aim of technology education in *Technology in*

the New Zealand Curriculum (Ministry of Education, 1995) is to develop student technological literacy through the development of technological knowledge and understanding, technological capability, and an understanding and awareness of the interrelationship between technology and society. The three aims are also the three inter-related strands for technology. Their inter-related nature emphasises a holistic approach to developing technological literacy.

Seven technological areas are specified to represent the diversity of technological practice in New Zealand. The areas are materials technology, information and communication technology, electronics and control technology, biotechnology, structures and mechanisms, process and production technology, and food technology. Each technological area has its own technological knowledge and ways of working, although not totally mutually exclusive, as technological activity may cover more than one technological area. It is within the technological areas and across the strands that schools develop technological learning programmes for students. Further, school programmes are explored using a variety of broad, overlapping contexts - personal, home, school, community, environmental, energy, business and industrial. Then each broad context provides many more specific contexts for exploration. So, for teachers to achieve the best possible learning outcomes for their students, and for students to develop a broad understanding of technology, programmes reflect a combination of aims, achievement objectives, technological areas and contexts.

Overlay assessment on this complex structure and it can be seen why many teachers find technology teaching and assessment problematic (Jones, Hawe & Mather, 1994; Moreland, 1998). After all, as technology is a relatively new curriculum area, a sound subculture of technology practice has yet to develop. With primary school teachers expected to teach a balance of different technological areas in different contexts, the PCK needed to teach and assess technology effectively is very extensive and highly complex. Therefore in this study, attention is paid to primary technology teachers, the development of their pedagogical content knowledge and their classroom teaching and assessment practices.

When this study began in 1998 primary teachers were not compelled to teach technology in their classrooms. It was not until 1999, the second year of data generation, that the Ministry of Education mandated technology education and from there it become compulsory. The research teachers were therefore novice technology teachers and had indicated that they needed support and guidance to teach and assess technology in their classrooms. The teachers' changing perspectives and practices related to technology education were therefore important to this study.

Assessment in a primary classroom context

Very little is known about "how, why and with what effect teachers use assessment in the classroom" (Broadfoot, 1996a: 33). Very little is also known about assessment in New Zealand primary school technology classrooms. It was therefore important to examine current classroom happenings in technology and so classroom-based research was considered essential. A study of individuals undertaking specially designed tasks was not seen as a way to understand the complex practices of learning and assessment in everyday technology classrooms (Hennessy & Murphy, 1999). The practice of assessment requires attention to the social and cultural context of learning and assessment (Gipps, 2002) so this study pays attention to assessment embedded in actual classrooms. Formative assessment is also positioned as built into tasks rather than separated from them (Black, 1998; Harlen, 1998) and includes specially formatted instructional dialogue (Duschl & Gitomer, 1997). In addition, research in assessment indicates that student responses to assessment are affected by the tasks (Murphy, 1995), hence examination of formative assessment based in everyday classrooms is critical for gaining worthwhile insights.

Teachers have an important role in formative assessment communicating valued criteria and providing feedback (Sadler, 1989). The practical implications for teachers are the need to have a concept of the learning goals and possible paths of progression towards them, to have an ability to recognise where students are in their learning, and to provide feedback that helps close the gaps and foster self-assessment. It is argued that formative assessment is reflective of social and cultural issues and is also informed, moderated and transformed by the contexts of

different learning areas. The characteristics of different learning areas impact on formative assessment practices, especially descriptive feedback. Therefore, teacher's understandings of the subject, their knowledge of learners, and their knowledge of learning and assessment in particular subject areas becomes significant for giving appropriate descriptive feedback. Teacher insights are therefore critical and they form a strong base for this thesis.

1.4.2 The researcher

I believe technology education to be a significant learning area for all students. My hope is that everyone involved with children's learning will come to see technology education in a prime role. To see it as a learning area capable of assisting learners to become responsible people safeguarding the environment, respecting human rights, valuing others, respectful of different ways of knowing and being, and better understanding themselves as essentially technological. It would be folly if the role that technology education can play in the all-round development of children as empowered people remains unseen.

My views of technology developed over many years of involvement. I was introduced to technology education with the *Draft Technology Education Curriculum* (Ministry of Education, 1993) in 1994 when I used it with my Year 2, 3 and 4 students. In 1996 and 1997 I worked as a technology education facilitator assisting other teachers to implement technology education and from 1998 I have been at university lecturing and researching technology education. These experiences assisted me to research in primary school technology classrooms with credibility and confidence.

This study is involved with change, exploring teachers' developing views of technology and technology education over two years. Accounts of the existing classroom practices were sought, and then teacher professional development was undertaken to challenge and transform the existing practices. Collaborative methods between the teachers and myself were therefore included, as teachers needed to have direct input into the professional development programme. A partnership was built between teachers and myself. This was not a bystander view of research with the researcher removed from everyday classroom reality (Cohen

& Manion, 1994). Rather, I was submerged in the research working alongside the teachers. With the long-term involvement I was able to develop relatively personal and informal relationships with teachers. Teachers worked easily in a comfortable, friendly environment where they gave opinions freely, expressed difficulties and openly debated issues. An unexpected effect related to teachers observing my questioning and discussions with students. Teachers observed various questioning strategies as I investigated student thinking and were able to "consider inquiry practices they might adopt in order to assess their students thinking" (Rhine, 1998: 28).

1.4.3 The research aims

This study is concerned with assisting primary teachers to enhance their students' technological potential through engagement in challenging, innovative technology learning experiences. The aim is to weave the three fields of PCK in technology, formative assessment and primary school students learning technology, together. In the context of primary technology classrooms the intention is to examine and explore the interrelationship between teachers' PCK in technology education and their formative interactions with their students.

The first purpose is to describe teachers' existing technology teaching and assessment practices, next review the teacher professional development programme developed to enhance teachers' views and practices, and then investigate any subsequent changes in teachers' views and practices. Student learning in technology before, during and after the intervention is investigated. The aim is to explicate and provide an empirically based account of the whole process.

1.4.4 Outline of the thesis

Chapter 2 reviews the literature on (i) assessment and effective learning, (ii) pedagogical content knowledge and enhancing assessment practices, and (iii) technology pedagogical content knowledge and primary school students. Chapter 3 outlines the research methodology. Chapters 4 and 5 set out the data related to the 1998 research when teachers' existing teaching and assessment views and practices in technology were explored. Chapter 4 presents teacher views of

technology and technology education, their understanding of the technology curriculum, their reasons for teaching technology and their views of assessing technology while Chapter 5 details their 1998 classroom practices. Chapter 5 also includes student views and practices. Chapters 6, 7 and 8 describe the data related to the second year of research (1999) when teachers' developing teaching and assessment perceptions and practices in technology were explored. Chapter 6 is solely focussed on the intervention strategies and teacher development workshops rather than teachers' work in classrooms. Teachers' classroom work is described in the following chapter, Chapter 7. Chapter 8 outlines student learning in 1999 and makes some comparisons with student learning in 1998. Chapter 9 summarises the study and outlines implications in technology education and formative assessment.

2. ASSESSMENT AND TECHNOLOGY EDUCATION IN PRIMARY SCHOOLS

2.1 Introduction

Educational assessment serves several purposes such as promoting learning in classrooms, measuring how well students and schools have achieved agreed standards in externally-prescribed tests and providing information about individuals when they transfer between classes, schools and beyond school (Black & Atkin, 1996). Much current widespread interest in educational assessment is concerned about the mismatch between assessment practices and understandings of the nature of learners and the learning process (Murphy, 1995). Emphasis is now being placed on relationships between assessment and learning and how assessment should support learning (Delandshere & Petrosky, 1998; Glaser, 1990).

Connections between assessment and learning can promote a positive view of learning where "achievements are attainable by all students but how and when they attain them varies from individual to individual" (Murphy, 1995: 249). The view supported is that student potential is dynamic, changeable and responsive to adult and peer support and instruction. Also supported is that assessment should support and enhance learning in everyday classrooms and relate to activities students undertake as an integral part of their enrolled programmes (Crooks, 1988). The focus is on classroom interactions, the connections between assessment and learning, and the premise that classroom assessment enhances learning (Black & Wiliam, 1998a; Brown, 1990b; Gipps, 1994; Glaser, 1990; Resnick & Resnick, 1992, Wiggins, 1993).

Black, et al. (2001) assert the need to analyse the interconnections between learning and assessment, as well as between views related to the nature of subject matter and the selections and articulations of goals and subject matter that follow. They further suggest the importance of the two-way relationships between teachers and subject matter, students and subject matter, and between teachers and students. These relationships, with respect to assessment in technology education will be examined.

Figure 2.1 provides an organising framework for the literature themes. A sociocultural perspective of learning and assessment is taken. Teachers' knowledge of technology, technology education and assessment and their pedagogical content knowledge relevant to teaching, learning and assessment of young students' and technology education are considered. Student knowledge of technology and technology education and their involvement in technology learning and assessment are examined. Together these aspects impact on enhancing formative assessment views and practices, and particularly influence descriptive feedback practices.

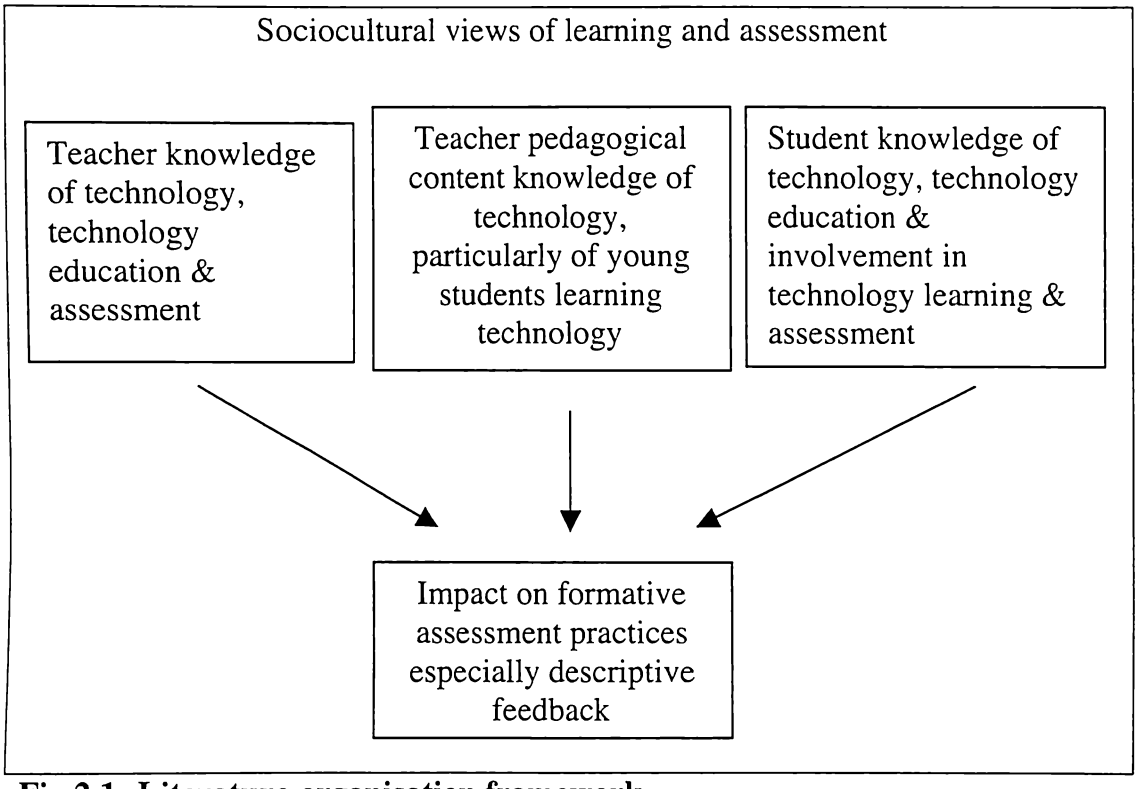


Fig 2.1: Literature organisation framework

Section 2.2 outlines literature related to connections between assessment and effective learning. Emphasis is placed on formative assessment, with descriptive feedback receiving particular attention. The section also examines students and assessment. Section 2.3 describes literature associated with the importance of teachers' pedagogical content knowledge in relation to enhancing assessment practices, especially their descriptive feedback. Section 2.4 examines literature focussing on technology pedagogical content knowledge considered relevant to

teaching, learning and assessing primary school technology students. In Section 2.5 the research questions are proposed.

2.2 Assessment and effective learning

2.2.1 Introduction

For most of the 20th Century educational achievement was calculated through measurement where students were assigned grades or numbers to test responses and where the resulting scores or grades were used to make value judgements about the quality of performances (Delandshere & Petrosky, 1998). These models of assessment were based on the assumption that assessment is a neutral, objective undertaking used to measure students' competencies and skills. They are also based on ideas of knowledge as objective and the individual as a rational learner with an innate capacity and fixed intelligence. Assessment therefore could predict future performance (Blackmore, 1998; Galbraith, 1993; Gipps, 1994; Greeno, Collins & Resnick, 1996; Willis, 1992, 1994).

In more recent years a greater interest has been paid to connections between assessment and classroom learning and the view that improvement in classroom assessment will make a strong contribution to improved learning (Black & Wiliam, 1998a). This shift in educational assessment places more emphasis on the support of learning and teaching than on the sorting and ranking of individuals (Delandshere & Petrosky, 1998; Gipps, 1994; Resnick & Resnick, 1992; Wiggins, 1993). "The focus has shifted towards a broader assessment of learning, enhancement of learning for the individual, engagement with the student during assessment, and involvement of teachers in the assessment process" (Gipps, 1999: 367). Assessments are designed to provide more detailed information about students (Wolf, Bixby, Glenn, & Gardner, 1991) in order to support learning.

2.2.2 A sociocultural perspective

Sociocultural views of learning

A sociocultural perspective views learning as a process of knowledge construction where a learner is involved in a reorganising and restructuring interpretative, organic process (Broudy, 1988; Driver, Guesne & Tiberghien, 1985; von

Glasersfeld, 1993). Learning is seen as an active, intentional and somewhat idiosyncratic process (Salomon, 1989). It shifts views of instruction from a direct transfer of knowledge for students to record information, to intervention in an ongoing knowledge construction process (Resnick, 1991). Relationships between human mental processes and their cultural, historical and institutional settings are considered significant (Wertsch, 1991) where the socially situated nature of learning is emphasised (Driver, Asoko, Leach, Mortimer & Scott, 1994; Pollard, 1990), as is the focus on the individual constructing knowledge in social action (Brown, Collins, & Duguid, 1989). Emphasis is placed on deriving meaning from interactions where the individual is viewed in relational activities with others (Gipps, 2002).

Vygotsky (1986) argued that not only is it important to examine the child and his or her interactions with the physical world but also the immediate social world in which the child is located and the nature of the interactions that take place within it. Importance is placed on interactions with more knowledgeable others and the role of society in providing a framework for children's learning. Building on Vygotsky, sociocultural views describe learning as apprenticeship occurring through guided participation in social activities with knowledgeable others, who support and guide students' understandings to use the tools of a culture (Brown, Ash, Rutherford, Nakagawa, Gordon & Campione, 1993; Glaser, 1990; Rogoff, 1990). Likewise Lave and Wenger (1991) situate learning in social processes and see learning as legitimate peripheral participation distributed among the co-participants. Concepts are socially determined and socially acquired. Understanding is achieved by individuals coming to share meaning through negotiation and discussion (Murphy, 1995; Newman, Griffin & Cole, 1989) and learning is a process of enculturation into a domain through participation in shared activities (McCormick, 2000). Therefore, human knowledge is situated in the context in which the learning took place (Murphy, 1995). As McCormick (2000) puts it:

> The way we think depends on where we are, and the specifics of the context and the tasks we are doing. We don't think about problems or situations in abstract ways; we tend to think about them in relation to what we are doing in the situation (p. 6).

When something is learned with understanding it is actively understood and appropriated by the learner. It makes sense in terms of the learners' experience of the world and is not a collection of memorised facts (Harlen & James, 1997). Learning can be most usefully seen as a social, interactive process involving the communication and negotiation of meaning between participants with varying degrees of knowledge or expertise (Hughes, 1996). When teachers and learners see effective teaching and learning as a transactional process, learners learn through a process of being exposed to new knowledge and then attempting to make sense of the new knowledge in terms of existing knowledge. Understanding involves creating links to existing mental frameworks. The acquisition of new concepts by students is dependent on the learner's previous learning experiences and the analysis of what the student is now ready to learn with the help of an adult or peer. For learning to be effective it should take place in the zone of proximal development (Vygotsky, 1986). As Harlen (1998) states:

> In order to promote this learning it follows that learning experiences have to be well-matched to existing ideas, skills and attitudes, have to be linked with previous experience and have to be seen by the learner as relevant, important, stimulating and valued for themselves (p. 1).

Therefore, a crucial role of teachers involves providing an appropriate framework to support learners' efforts to a greater understanding, which can gradually be removed as understanding is achieved.

Sociocultural views of assessment

The sociocultural view of assessment becomes value laden, socially constructed and certainly not an exact science (Broadfoot, 1994). Rather than performance being objective, it is construed according to the assessor's values and perspectives, whether they are the designer of the assessment and marking scheme, or grading open-ended performance (Gipps, 1999). The focus is on participants' own perspectives and how experiences and views are conceptualised and reconstructed. As learning is viewed as a complex, diverse process of personal knowledge construction and meaning making, assessment needs also to be diverse and to examine in depth the structure and quality of students' learning and understanding (Gipps, 2002).

The practice of assessment requires attention to the social and cultural context of learning and assessment (Gipps, 2002), the assessment of the process as well as the product and the conception must be dynamic rather than static (Lunt, 1994). Teachers become reflective agents sensitively and accurately assessing student needs and prioritising their assessments of student understandings (Driver, 1989). An integrated role for assessment in the learning process itself is identified (Torrance & Pryor, 1998). Assessment within the framework of sociocultural theory is seen as interactive, dynamic, and collaborative, integral to the teaching process and embedded in the social and cultural life of the classroom. It focusses on assessing the process of learning, attempts to elicit elaborated performance and emphasises collaborative activity (Gipps, 2002). This is crucial for technology where the aim is to get students to think through their doing, and for the feedback from undertaking practical activity to affect their thinking (McCormick, 1992; 1997; 2000). Activity is an integral part of what is being learned and "there is an intimate connection between knowing and doing" (Murphy, 1995: 253). Research shows that the effect of thinking and action is not a one-way process, where a person thinks first and then does (Scribner, 1985).

2.2.3 Formative assessment enhances learning

After an extensive review of research of formative assessment, Black and Wiliam (1998a) concluded that formative assessment improves learning.

> There is a body of firm evidence that formative assessment is an essential feature of classroom work and that development of it can raise standards. We know of no other way of raising standards for which such a strong prima facie case can be made on the basis of evidence of such large learning gains (p. 13).

A decade earlier, Crooks (1988) had come to a similar conclusion, believing classroom evaluation to be "one of the most potent forces influencing education" (Crooks, 1988: 467). The view is that attention to formative assessment can lead to significant learning gains.

Formative assessment is about recognising and responding to learning for the purposes of enhancing learning and is undertaken during the learning (Bell & Cowie, 2001). It relates to finding out about student learning and "the principle that feedback is essential to the conduct of effective teaching" (Black, 1998: 25).

It is expected that formative assessment practices will provide feedback so obstacles to learning can be identified and tackled (Bell & Cowie, 1997). Ramaprasad (1983) describes assessment as formative when comparisons are made between actual and reference levels in order to give information. The information is then used to alter the gap. It follows that the activity of formative assessment is a process requiring an interaction of two actions. The first action requires an understanding by the learner that there is a gap between desired goals and their current position, knowledge, understanding or skill. The second action is that taken by the learner to close the gap so that the goals may be attained.

Formative assessment includes a focus on student learning strengths (Sadler, 1989). Lally and Hurst (1992) examined teachers, young students and the assessment practices used with a particular focus on the special characteristics of young children and on the activities young children engage in spontaneously. They posit that a positive framework focussing on student strengths is the aim. Formative assessment's importance lies in its capacity to describe the strengths of individuals to help identify next learning steps (Harlen, 1995; Harlen & James, 1997) and with making public what students understand and then using that information to suggest appropriate instructional next steps (Duschl & Gitomer, 1997).

A distinguishing characteristic of formative assessment is that it must be accompanied by teacher and student action to enhance student learning (Black, 1995, 1993; Gipps, 1994). It is at the intersection of teaching and learning as it occurs within the interactions between teachers and students (Bell & Cowie, 2001; Gipps, 1994). Teachers are involved in gathering and using information about student learning and encouraging students to review their work constructively and critically (Harlen, 1998). Harlen suggests that assessment is for formative purposes if its use supports and helps learning and if it shares learning goals with students, involves students in self-assessment and provides feedback. This should lead to students recognising the gap and closing it. It "is underpinned by confidence that every student can improve, and involves reviewing and reflecting on assessment data" (p. 3). Extensive feedback to learners leads to

greater student engagement and higher achievement when learners plan and respond to such feedback (Black & Wiliam, 1998b).

Black (1998) and Harlen (1998) believe that there is an interconnection between formative assessment and tasks. Formative assessment cannot be added as an extra to learning programmes and procedures need to be built into the tasks. Duschl & Gitomer (1997) agree, asserting that formative assessment includes specially formatted instructional dialogue embedded into the classroom activity structure. Teachers and students generate opportunities for developing and challenging student understandings and skills *during* learning activities. Teacher to student feedback and teachers and/or students taking action to improve learning while undertaking learning is a characteristic of formative assessment (Bell & Cowie, 2001; Gipps, 1994; Sadler, 1998).

Learning gains made through formative assessment may be negatively affected by the use of summative assessment. The negative effects of summative assessment are referred to as 'backwash', and can be stronger than the positive effects of formative assessment (Biggs, 1996). Biggs suggests that significant gains could be made to mitigate or reverse backwash by enhancing feedback based on summative assessment. Studies by Butler (1987) and Schunk and Ames (cited in Biggs, 1998) bear this out. Both formative and summative assessment can be conceptualised in the same framework by being incorporated in an overall synthesis. For example, the portfolio as an information-rich mode of summative assessment can be used positively when graded qualitatively as it can set in motion metacognitive and reflective learning processes that generate much feedback. Students can then focus on the gap between their actual achievement and the desired achievement. In this situation the backwash from the summative assessment tool can be very positive. Even if the student is not able to do much with regard to their present learning situation, it can certainly provide valuable feedback for the next. Biggs asserts that summative assessment, like formative assessment, can lead forward to next learning opportunities and therefore minimise the negative effects of backwash.

Feedback for improvement

The two concepts of formative assessment and feedback overlap strongly. Feedback can be the vital link between the teacher's assessment of the students and the action following the assessment that then has a formative effect on the child's learning (Hargreaves, et al. 2000). It broadly refers to any information that is provided to the learner of any action about the learning. Sadler (1989) suggests that if feedback does not have a formative effect on learning, then it is not truly feedback. Formative in this context is taken to mean that students' "learning strategies or understanding are formed into a more developed stage than they were prior to the particular assessment being made" (Hargreaves, et al. 2000: 21).

Gains are made when teachers and students focus on specific problems of student work and students develop a clear understanding of what is wrong and how to right wrongs through achievable targets. In Black and Wiliam's words: "feedback to any pupil should be about the particular qualities of his or her work, with advice on what he or she can do to improve, and should avoid comparisons with other pupils" (Black & Wiliam, 1998b: 6).

Sadler (1998) makes the point that the more complex the learning situation, the more sophisticated the feedback needs to be. The focus is on processes, concepts and products. Assessment strategies need to be both focussed and detailed, and yet able to be conducted on a day to day basis as part of normal classroom routines (Blenkin, 1992). Informed assessors need to operate in a focussed, detailed and consultative manner (Sadler, 1998). Effective assessment is thus dependent on informed assessors who are able to interpret observations and student outcomes.

2.2.4 Descriptive feedback desired

Evaluative and descriptive feedback defined

It cannot be assumed that any type of feedback enhances learning. Descriptive feedback is the key. Evaluative feedback focusses on implicit or explicit use of norms and is either positive or negative. Strategies include giving rewards and punishments and expressing disapproval and approval. On the other hand, descriptive feedback is specifically referenced to students' actual achievement or

competence. It is more likely to contribute to achievement and improvement (Hargreaves, et al. 2000, Tunstall & Gipps, 1996). Descriptive feedback implies making judgements about past, current and future progress students understand, so they can respond, make reasoned decisions and act. Strategies include telling students they are right or wrong, describing why and how the answer is correct, telling students what they have and have not achieved, specifying or implying a better way of doing something and getting students to suggest ways they can improve (Tunstall & Gipps, 1996).

Descriptive feedback focusses on student control of feedback. Tunstall and Gipps (1996) found in their two-year detailed study of primary teachers' teaching, assessment and feedback that evaluative feedback kept all feedback control in teachers' hands. Descriptive feedback, where students suggested their own ways to improve, put feedback control with students as they took the initiative, provided feedback to themselves and were supported by the teacher. Descriptive feedback strategies were used when teachers believed that students learnt by building on what they already knew, by asking and answering questions and by making connections. Evaluative strategies were used when teachers thought students learnt by teachers transmitting information and telling students they were right or wrong.

Descriptive feedback guides students towards valued learning goals

Descriptive feedback assists students to understand what they should be aiming for and provides assistance for students to develop skills and strategies for taking next learning steps. The teacher is therefore required to share goals and expectations with students and help them to develop skills and strategies to enable them to make progress (Harlen, 1998). Goal setting together with descriptive feedback enhances learning (Black & Wiliam, 1998a; Hattie & Jaeger, 1998). Required is the setting of challenging goals, structuring situations so goals can be attained effectively and providing feedback relevant to attaining the goals. This means that to provide descriptive feedback teachers need to be informed about the curriculum, the goals and how students might progress.

> The practice of formative assessment has to be informed by a model that is quite detailed, in that it has to provide some guidance about the ways in which a pupil might progress in

learning, linked to a clear conception of the curriculum and its learning goals (Black, 1998: 26).

Bell and Cowie (2001) also assert that formative assessment includes teachers guiding learners towards valued learning goals. This can only be generated with tasks that work to those goals. Action will be inhibited if there is a mismatch between goals, tasks and how the tasks are organised and undertaken. Formative assessment then includes teachers' considering the effectiveness of the learning activities and the process by which they gather information about student learning and then respond with descriptive feedback to promote further learning.

Descriptive feedback focusses on tasks and their substance

If feedback focusses towards the self rather than towards tasks, a negative effect on learning may occur (Black & Wiliam, 1998a; Butler, 1987). For example, if feedback focusses on praise and the promotion of social and managerial aspects it draws attention away from tasks (Black & Wiliam, 1998a). Crooks (1988) in his assessment literature review likewise found little support for making praise a prominent part of feedback. Crooks argues that where used, it should be task specific. Driver (1989) argues that descriptive feedback is important for teaching the conceptual, procedural and attitudinal aspects perceived to be the most important for the learner by the teacher and the student. Often teachers emphasise the quantity of students' work rather than its quality, and while tasks are framed in cognitive terms, assessments are often in affective terms, with social and managerial aspects over-emphasised (Black & Wiliam, 1998a; Duschl & Gitomer, 1997).

In contrast, students benefit from feedback that identifies the strengths and weaknesses of their work, enabling them to take control of their own learning (Butler, 1987; Harlen, 1998; Mavrommatis, 1997). It is descriptive feedback that is beneficial as it identifies the strengths and weaknesses of student work, enabling students to take learning control. As such it has motivational and social effects. It focusses on the qualities of student work, specific ways in which student work can be improved, and improvement (Tunstall & Gipps, 1996).

Like Tunstall and Gipps (1996), Crooks (2002) reasons that emphasis should be given to classroom formative assessments that place weight on giving descriptive feedback to students that is focused on the task, regular, undertaken while still relevant, and specific to the task. Most importantly, he argues that descriptive feedback must emphasise the skills, knowledge and attitudes thought to be the most important, even if this is technically difficult. Harlen (1998) also asserts the importance of commenting on the substance of the work, rather than superficial aspects, as this conveys to the learner what is important.

2.2.5 Student ownership of learning and assessment

A collaborative enterprise

Pryor and Torrance (1996) posit formative assessment as a collaborative enterprise bringing student views into sharp focus. A range of insights, including those of the students, is required to strengthen understandings of student learning and achievement. Formative assessment requires that learners become members of the same community of practice (Wiliam, 1998) for when students engage in school activities they need to do so with some shared understanding (Murphy, 1995). Sadler (1989) believes there is the need for mutual understanding and appropriate action on the part of the teacher and the learner.

This is an ambitious perspective in that teacher-student interaction is conceptualised to include a role for the teacher in assisting the student to engage with and comprehend new ideas and problems (Torrance & Pryor, 1995). The problem becomes one of assisting the learner to make refined judgements about quality. By definition this is difficult for learners to do. Gipps (2002) suggests that to develop student skills in evaluating the quality of their own work, especially during the process of production, teachers need to shift responsibility to the learner. Further, she contends that feedback findings clearly show that teachers should use the assessment process to support the learner and at the same time encourage self-evaluation and self-direction. Therefore, student involvement in assessment becomes vital with student self-assessment a desired goal. Sadler (1989) advises that teachers need to provide direct, authentic evaluative experiences for students so that they develop their own evaluative knowledge. This knowledge can only be communicated by example and is acquired through

explicit provision during the teaching-learning process. This assists in transferring some responsibility for making evaluative decisions from teacher to learner. Cowie (2000) further states that for this to occur, students must be willing to disclose what they do and do not know.

Understanding student perspectives

Students are regarded as active meaning makers who give contextually based meaning to others' words and actions (Lave, 1991) and it is easier to learn if they can make sense of the learning (Shepard, 1991). Therefore attention needs to be paid to students' interpretation of assessment tasks and their role and understandings in judging their own difficulties. Sadler (1989) proposes that students need to come to hold a concept of quality roughly similar to the teachers, to monitor the quality of what is being produced during production, and to use strategies to close any gap between their performance and what they are aiming for. Teachers therefore, are required to understand the learners' expectations and assumptions, interpretations of task demands and criteria for success (Gipps, 1999).

Messick (1989) suggests it is important to probe ways that students cope with tasks in order to see the processes underlying their responses and performances. Since it is not entirely predictable what tasks will offer to students, teachers will need to find ways to enable students to find, create and negotiate their meanings (Lerman, 1993 cited in Murphy, 1995). It implies "part of the teacher's role in assessment for learning is to help students to come to these metacognitive understandings" (Harlen & James, 1997: 369). For assessment this means that account has to be taken of different contextually based meanings students might use to make sense of an assessment situation (Murphy, 1995).

Guba and Lincoln (1989) believe that taking into account the 'thick descriptions' of contexts and participants are the keys to evaluation, as evaluation must include a focus on the ways in which individuals and groups deal with tasks and must take into account different ways students make sense of the world. The aim is to understand from the learner's perspective and includes methods such as portfolios and concept mapping (Ryan, 1988). If assessment information is to play a

constructive and formative role in teaching and learning it must provide teachers and students with information they need to be more effective (Murphy, 1995). Therefore, as Sadler (1989) makes clear, teachers have an important role in formative assessment in communicating valued criteria and in providing feedback to students. The practical implications for teachers are to have a concept of the learning goals and possible paths of progression towards them, to have an ability to recognise where students are in their learning, and to provide feedback that helps close gaps and fosters self-assessment.

Student self assessment

The role of students is an extremely important aspect explicitly seen when students are involved with self and peer assessment (Black & Wiliam, 1998a). A shift in the traditional roles of teacher and students in classrooms is required for fostering self-assessment (Bell & Cowie, 1997). In traditional assessment the relationship between the teacher and student is hierarchical, with the teacher setting and defining tasks and determining how performance should be evaluated. The student is the object of the activity and is graded on completion of tasks. In fostering self-assessment, the student discusses and negotiates tasks and the terms and outcomes of assessment, and becomes involved in the assessment process through monitoring and reflecting on their own performance. They consequently become self-monitoring and self-regulating learners (Broadfoot, 1996b; Gipps, 2002; Wolf, et.al 1991). The use of student self-assessment encourages students to become insiders rather than consumers of assessment (Sadler, 1989) and it supports greater student learning autonomy (Bell & Cowie, 1997).

If students rely solely on teachers' comments about their work, the number and content of the feedback depends on the willingness of the teacher to express the feedback, and the ability of the student to interpret it. What is needed is for the learner to develop an appropriate body of knowledge to enable the interpretation of teachers' statements (Black & Wiliam, 1998a). Students must become intimately involved in assessing their own progress. As it is students who take the next steps, the more involved they are, the greater their understanding of how to extend their learning (Harlen, 1998). The process of formative assessment therefore always includes learners finding out about their learning, recognising,

reacting and evaluating their learning from their own viewpoint or others (Bell & Cowie, 2001).

Students can only assess themselves when they have a sufficiently clear picture of their current position, learning goals and ways to close the gap between the two (Sadler, 1989). For effective formative assessment students need to self assess, so they can understand the purposes of their learning and hence understand what they need to achieve (Black & Wiliam, 1998b). Black and Wiliam further contend that many students do not have this understanding and are accepting of arbitrary activities with no overarching rationale. If students acquire an overview, they become more effective, committed learners and self-assessment becomes a discussion point with teachers and peers, further promoting more self-reflection.

Students need to come to know and value the learning intentions and to develop an understanding of their own strengths and weaknesses, how they might deal with them, and where they might go to next. Sadler (1989), building upon Ramaprasad's gap notion between feedback revealed state and desired state, emphasises that action will be inhibited if this gap is viewed as too wide. Further, the student is the only one to close the gap, so self-assessment by the student becomes essential. The students therefore, need to share the teacher's vision of the subject matter for the orientation of their work to be productive (Black & Wiliam, 1998a).

Claxton (1995) believes much student self-evaluation is intuitive rather than goal directed, as there are many situations where students develop their sense of what counts as good work for themselves. If students are helped to reflect on and identify their own strengths and weaknesses as learners, and to plan their learning in the light of their developing self-knowledge, they are more likely to be able to develop reflectivity and responsibility in learning. Like Wiliam (1998), he believes that guidelines or criteria for helping students to understand the goals the teacher has in mind may not have the same meaning for learners as they do for teachers. They can provide a basis for negotiating meaning, but ultimately, learners will understand the statements only by developing their own implicit notions of quality.

Students are required to become active learners taking responsibility for and managing their own learning, rather than being passive recipients (Black et al. 2001). Meta-cognition (White, 1992) and self-regulated learning (Butler & Winnie, 1995; Schunk & Zimmerman, 1996) are relevant and consistent with constructivist views of learning emphasising student thinking (Bell & Gilbert, 1996). Involvement of students means that more than one perspective can be used to clarify interpretations and generate suggestions. When students monitor their own progress, evaluate their strengths and weaknesses, and devise strategies for improving their learning, their commitment to learning is strengthened (Bell & Cowie, 1997).

2.2.6 Summary of assessment and effective learning: relevance to this study

Formative assessment involves information being reciprocated between teachers and students about students' learning and is an essential part of teaching and learning. Of significance is the use of descriptive feedback, for it is this type of feedback that fosters gains in learning. In the literature formative assessment was often theorised as generic for all subject areas and for all types of problems within those areas. Little was derived about formative assessment related to longitudinal, complex problem-solving tasks common to technology education. It is argued that formative assessment reflects social and cultural issues and is also informed, moderated and transformed by the characteristics of different learning areas. The characteristics of different learning areas impact on formative assessment practices, especially via descriptive feedback. Therefore, teachers' understandings of the subject, knowledge of learners and knowledge of learning and assessment in particular subject areas become significant for giving appropriate descriptive feedback. The importance of teachers' pedagogical content knowledge in relation to formative assessment and descriptive feedback is addressed in the next section.

2.3 The importance of pedagogical content knowledge and significance to formative assessment

2.3.1 Pedagogical content knowledge

While much teacher education and teacher development research had focussed on the importance of teachers' subject knowledge, the research rarely distinguishes

between abstract content knowledge and pedagogical content knowledge. Pedagogical content knowledge (PCK) is a blending of pedagogy and subject content (Shulman, 1987). Askew, Brown, Rhodes, Johnson and Wiliam (1997) found no relationship between teachers' level of subject qualifications and student progress in mathematics. Instead there was a strong correlation with their PCK. Black, et al. (2001) support the view that the specific nature of subject matter is an important determinant in how teachers carry out teaching in their classrooms and types of classroom interactions in the learning contexts of different subjects may not have many commonalities. Black and Wiliam (1998a) show that effective formative assessment involves more than tinkering with existing programmes. Careful scrutiny of all teaching aspects is required with formative assessment requiring embeddedness in teaching and learning.

Shulman (1987) suggests that teachers require PCK to be effective teachers. An expansive teaching repertoire is required to undertake the act of pedagogical reasoning. As PCK is a complex blending of pedagogy and subject content, it includes several aspects. These relate to an understanding of what is to be taught, learned and assessed; an understanding of how learners learn; an understanding of ways to facilitate effective learning; and an understanding of how to blend content and pedagogy to organise particular topics for learners. Teaching also requires an understanding of what is to be learned and taught. Shulman's comprehensive framework includes knowledge of content, general pedagogy, curriculum, pedagogy content, learners, educational contexts and educational ends. PCK is acknowledged as important for this identifies the distinctive bodies of knowledge for teaching.

Shulman examines how teacher knowledge is used in the processes of pedagogical reasoning and action. Teachers must learn to use their knowledge base for decision making about what they are going to do next. Not only do teachers need to understand content and purpose; they must be able to transform the content knowledge so that it becomes pedagogically powerful. The instruction process is tied to comprehension and transformation. Evaluation also requires pedagogical content knowledge and this leads to reflection, where a professional learns from experience. New comprehension is the result of involvement with all

of these processes. Together, content knowledge, pedagogical knowledge and PCK represent a complete picture of pedagogy (Shulman, 1987).

The difficulty for teachers in technology education is that they have been expected to add technology education to the learning areas they already teach whilst still carrying on teaching. It is against the pressures of carrying on as usual that a new set of meanings and practices must be incorporated (Anning, 1993). As teachers are the fulcrum for any changes to their assessment practices (Black & Atkin, 1996), any system for incorporating good formative and summative opportunities has to be constructed by the teachers themselves (Black, 1998). This critical involvement of teachers was highlighted in Britain's failed attempt to impose on teachers a 1990 National Curriculum, which expected them to embark on a rigid, formulaic assessment system (Kimbell, 1997). Best and efficient ways of teacher development for practising teachers become crucial to achieving sustainable, worthwhile change (refer Chapter 6).

2.3.2 PCK and assessment practices

The ties between teachers' subject knowledge, how that is transformed for classrooms and assessment practices are acknowledged (Bell & Cowie, 1997; Black & Wiliam, 1998a; Sadler, 1998; Shulman, 1987). Teacher discipline knowledge is related to assessment procedures since knowledge of disciplines provides direction to learning (Carr, et al. 2000). Science education assessment research shows that formative assessment is dependent upon teachers' professional knowledge and experiences (Bell & Cowie, 1997). Black and Wiliam (1998a) show close links between teachers' formative assessment practices, the components of a teacher's personal pedagogy and conceptions of their role. Sadler (1998) outlines resources that competent teachers bring to assessment. This includes knowledge about the content or substance of what is to be learned, attitudes towards learners and learning, skill in devising tasks, knowledge of criteria and appropriate standards, skill and expertise in previous similar tasks, and expertise in giving appropriate, targeted feedback. As Fleer (1999) comments, "it can be expected that the way the learning context is structured is likely to be as a direct result of the teachers' pedagogical content knowledge and philosophy about how children think and learn" (p. 275).

Gipps and Brown (1999) equate a blending of formative assessment, student understandings and pedagogic strategies to Shulman's (1987) act of pedagogic reasoning. Duschl and Gitomer (1997) also declare that

> successful facilitation of assessment conversations requires a reasonable grasp of the subject matter being explored. ... Teachers also need to develop a clear sense of the conceptual terrain they are exploring and will also need to have a pedagogical sense of the likely understandings the students will bring to a domain (p. 66).

In contrast where teachers' subject knowledge is weak, their confidence levels to teach that subject are low. This leads to restricted classroom assessment practices inhibiting creativity and questioning (Harlen, 1999). Dunkin and Welch (1996) concur, positing that when teachers attempt to implement unfamiliar material more prescriptive, teacher-directed methods are adopted.

In a review of 600 research articles on curriculum, assessment and pedagogy, Carr, et al. (2000) argue that teacher knowledge of their subject, how students learn and the interaction of these two factors are essential to support learning. Good teacher knowledge of the content of their subject was found to have a positive effect on decisions to change pedagogical strategies for creating learning opportunities. In addition, sound content knowledge seems to have a positive effect on planning, assessment, implementation of curriculum and curriculum development. Sizmar and Sainsbury (1997) likewise argue that the centrality of teachers' professional knowledge links to the process of teacher assessment.

Teacher knowledge of the discipline is related to the use of various assessment processes, since it is crucial that a teacher has knowledge of the discipline to provide direction for learning. When teachers are unsure of their discipline's structure they are not well equipped to guide learning in it or assess that learning. Black (1995) cites the research of Simon and Jones with Fairbrother, Watson and Black (1992) where teacher-given feedback needs to reflect important aims, be criterion-referenced, and reflect well-founded knowledge of the sequences in which students learn for guiding and assessing learning.

The work of Black, et al. (2001) in formative assessment examined mathematics, science and English classrooms. Their findings support Grossman and

Stodolsky's (1994) view that subject disciplines create strong differences between the identity of teachers and how learning is undertaken in classes. They argue that the teacher, the subject and the student and their various interactions should be the focus in accounting adequately for what is going on. A focus on either the teacher or students in isolation is inadequate. They believe any model must take into account the features specific to different school subjects as the types of classroom interactions entailed in learning contexts of different subjects may not necessarily have a great deal in common with one another. There is a connection with Perrenoud's (1998) analysis of formative assessment needing to be understood in terms of a broader theory of teachers' classroom actions as a whole.

Duschl and Gitomer (1997) found teachers' science assessment practices were influenced by their views of science and how to teach science. Where they placed teaching emphasis influenced student learning. Often the tasks and the activities, rather than conceptual structures and scientific reasoning, dominated teaching perspectives. Steps focussed on activity were more readily mastered than those focussed on conceptual structures and reasoning.

2.3.3 PCK and assessment in technology

Understanding the nature of technology

To develop strategies for the assessment of technology, teachers require clear understandings of the nature of technology and the conceptual and procedural aspects of different technological areas (Jones, et al. 1994). Jones and Carr (1993a) propose that when teachers have a view of technology not consistent with the technology curriculum they are teaching, assessment becomes problematic. Technological areas, contexts, and the way related variables are identified and operationalised, affect the complexity of the task. Therefore Jones, et al. (1994) argue that students need to be involved with and assessed across a variety of areas, contexts and variables.

As the learning outcomes of the technology curriculum involve both knowing and doing, procedural and conceptual aspects are equally important in teacher and student formative interactions. Relying on one form of assessment may not offer

an acceptable way of assessing technology as both practical capability and technological understandings are integral components of technological activity. Ways of assessing the procedural and conceptual outcomes and using a multitude of methods need to be understood as emphasis on either conceptual or procedural aspects in isolation will distort student learning in technology (Jones, et al. 1994; Jones, with Hawe & Mather, 1995).

Teachers' roles, understandings about the nature of a subject, the way a subject should be taught and assessed and expectations of student learning in a subject are influenced by teachers' existing subject subcultures (Paechter, 1992). For example, Paechter indicated that ties between existing subject beliefs in craft design, home economics and art were transferred to technology education. Linblad (1990) likewise found that primary school teachers designed new technology classroom experiences based on past experiences. For example, art teachers transformed technology to a design course and science teachers remade it into a laboratory course. Jones (1999) also notes that teachers' classroom strategies are often positioned within that particular teaching and subject subculture. Subcultures directly influence the way teachers structure lessons, plan learning outcomes and develop classroom strategies. Further, they develop strategies to allow for learning outcomes, which more often closely relate to their existing subject subcultures than to technological outcomes. Sometimes they revert to learning outcomes of familiarity, such as discussion and debating skills in isolation from technological outcomes.

Holistic assessment

Jones, et al. (1994) argued for a holistic approach to assessment as a preferred method since technological activity is so integrative. Likewise Kimbell (1994, 1997) argued for student performance to be initially assessed holistically, followed by the identification of constituent strengths and weaknesses as it is important to see how the individual elements work together and how the complex interaction of capabilities affects performance. He believed the actual technological situation/performance needs to be assessed requiring assessment of the authentic or actual performance as it occurs rather than the assessment of isolated bits at the end, or at set times not part of the whole context. Often

assessment information gathered by teachers is untidy, incomplete and contradictory. Harlen and James (1997) believe that with the untidy, contradictory nature of assessment information, it means teachers need to look across the range of work of a student to judge the extent to which the profile as a whole matches in a holistic way. Professional judgement is required, as criteria cannot be so detailed and specific that their application is purely mechanical.

Evidence for some aspects of technology is highly ephemeral, hence a number of different approaches are required to explore and report upon students' technological capability. Traditionally, the permanent outcomes from a technological activity are the basis for judgements of technological capability. Kimbell, Stables, Wheeler, Wozniak and Kelly (1991) illustrate the problem of relying on making judgements only on permanent outcomes:

> If the technology folder contains a detailed account of how a questionnaire was designed and administered and evaluated then there is a good prima facie evidence that this pupil has some capability in the field of information gathering. But if the folder contains no such information, what does it prove? It does not prove that the pupil is incapable but neither does it prove that the pupil is capable. All one can say is that the case is unproven. (p. 236)

Criterion-referenced assessments have also been suggested as inappropriate, as criterion-referenced assessments are appropriate for achievements that are both reducible and definable (Jones, et al. 1994; Kimbell, 1994; Wiliam, 1998). These assessments suggest that teachers can make a prior overview judgement of what will be taught and that criteria can be pre-selected for assessment. Learning in technology is more than simply the sum of its parts; therefore progression is not a linear development of atomistic individual skills or knowledge or bits of procedural quality. Using sliding scales is preferable for describing student learning as achievement can be described as better and worse, improvement can be discussed, and a sense of quality developed (Kimbell, 1997). Therefore, constructs of holistic judgements are both more reliable and valid as they describe a balanced reflection of the whole of the student learning in technology backed by detail (Jones et al. 1994). Making holistic judgements involves subconsciously unpicking work to look for evidence of qualities and putting it back together again to see how the parts work together (Kimbell, 1997).

Wiliam (1998) argues that interpretation of student learning is referenced to shared constructs of quality that exist in well-defined communities of practice (Lave & Wenger, 1991). Quality is defined by the consensus of those making the assessments and the level of performance is not defined; rather appropriate inferences are exemplified. For example, where written statements merely exemplify the kinds of inferences that are warranted the assessment is construct-referenced.

Jones and Carr (1993a) additionally indicate a relationship between views of learning, teaching subcultures and views of assessment. Conflict may exist between holistic learning outcomes and construct-referenced assessment, and summative assessment focussed on a small number of objectives. The result could be students working towards itemised objectives rather than overall, integrated task goals. Eisner (1993) also argues for assessment that requires students to display sensitivity to configurations or wholes, not simply to discrete elements. Assessment in a construct-referenced context is holistic and embedded in the learning process. When the sequence of learning in the technological process is completed, holistic assessments also attempt to report the intentions, content and quality of the learning that took place (Jones, with Hawe & Mather, 1995). Kimbell (1997) agrees with holistic assessment and that to assess technology holistically, depends on understanding technology and understanding learning in technology.

2.3.4 Summary of PCK, its significance to formative assessment and relevance to this study

This study is underpinned by the view that pedagogical content knowledge is significant in the ways teachers teach and assess, as there are relationships between teachers' subject knowledge, how that is transformed for classrooms and assessment ability (Bell & Cowie, 1997; Black & Wiliam, 1998a; Sadler, 1998; Shulman, 1987). Carr, et al. (2000) found that sound teacher knowledge of the content of their subject has a positive effect on decisions to change pedagogical strategies that create learning opportunities. In addition, sound content knowledge has a positive effect on planning, assessment, implementation of curriculum and curriculum development. Shulman (1987) argued that teachers must learn to use

their knowledge base for decision making and what they are going to do. As well they must be able to transform the content knowledge so that it becomes pedagogically powerful. This study argues that assessment models are influenced by teachers' subcultures (Paechter, 1992) and must account for specific features of different subjects, as the types of classroom interactions of different subjects may not necessarily have a great deal in common with one another (Grossman & Stodolsky, 1994).

For teachers to be effective technology assessors, they require clear understandings of the nature of technology and the conceptual and procedural aspects of different technological areas (Jones, et al. 1994). As the learning outcomes of the technology curriculum involve both knowing and doing, procedural and conceptual aspects are equally important in teacher and student formative interactions. They need to devise assessment strategies to suit the intended technology purposes and activities (Eisner, 1993). Argued for is an holistic, construct-referenced approach to assessment since technological activity is so integrative and a balanced reflection of all student learning in technology backed by detail can then be undertaken (Jones, et al. 1994; Kimbell, 1994, 1997).

It is argued that the way the learning context is structured is a direct result of teachers' PCK and philosophy about how children think and learn (Fleer, 1999). Teachers of elementary and primary students therefore require an understanding of how young learners learn and make progress in technology. These aspects are attended to in Section 2.4.

2.4 Primary school students' learning technology

2.4.1 Introduction

The area of early childhood and primary school students learning in technological situations is under-researched (Anning, 1994; Fleer, 1999; Solomon & Hall, 1996) with most technology classroom studies based on snapshots of what certain students manage to do at certain ages while undertaking structured tasks

(Solomon & Hall, 1996). This study aims to fill some of the void related to young students learning technology in everyday classroom situations.

Technology is an important dimension of a child's curriculum (Jones & Carr, 1993a; Kimbell, Stables & Green, 1996) and should include organised experiences and some equity in opportunities (Stables, 1997). From very early years young children utilise their creative capacity to develop their technological capability (Carr, 1997) and so young students' school work in technology should build on their early explorations (Bottrill, 1995). Stables' (1997) contends that it is important to introduce technology to young students because their enthusiasm, curiosity and lack of inhibition creates optimum opportunities for development in technological activity. Additionally, the more they are engaged, the more they can establish confidence in their technological abilities. As well, technology education provides opportunities for developing problem solving skills and primary teachers have reported that technological activities are a valuable vehicle for fostering all types of learning (Jones & Carr, 1993a). The technological activity often promotes rich learning environments for a range of learning opportunities.

In planning, teaching and assessing technology, the literature indicates the need to consider a range of factors when enhancing young students' development. Section 2.4.2 outlines the iterative nature of undertaking technology tasks and section 2.4.3 details the importance of turning ideas into working realities. Section 2.4.4 describes the need to build an environment that will foster technology learning. An overall section summary is detailed in section 2.4.5.

2.4.2 Iterative nature of undertaking technology tasks

Fostering iteration

Teachers of young students need to foster an understanding of the iterative nature of the process people engage in when designing and making (Stables, 1997) so that when they work technologically they also work in a non-linear fashion (Anning, 1994; Jones & Carr, 1993a). To do this students need to think reflectively and projectively about the tasks they are undertaking and take action to turn ideas into working realities (Jones & Carr, 1993a; Kimbell, et al., 1991;

Kimbell, et al. 1996; Stables, 1992). Students need to work iteratively between developing 'thought' skills and 'action' skills (Anning, 1993; Benson & Raat, 1995; Kimbell, et al. 1996).

Language can be used to convey iterative thinking and when design ideas cannot be represented graphically or realised, language becomes the tool to express ideas. Anning (1993, 1994) examined students' evaluative language, and Solomon and Hall (1996) examined how knowledge of terms to label physical actions was necessary to work technologically. Both found that inability to express ideas inhibited technological progress. Medway (1994) goes as far as suggesting that the ability to use language is central to students' technological capability. Solomon and Hall (1996) found that primary teachers perceive student self-evaluation in technology as difficult because two acts are required, comparing products with original designs and comparing products with the purposes of the client's brief. They suggest that language of technological evaluation is required and is probably the key to linking thought to action in an iterative way.

Conceptual understandings and procedural aspects

Some believe practical activity is central to developing technological capability (Kimbell, et al. 1996; Stables, 1997). Stables (1997) commented how hands-on exploration builds on the approach very young children already have in finding out about their world. Kimbell, et al. (1996) found that hands-on exploration was a useful way for children to model design ideas and to develop iterative ways of thinking and working. Working directly with materials assisted students to think in 3 dimensions, to work kinesthetically with materials and to create designs by trial and error. This assisted students to enhance their understanding of the working properties of materials. However, many primary teachers see students struggle to create designs for artefacts and then link designing to making (Kimbell, et al. 1996; Solomon & Hall, 1996).

Several researchers acknowledge the importance of developing conceptual understandings alongside procedural aspects (Anning, 1994; Jones & Carr, 1993a; Kimbell, et al. 1996; McCormick, 1997). Research also indicates that

there are a number of problems associated with conceptual knowledge in a curriculum with a strong emphasis on procedural knowledge (Beynon, 1992; Bereiter, 1992; McCormick, Murphy & Hennessy, 1994). They indicate that students' inability to transfer between skills, processes and understandings and to work iteratively are obstacles in undertaking technological activities. The inability to utilise knowledge limits students' performance. Jones, et al. (1994) concur and they provide numerous examples of the difficulties students have in translating knowledge from alternative subjects to technological activities.

Often in technology classes the design process is treated as a series of steps (McCormick, 2000). This can be characterised as posing and thinking about the problem, clarification, thinking of alternatives, implementation and evaluation and can become ritualised with lessons structured around it. It is a ritual that does not affect student thinking. Students undertake the process, often tidying up portfolios or work after the event, as they are required to show the development of ideas. A 'veneer of accomplishment' is apparent (Lave, 1988).

Hence, how teachers' structure lessons strongly affects how students undertake technological processes (Jones & Carr, 1993a; 1993b). Teacher knowledge of the technological problem solving process students are engaged with is important. Advice is for teachers to work alongside students helping, guiding, prompting, providing feedback and direction, assessing and evaluating to help the students learn and to feed information back into the process (Jones et.al, 1994). For example, to enhance the iterative process between thinking, designing and making, students need to be cued by the teacher to think about materials before they start design drawings, to think about material qualities and to think about fixing and joining devices and mechanisms (Anning, 1994, 1997). It is about undertaking focussed design drawings with making in mind so that drawings can be used as useful reference points. Evaluation needs to be regarded as a key feature of the process linked to solving the defined problems (Jones & Carr, 1993a).

2.4.3 Transforming ideas into working realities

Students are encouraged to develop their mental images and ideas into working realities in technology education. Actualising ideas is an important aspect in young students' technological learning as this assists students to develop their ideas from hazy ideas in their heads towards tangible, working realities (Kimbell, 1994). Approaches to assist this in primary schools should not be dominated by approaches in secondary schools (Stables, 1997). The indiscriminate introduction of any strategy for primary school students, especially those utilised with older learners could be detrimental to their learning. For example, Stables (1995) found some evidence that primary students are doing better in developing autonomy and level of discussion than secondary students, so the need is to continue utilising primary approaches.

Students' perceptions are linked to their performances in technology (Burns, 1992, 1997; Jones & Carr, 1993b; Jones, et al. 1994), as strong links are evident between students' concepts of the nature of technology and their technological practice, including the learning and use of technological concepts and processes. Though little research has been conducted on students' understandings of technology concepts or technical knowledge, Davis, Ginns and McRobbie (2002), assert that an increasing awareness of students' understandings of design and technology concepts can impact on teaching and learning.

Research (Anning, 1994, 1997; Jones & Carr, 1993a) suggests that many teachers are unaware of the difficulties young students encounter when trying to envisage their thinking in 2 or 3dimensions. For example, young students often become confused between what is real and what is not when making models (Jones & Carr, 1993b). When making the real thing measurements, materials and equipment are considered, testing can be undertaken and modifications made. When model making, measurements and appropriate materials are often ignored and complicated components are included without appropriate explorations.

Drawing is also a minor mode of communication in primary schools and few teachers' model appropriate practices as in reading, writing and mathematics. Word and number-rich classrooms are taken as the norm, not so with drawing,

which is under-represented. Further, Anning (1997) believes teachers are confused about how to approach the teaching of drawing and are unsure of the role of graphicacy in promoting technological learning.

Developing designerly thinking

Kimbell, et al. (1991) describe the "recursive cycle from images generated in the mind's eye to their explication in speech, gesture, writing, models or drawing" (cited in Anning, 1997: 222) as the cornerstone of capability in technology. However, in a research project undertaken with 5 to 11-year-olds Anning (1994) found that teachers were uncertain whether students were capable of matching their imaginative abilities with representational skills. Difficulties included teachers not modelling drawing in front of students, drawing not usually being used as a tool to represent ideas and young students believing that drawing should be aiming for a perfect end product. Anning (1997) therefore advocates the need to introduce students to drawing in order to help them develop 'designerly thinking' and behaviours. She suggests that sketch pads, notebooks, annotated drawings, story-boards, orthographic drawings, architectural and engineering drawings should be part of a teacher's tool-kit as examples for fostering student designerly thinking and behaviours. Teachers also need to be skilled themselves with drawing or they cannot give guidance or appropriate feedback on how to improve. Then there is the added problem for primary technology teachers of interpreting what students mean by their drawings (Solomon & Hall, 1996).

Anning (1994, 1997) cautions about the technical limitations of students' ability to represent 3D shapes in 2D drawings, and believes it may be unrealistic to expect young students to draw before producing an outcome. Gura (1991) cited in Anning (1997) demonstrated that drawing after making ensured a fit between models and drawings and an understanding of the properties and dimensions of the materials used could be demonstrated. Another supportive strategy is student sketching of everyday objects from various viewpoints as this helps them to develop confidence in using sketches and to represent 3-dimensional objects in 2-dimensional form (Anning, 1997).

A significant factor for students to work successfully in technology contexts is their spatial abilities in working in 3 dimensions, and seeing how 2D shapes become 3D. Young students need to be able to design in their heads and then on paper how an artefact can best be constructed so as to serve its purpose (Solomon & Hall, 1996). Rogers (1998) found a weak link between students' design intentions and their subsequent constructions. However, when teacher support is provided students are able to show a strong correlation between what they intend to do and what they produce (Fleer, 2000). Her pilot study with children of 3-8 years examining young children's ability to design and then use their designs for making indicated well-developed representational skills with ability to draw their intended construction when supported by an informed teacher. To foster students' ability in realising design ideas teachers need a clearer understanding of how students' drawing ability develops (Anning, 1994). Solomon and Hall (1996) argue that students' drawing skills are learnt skills. Fleer (1992) demonstrates students' enhanced ability to draw and use designs in plan-view after direct teaching.

Teacher knowledge of designing is also significant. Davies (1996) in his classroom work with 9-and 10-year-old students found parallels between the ways in which young students design and professional designers. Both groups used play to develop ideas. The students also formed mental images of a perceived future as the result of concrete manipulation of objects. Both groups told stories about the people for whom they were designing to gain deeper insight into requirements. They used narrative language when discussing mental images of possible solutions in order to bring ideas into the public domain for analysis and refinement. Finally both used drawing and modelling to bring ideas into the open and drew on pools of personal knowledge of materials, techniques and forms. Students learned well in an apprenticeship model offered by the designer in the classroom. They refined and integrated their design skills and understandings through engaging with real design projects with real designers. Hill (1998) likewise believes technology classrooms should involve problem solving in real-life contexts using design processes.

Technical skills

Teachers need 'knowing how' procedural knowledge in order to better support students by correcting inappropriate behaviours and in fostering the correct use of appropriate tools (Anning, 1994). There is a need to give direct instruction in technical skills to assist student learning. Hidden dilemmas related to the status of practical work need to be addressed as teachers must acknowledge that procedural knowledge is not simply acquired by learning through doing, it needs to be planned for and taught. For example, young students need to be introduced to the different genres of drawing in order to develop useful designs (Anning, 1994; 1997; Fleer, 2000). To fast-forward students' technological capability teachers need to see planning and 2D design work purposes, include design work from multiple perspectives, include details of joining materials in designs and see the benefit of working in a non-linear process.

Planned opportunities for student interaction

Anning (1994) found that teachers rarely see and interact with students while they were working through technology tasks. This means teachers have little understanding of technological progression and learning. Equally problematic are overly constrained tasks as teacher over-specification leads to lack of student ownership and control (Solomon & Hall, 1996). Fleer (1999) believes that students should be setting the technological agenda, as this gives them more personal meaning and buy-in. Fleer's study, of two different groups of students designing and making cubbies, demonstrates the importance of open-ended approaches for fostering student task ownership and is consistent with the findings of Solomon and Hall (1996). Fleer also concludes that open-ended design briefs encourage students to work in an iterative manner.

2.4.4 An environment to foster technological learning

Focussed on educational development

For young students the focus in teaching technology must be on educational development rather than vocational needs. The importance of educators protecting children's rights to remain children is advocated (Stables, 1997, Fleer, 1999). The specifics of technological experiences of young children "should not be planned by looking at skills required for them to pass examinations at the end

of schooling, or to become mechanical engineers, architects or food technologists of the future" (Stables, 1997:6). Instead primary teachers should aim to develop general technological competencies through an integrative, holistic approach. This is likely to result in a greater potential to utilise technological capabilities in a broad range of settings (Stables, 1997). This is not to say that anything goes. Developing technological capability should be organised so students learn in terms of procedures, concepts and skills in a structured way rather than haphazardly (Anning, 1994).

Positive, supportive, challenging environment required

The classroom culture and student expectations influence the way students carry out technological activities (Jones & Carr, 1993a). McCormick et al. (1994) indicate the impact of classroom management, culture and teacher subculture on student learning. For example, though primary teachers advocate the importance of practical work, two-thirds of their time in working with students is involved with seat-based basic skills pointing to significant implementation problems for a subject such as technology, which is based on a heavy practical weighting (Anning, 1993). Gipps and MacGilchrist (1999) argue that teachers need to learn how to develop learners as thinkers and incorporate an understanding that all students can achieve. This belief is manifested through teachers setting high expectations for students. Effective primary teaching includes developing a good positive atmosphere in the classroom with plenty of encouragement and praise, high levels of expectations for all students and high levels of work-related talk and discussion.

An environment that is supportive and challenging fosters positive attitudes of self-esteem and motivation and these help to create the conditions in which technological capability can thrive. Students therefore need opportunities to work on tasks within their capability but at the same time stretch them, where risk taking and failure are seen as positive and beneficial. Activity should be driven by a need to know, where new material is introduced to children at the point they need it to further pursue their designing and making. It is vital for students to be engaged in designing and making that is within or just beyond their reach. This challenges students constantly to extend into new understandings in order to

achieve success (Kimbell, et al. 1996; Stables, 1997). Stables (1997) found that when students are given support to find out how things work, to make things work, and to create and express themselves they will have better chances to develop technological capability. Teachers as more knowledgeable and technically competent can assist student development through intervention and modelling of ideas and skills and thus accelerate students' acquisition of ways of representing meaning (Anning, 1997).

However, Anning (1997) reports that many teachers are reluctant to intervene in a direct way particularly when young students are engaged with drawing. For them intervention is seen as interfering with students' creativity. Eisner (1972) cited in Anning (1997) challenges this view, advocating that students' art is a process very much affected by previous experiences and their abilities are a function of what has been learned. Thus the role of the teacher has a direct influence on progressing student learning in graphicacy even though evidence suggests that art and especially drawing is often an unsupervised activity and accorded low status. In consequence students learn that improving "drawing is a self-help zone and that it is not valued as a tool for clarifying their thinking or recording their ideas" (Anning, 1997: 226).

In contrast, where teachers value student drawings and foster graphicacy through instruction, drawing becomes a powerful tool for students to make sense of the world. Anning (1997) cites an intervention programme, undertaken in Italy by Malaguzzi (1987), where students were encouraged to develop their intellectual abilities through various modes of symbolic representation. Recording ideas in graphic modes was not a one-off process, rather students were encouraged to revisit recorded work repeatedly to develop and reformulate ideas. This resulted in high levels of drawing competence. Anning (1997) also describes research undertaken in the UK by Cox, Eames and Cooke (1994) about negotiated drawing experiences with 5- to 7-year-olds. The negotiated drawing experiences facilitated by talk and adult demonstrations guided students through drawing real artefacts. Modest improvement in standards was evident. Both studies demonstrate the importance of an informed adult for fostering progress in student graphicacy skills.

Need to reflect principles of technology

Technological learning is enhanced when students are engaged with authentic activities (Brown, et al. 1989). This does not always happened in technology with many classroom approaches having students beginning from scratch, rather than reflecting actual technological problem solving, which usually involves modification and adaptation of existing technologies (Hennessy, et al. 1993). Research indicates that very few activities developed by teachers reflect principles of real technological practice (Jones & Carr, 1993a). McCormick (2000) declares two sides to authenticity. The first, culturally purposeful authenticity, is a reflection of the technology world outside the classroom, and the second, personal authenticity, is where the student is involved and the learning meaningful.

Some researchers advocate a topic-based approach for developing authentic activities as it lends itself especially well to the wide-knowledge base required for technology education. Technology experiences are often set in an environment where the work is handled in an integrated way, initiated by topics or themes (Solomon & Hall, 1996; Stables, 1997). Jarvis (1993) is also positive about the role of cross-curricular links for technology. Not seen as problematic she believes this allows students to appreciate the application of many cognitive skills in real situations. Kimbell's (1994) APU project recommends placing tasks in everyday contexts to give them more meaning for students. However, though agreeing with teaching in meaningful contexts, research by Jones and Carr (1993a) cautions against novice technology teachers teaching technology in an integrated way as teachers' more familiar subject subcultures then dominate technology and technology may be subsequently subsumed altogether.

Problem-solving culture

McCormick (2000) believes that when technology students encounter difficulties solving problems, teachers should foster student engagement with the problem to build a 'problem-solving' culture. This may be fostered, for example, by asking students' questions about the problem, or posing several alternative solutions for them to choose the one they consider to be the most suitable. On the other hand, when students receive the solution from the teacher without being involved in

solving the problem, a culture of continually being 'given solutions' becomes the norm at the expense of creating a 'problem-solving' culture.

A problem solving approach to technology is excellent for primary students as it is motivational and involves students in risk taking situations (Kimbell, et al. 1996). Waetjen (1993) also believes problem solving is an important skill for developing technological literacy. Problem solving facilitates task ownership, can be cross-curricula and enhances communication (Watts, 1991 cited in Parkinson, 2001). Problem solving can be group and socially based which benefits the sharing of ideas that then impact on the problem-solving situation (Lave & Wenger, 1991; Rogoff, 1995).

Stables (1997) believes that as young students are familiar with working collaboratively and individually in primary classrooms, technology education is a particularly effective learning area for them as it is a subject built around collaborative and individual ways of working. McCormick (2000) writes of three collaborative strategies that could be employed. First, students co-operate with each other while working alongside each other on similar individual tasks. Second, a task is divided up and involves collaboration, as the pieces have to come together at some stage. Third there is a shared task requiring reciprocal dialogue, more than one person to solve it and collaboration. Individual assessment regimes where students are required to have their own products and their own designs mitigates against such possibilities. McCormick concludes that teachers should be mindful of organising problem solving processes as well as collaborative opportunities. There is then a need for formative interactions to foster student problem solving and for detailed assessments to ascertain how students solve problems (Custer, Valesey & Burke, 2001).

Technology education should be conducted in a supportive atmosphere where students are encouraged to see the issues surrounding any technological decision and are involved in meaningful decision making. Teachers therefore need to involve children in problem-solving tasks where the value positions become clear to them and presented in a way to which they can relate (Stables, 1997). Stables' believes that to teach in context is to bring relevance to an activity and this helps

students take ownership of the activity. In technology the context is also a vehicle for bringing design ideas into the open. By considering the user considerations, for example, the task becomes richer and student decision making more meaningful. Likewise Solomon and Hall (1996) believe that knowledge construction in technology must be learnt in context as in these circumstances students develop tacit 'doing' knowledge.

2.4.5 Summary of primary school students' learning technology and relevance to this study

Though much of the literature reviewed relates to snapshots of what students do on structured tasks, rather than student learning in complex, extended classroom tasks, features drawn out include the importance of:

- focussing on educational development rather than vocational ends in a supportive, challenging environment with technological problem solving the focus
- fostering the iterative nature of tasks, between conceptual and procedural aspects and between stages in student technological problem solving,
- assisting students to realise ideas, working alongside them, directly intervening when needed, conversing and guiding them in their progress,
- promoting linguistic, conceptual and procedural understandings and skills, and
- fostering student self-assessment - prior to, during and after technological activity.

For students to confidently undertake self-assessment they need to develop understandings of their learning in technology so they can review their work constructively and critically (Harlen, 1998). The overarching model sees young children as active learners involved with synthesising abstract thinking and practical activity (Stables, 1997).

2.5 The research questions

The literature review found little that related to examining teachers' PCK in technology education and to teachers and students working on longitudinal technology tasks. Even less literature related to primary students' learning

technology as part of their usual classroom experiences. An examination of formative assessment literature showed that much was rhetorically based and little related to primary school technology teachers and their everyday interactions with students. The aim is to pull the three fields – PCK in technology, primary school students learning technology and formative assessment, together. Examined is the interrelationship between teachers' PCK in technology education and their formative interactions with their primary school students. This is examined in real classroom situations when the students were undertaking and solving extended technology problems.

The purpose of this study is to describe teachers' existing technology teaching and assessment practices, design and undertake an intervention programme to enhance teachers' views and practices, and then investigate any subsequent changes in teachers' views and practices. Student learning in technology before, during and after the intervention is investigated to examine the inter-relationships between teachers and students and the effects on student learning. To this end, the main research questions that guided data generation are:

> What are primary teachers' emerging planning, teaching and assessment practices in technology education? How do these influence student learning in technology?
>
> What can assist teachers to develop their teaching, learning and assessment practices in technology?
>
> In what ways does teachers' enhanced pedagogical content knowledge in technology impact on planning, teaching and assessment practices and especially their formative assessment practices? What is the impact on student learning?

In Chapter 3, the methodology used to generate data on teachers and students working in technology classrooms is outlined.

3. METHODOLOGY

3.1 Introduction

Chapter 2 supported the enhancement of primary teachers' practices in technology education as a legitimate topic for investigation. From this broad topic more specific justifiable fields for study emerged. These included: the development of teachers' pedagogical content knowledge to achieve enhancement of teachers' practices; the links between teachers' more informed pedagogical content knowledge base and formative interactions, especially effective descriptive feedback; and the links between enhanced formative interactions and student gains in technological understandings and abilities.

This chapter sets out the research methodology for undertaking such a study. Methodology is the theory of knowledge and the interpretive framework within which the research project develops (Lather, 1992) aimed at helping to understand the process of inquiry. It describes and analyses the methods used to gather data and guides the way that inferences, interpretations, explanations and predictions are made (Cohen & Manion, 1994). Research methodologies provide technical details of how problems were investigated and why (Bell, 1987) and make explicit the social context and the researcher's theoretical views and assumptions.

This study's research methodology is outlined in Section 3.2. Section 3.3 outlines the characteristics of the interpretive, mostly qualitative, case study method chosen. Also described are various methods for collecting and analysing data, ethical considerations, and accountability and generalisability issues. Section 3.4 provides an overview of the research design. Section 3.5 encapsulates the major chapter points.

3.2 Methodological paradigms for research

To research is to undertake more than a technical exercise for the task is underpinned with concerns related to gaining understandings of the world informed through particular world-views. Methodologies and methods are closely

tied to different views of social reality and how these should be studied (Bryman, 2001). As the aim is to understand and describe meaningful social action of teachers and students in primary technology classrooms, the most appropriate methodological stance to take is interpretive as understanding the subjective world of human experience is at the core of interpretive methodology (Cohen & Manion, 1994). The interpretivist epistemological position stresses "the understanding of the social world through an examination of the interpretation of that world by its participants" (Bryman, 2001: 264). A case has been made (Chapter 2) for technology education, formative assessment and the development of teachers' pedagogical content knowledge to be interpreted as context-related and socially situated activities. A necessity was therefore created for this research to be observed in natural settings and for teacher and student meanings to be taken into account (Bryman, 2001; Erickson, 1985; Maykut & Morehouse, 1994). Thus the ontological position taken is social constructivist, implying "that social properties are outcomes of the interactions between individuals, rather than phenomena 'out there' and separate from those involved in its construction" (Bryman, 2001: 264).

Interpretive methodology seeks empathetic understandings of human actions and participants' thinking, and attempts to interpret their actions and their social world from their point of view (Bryman, 2001). This imposes on the researcher an involvement with participants as knowledge is viewed as personal, subjective and unique (Cohen & Manion, 1994). When this study began in 1998 little was known about teachers and students in New Zealand primary technology classrooms with regard to their understandings and practices (Jones & Carr, 1993a, 1993b; Jones with Mather & Hawe, 1995; Moreland, 1998). So interpretive methodology that searches for ways individuals' create, modify and interpret their world (Bryman, 2001; Cohen & Manion, 1994; Maykut & Morehouse, 1994) was deemed a suitable approach. The methodology chosen emphasises a preoccupation with these aspects: seeing through the eyes of the research participants; description and context; process; flexibility and lack of a pre-determined structure; and concepts and theory as outcomes of the research process (Bryman, 2001).

3.3 Interpretive research design

With interpretive research a process of deliberate inquiry (Cohen & Manion, 1994; Miles & Huberman, 1994) builds a complex, holistic picture in natural settings (Creswell, 1998), in this case primary technology classrooms. It is appropriate in educational settings for both the researcher and researched are similarly concerned with daily classroom life (Erickson, 1985) and a process of dialogue is fostered where each brings insights to bear upon data. Multiple realities with people continually constructing and reconstructing meanings and actions are assumed. Therefore the knower and the known are interdependent; the world is co-constituted (Maykut & Morehouse, 1994) and the joint construction of meanings and actions are continuously negotiated and influenced by context (Denzin & Lincoln, 1994). A sense of rapport and a more reciprocal research relationship develops as a result of a more mutual focus (Alton-Lee, in Tolich, 2001).

Interpretive research seeks to understand all participants' intentions, motivations, actions and reasons (Robottom & Hart, 1993). The intent is to uncover and understand details so a detailed view of the topic (Creswell, 1998) is presented. People (in this case myself the researcher, teachers and students) continuously negotiate, jointly construct meanings and actions and are context-influenced. The need to examine situations through more than the researcher's eyes becomes crucial. The eyes of participants are valued and assist in gaining deeper understandings of different situations (Cohen & Manion, 1994). Hence, 'thick descriptions' (Geertz, 1973, in Cohen, Manion & Morrison, 2000) are essential, as reality is viewed as multi-layered and complex.

The interpretive researcher works directly with everyday experiences and understandings to build theory on the research data gathered (Glaser & Strauss, 1967 in Cohen, et al. 2000). An inductive view is taken of the relationship between theory and research, whereby the former is generated out of the latter (Bryman, 2001). The researcher aims to understand how interpretations of reality generated from one situation and time compare with different situations in

different times. The theories become sets of meanings, which yield insight and understanding of people's behaviour (Cohen, et al. 2000).

The research process is also flexible and responsive, as data gathering and analysis are ongoing and interactive (Guba & Lincoln, 1989) and the study may change over time in response to researcher and participants' perceptions and understandings and events (Erickson, 1985). With this study being longitudinal, developmental aspects impinged. This is not just a study that describes and interprets what is (Cohen & Manion, 1994); it also focusses on descriptions and interpretations of change. Overlaid is a tendentious perspective aimed to create change and action (Creswell, 1998). The main considerations when undertaking interpretive research therefore are multiple perspectives, multiple data gathering methods, ethics and ways of ensuring trustworthiness of data generation and analysis.

3.3.1 Multiple perspectives

With interpretivist methodology there are multiple interpretations of, and perspectives on, events and situations as it is assumed that reality is known imperfectly (Cohen, et al. 2000; Robottom & Hart, 1993). People are viewed as intentional participants and all perspectives are of interest (Erickson, 1985). A commitment to seeing events and the social world through the eyes of the people being studied is essential in order to interpret that world from the perspective of the participants (Bryman, 2001). This allows the researcher to take advantage of the interplay of multiple perspectives to enrich and verify the interpretation of data. The researcher's voice does not become "the sole authoritative commentary on a frozen image of educational practice" (Alton-Lee, 2001, in Tolich, 2001: 90). Including multiple perspectives means teachers and students speak for themselves (Maykut & Morehouse, 1994) and due weight is given to their interpretations (Denscombe, 1995). It means that a process of dialogue is necessary for both researcher and participants to bring their insights to bear upon the data (Alton-Lee, 2001 in Tolich, 2001; Creswell, 1998).

The researcher is a participant in the interpretive process, directly involved in the data generation (Bryman; 2001; Guba & Lincoln, 1989; Miles & Huberman,

1994) and taking a variety of connected, subjective positions from an observer to an internal participant (Robottom & Hart, 1993). Values are embedded in the research, the topic, in the way the researcher examines the topic and in the researcher herself (Maykut & Morehouse, 1994). Hence reflexivity on the part of the researcher is essential in acknowledging her central position in the research, the implications and significance of methods, values, biases, decisions and even presence in the investigated situations. Researcher biases and assumptions and how these may have influenced subsequent findings require reflective examination. Attempts are made to explicitly consider design, process and personal experience of undertaking research in a critical, reflective and ongoing process (Banister, Burman, Parker, Taylor & Tindall, 1949; Bryman, 2001). Discussing this study with colleagues and an advisory group assisted in extending and challenging my ideas, to maintain high quality personal awareness and to gain a balance between participants' and my understandings.

This interpretive study is also coupled with notions of change, as I aimed to explore the participant teachers' developing views of technology and technology education over two years. Of significance were my various research positions whereby not only an account was sought of existing classroom practice in technology, but also a negotiated intervention was undertaken to challenge and transform the existing situations. Collaborative methods were therefore included, as the participants had direct input into the teacher development programmes they undertook. This was not a bystander view of research with the researcher removed from everyday classroom reality. Rather, I was submerged in the research working alongside the teachers undertaking different roles in different situations. Attending to teacher and student perspectives enhanced the ecological validity of the study, as this assisted to ensure that variables present in the 'real world' were present in the research setting (Banister, et al. 1994).

3.3.2 Multiple data generation methods

This section describes the multiple interpretive methods used in the research. Methods are techniques for gathering empirical knowledge (Lather, 1992) and "the range of approaches used to gather data which are to be used as a basis for inference and interpretation, for explanation and prediction" (Cohen, et al. 2000:

44). They are methodological tools used to look for contextualised accounts of everyday life from the inside (Miles & Huberman, 1994).

In this study data generation was ongoing, undertaken over two years, and conducted in the natural settings of classrooms and teacher professional development workshops. Data analysis was also ongoing and undertaken over a longer timeframe of five years. The generation and analysis of data were undertaken in an iterative manner, with the analysis of data often informing subsequent data generation phases. Flexibility in data gathering methods was essential as perceptions and understandings of events altered throughout the research process (Cohen & Manion, 1994). The methods used included interviews, conversations, participant observations and documents. This multi-method form of research was encapsulated in a case study approach. The principles of case study are first examined followed by the data collection forms of interviews, participant observation and documents and records.

Case Study

Case study is one type of qualitative research, although it can also be quantitative, and has been described as an "umbrella term for a family of research methods having in common the decision to focus inquiry around an instance" (Bell, 1993: 8). It focuses on a few instances of a particular phenomenon with a view to providing an in-depth account of events, relationships, experiences or processes occurring in those instances (Denscombe, 1998). It is an intensive, holistic description and analysis of a single unit or bounded system such as an individual, event, group, intervention, or community (Merriam, 1998). It also encompasses the systematic collection of evidence, the study of variable relationships and the involvement of methodical planning (Cohen & Manion, 1994). The single most significant characteristic of case study lies in defining the object of study, the case. One can 'fence in' what is going to be studied (Merriam, 1998). Miles and Huberman (1994) describe the case as "a phenomenon of some sort occurring in a bounded context" (p. 25). In educational situations, the case study is often concerned with the understanding of educational action to enrich the thinking and discourse of educators (Bassey, 1999).

Case study is concerned with depth rather than breadth; attends to the particular; attends to relationships and processes; takes a holistic view to gives insights into particular instances, events or situations; and is conducted in natural settings emphasising multiple data sources (Cohen & Manion, 1994; Denscombe, 1998). Situations, behaviours, artefacts and events are not artificially generated; rather they are in the natural settings under study with no deliberate manipulation of variables (Banister, et al. 1994). In this case, all research settings were as 'real world' as possible to ensure ecological validity. There is then the possibility that the findings of this study may be "extrapolated to a wider population than the sample being used in the study and if the findings are to be generalised beyond the particular situation constructed by the researcher" (Brunswik, 1947, in Banister, et al. 1994: 5).

As a step to action, insights generated in case study may be directly interpreted and put to use by others involved with education. People who wish to 'do something' can be guided by the findings of the case study (Cohen & Manion, 1994). Presented in readily accessed forms, case study reports are capable of informing multiple audiences and making the research process itself accessible. It therefore provides an ideal method for this particular study which was situated in the context of technology education and primary classrooms. It is also preferred for its suitability for an individual researcher and for its best-fit for an in-depth study of the small group of nine teachers from two schools over two years. The aim is to gain insights by looking at individual cases that may then have wider implications – to illuminate the general by looking at the particular (Denscombe, 1998).

The strength lies in the attention to the subtlety and complexity of the case in its own right (Cohen & Manion, 1994). A case study studies in detail, in order to discover things that might not have become apparent through more superficial research (Denscombe, 1998). Criticisms of case study include the difficulty of cross-checking such information and that generalization is not always possible. However, Bassey (1981 in Bell, 1987) makes the point that the merit of case studies is the extent to which details are sufficient and appropriate to which teachers can relate. Relatability is more important than generalisability.

As case study is a social process (Burgess, 1982) where participant meanings are considered significant, participants' own accounts are important. Individual perspectives, personal constructs, and explanations of situations are sought and the particular meanings that the participants give to their subjectively structured world are taken into account (Cohen & Manion, 1994). Participants are considered to be partakers, rather than objects of study. Feeding back information quickly to participants accesses their interpretations, as enlisting their responses strengthens the case. The focus is on interconnected and interrelated relationships and processes. Case study offers the chance to go into sufficient detail to unravel complexities of given situations and deals with the case as a whole, examining how parts affect one another (Denscombe, 1998).

An aspect of case studies is the freedom to alter the design. This study was flexible. For instance, the content of the workshops altered in accordance with the progress teachers made. Research questions were also refined and redefined in the light of preliminary and ongoing data gathering. As data collection and data evaluation occurred at the same time, analysed data were used to refine different stages of the study. Of particular significance were the findings generated from 1998 data, as these formed the basis for the teacher professional development programme undertaken in 1999 and the focus of subsequent data collection. As well the findings from 1999 teacher development workshops and classroom studies were continually taken into account to inform the ongoing professional development process and the ongoing generation and collection of data. The research process was dynamic rather than fixed. Several features mark this study as an appropriate case:

- The cases for study are identified - primary technology teachers and their students.
- The case has clear boundaries - bounded by time (2 years data generation and collection), place (primary school classrooms) and subject (technology education, pedagogical content knowledge and formative interactions).
- Time is spent describing the context and settings - the cases being situated in primary technology classrooms and specifically examining teachers' pedagogical content knowledge, formative interactions and student learning.

- Extensive, multiple sources of information in data generation and collection are used to provide the detailed in-depth picture of teaching, learning and assessment of technology education.

Interviews

The interview has been described as a conversation with a purpose (Lincoln & Guba, 1985; Maykut & Morehouse, 1994; Merriam, 1998). From an interpretive perspective the use of interview sees the centrality of human interaction for knowledge production, and emphasises the social situatedness of the research data (Kvale, 1996, in Cohen, et al. 2000). Knowledge is constructed between the participants; therefore data are generated rather than collected. Interviewers enable participants to discuss their interpretations and express their ideas from their point of view (Cohen, et al. 2000). It is discourse shaped and organised by asking and answering questions and a joint product of what is talked about (Mishler, 1986, in Bell, 1987). The interview reveals rich material, although it is time-consuming, a subjective technique and there are difficulties with classification and analysis of responses (Bell, 1987).

In qualitative, interpretive studies interviews range in type on a 'continuum of formality' (Grebenik & Moser, 1962:16 in Bell, 1987) from unstructured to highly structured. They can be informal conversations instigated and controlled by the participants (informant interviews) or very formal, highly structured and controlled by the interviewer (respondent interviews) (Powney & Watts, 1987). In respondent interviews a pre-conceived set of specific, closed questions are asked and researchers' issues are the most important. An interview schedule is typically given and very often a fixed range of answers is offered. On the other hand, informant interviews provide more insight into participants' perceptions as they allow prolonged engagement with interviewees. Interviewees are typically interviewed more than once fostering a deeper understanding by the researcher of their perceptions of the phenomenon under study (Maykut & Morehouse, 1994).

Qualitative/informant interviews are typically referred to as depth or in-depth interviews (Lincoln & Guba, 1985) and were used in this study to gain understandings about teacher understandings and practices and student learning

in technology education. Of importance were opportunities afforded by informant interviews to follow up on unexpected results and probe reasons for participant responses. They allowed for participant personal perspectives to be explored (Cohen & Manion, 1994).

Both semi-structured and less structured forms of informant interviews may be used. Semi-structured interviews are those where the questions are flexibly worded and there is a mix of more or less structured questions. When specific information is required from all participants, a highly structured form of interviewing is undertaken. But the largest part of the interview is guided by a list of questions or issues to be explored and neither the exact order nor wording of the questions is determined ahead of time. This form allows the researcher to respond to the situation at hand, to the emerging worldview of the interviewee, and to new ideas on the topic (Merriam, 1998). Semi-structured interviews imply a focus.

In contrast, unstructured, informal interviews are very useful when the researcher does not know enough about the phenomenon to ask relevant questions. There is no pre-determined set of questions and the interview is essentially exploratory. One of the goals is to learn enough about a situation to formulate questions for subsequent interviews. They are often used in conjunction with participant observation in the early stages of case study (Merriam, 1998). The issue is one of fitness for purpose, as the more a researcher wishes to acquire unique, personalised information, as opposed to more standardised and quantitative data, the more one veers towards qualitative, open-ended, unstructured interviewing (Cohen, et al. 2001).

In-depth interviews are useful for better understanding participants' educational experiences as they enable depth of conversation that moves beyond surface talk to rich discussions of ideas and feelings. Prolonged engagement with the interviewee is usual, permitting the interviewer opportunities to establish rapport and foster a climate of trust. Additionally, the interviewee may be interviewed more than once, as was the case in this study. This allows follow-up interviews to pursue topics that emerge from earlier data analysis. Persistent involvement

makes it more likely that the researcher will come to understand at a deeper level (Maykut & Morehouse, 1994).

Both unstructured and semi-structured interviews are flexible in approach with emphasis on how the interviewee frames and understands issues and events. There is room to pursue topics of particular interest to the interviewee, where they might raise additional or complementary issues (Bryman, 2001). The interview programme for this study did not adopt a rigid pre-determined set of questions and prompts; rather an open-ended discursive form of interviewing was adopted (Beardsworth & Keil, 1992, in Bryman, 2001).

Individuals and groups may be interviewed. Individual interviews are the most common form of semi-structured and unstructured interviews, involving a meeting between one researcher and one informant (Denscombe, 1998). They are relatively easy to arrange, individual's expressed opinions and views are prioritised, specific ideas are located with specific individuals, only one person's ideas need to be grasped and only one person needs guidance through the interview. Individual interviews can also be kept confidential. In contrast, group interviews are harder to manage, with the possibility that one person could dominate others' views and the opinions expressed may be those most acceptable to the group. However, they do have the advantage of interaction where discussion operates at the group level (Denscombe, 1998). They are used to explore how members of a group discuss certain issues, how they respond to each other's views and the joint construction of meaning (Bryman, 2001). They have been deemed suitable for interviewing children (Graue & Walsh, 1995), as children are used to working with friends and the interviews become more like conversations.

Interviews introduce a number of methodological difficulties especially when the interviewees are young children. Carr (2001) writes of the sensitivity and creativity required for interviewing young children to help them feel comfortable, confident and at ease. Young students may lack the language to explain their thoughts (McGee-Brown, 1995; Pollard, Thiessen & Filer, 1997). Carr (2001) used two devices to assist in overcoming such obstacles, including using an

object as a talking focus and the use of open-ended questions, which give control of the topic to the students. Bell (1995) also suggests that it is important to ask genuine questions. Both open-ended, genuine questions were asked and students always had their work as a focus while being interviewed in this study.

An unavoidable issue with interviews is that they take place after the event (Mehan, 1974). This means that the researcher relies on participants' recall ability and their willingness to provide bona fide accounts of their thoughts and experiences (Cazden, 1986). To increase the faithfulness of the data generated, interviews were undertaken as soon as possible after events (Cooper & McIntyre, 1996).

On-the-spot conversations between the researcher and participants may also be held where participant perspectives are sought in naturally occurring situations (Bryman, 2001, Carr, 2001). To understand participant thinking, conversation is treated as action, as situated discursive practice (Cohen, et al. 2000). Carr (2001) posits that adults and students facilitate learning and development by revealing to each other understandings about learning, what the topic is, what the intention is, and whose views are of value. Hence analysis of shared classroom talk and conversation was undertaken.

Relying on interviews and classroom conversations alone gives relatively fleeting contact with participants and the research becomes wholly dependent on what is said (Bryman, 2001). To increase the trustworthiness of data generated and to buttress the findings, other methods of data gathering were used to access important areas not amenable to interviewing and conversation. These were observation and document analysis.

Observation

At the heart of every case study lies a method of observation (Cohen et al. 2000). Participant observation in qualitative research entails the prolonged immersion of the observer in a social setting in which she seeks to observe the members of that setting, to elicit meanings attributed to their environments and behaviour and to explore the situated experiences of others. Prolonged immersion equips researchers to better 'see as others see' as they are in close contact with others for

long periods of time and often participate in many of the same kinds of activities as the members of the social setting being studied (Bryman, 2001, Denscombe, 1998). Preserving the naturalness of the setting is the key priority for participant observation (Denscombe, 1998). Extensive contact allows the context of people's behaviour to be mapped out fully and because people interact in a variety of different situations and often with different roles, links between behaviour and context can be forged (Bryman, 2001, Cohen, et al. 2000).

Participant observation assists the researcher to explain the social world of the classroom and the shared meanings that are established and maintained. It discloses things through the researcher's experiences of participating in the culture or event. The aim is to get insights into cultures and events through participating (Denscombe, 1998). Advantages include the researcher being able to discern ongoing behaviour as it occurs and being able to form more intimate and informal relationships with those being observed (Cohen et al. 2000).

Emphasis is placed on depth rather than breadth. Data produced reflects detail, subtleties, complexity and interconnectedness of the social world investigated. Attention is placed on the routine as well as the special and on holistic understanding. Things are also examined in relation to their context. Therefore, participant observation produces valid data (Denscombe, 1998). In this study my role was participation as observer, where my researcher identity was openly recognised. I followed teachers and students through their technology classroom lives and saw at first hand their technology experiences.

An adult researcher in a school is always identifiable and this may disrupt the naturalness of the situation (Denscombe, 1998). The participant observer attempts to enter the lives of others, 'to indwell', in Polyany's term (Maykut & Morehouse, 1994). Therefore it is necessary to build rapport and to establish open and honest exchange. Acceptance becomes the key issue for inquiry especially into student perspectives (Ball, 1984). Building a trustworthy relationship with students takes time and so educational research is often long-term (see for example Alton-Lee, 2001; Bell & Cowie, 1997; Jones, 1991). In this study each class was observed over two years during three separate technology units. This meant I was in each

classroom for ten to fifteen weeks. In addition, I carefully monitored my actions with students, their reactions to me, and I sought feedback from their teachers about how students were reacting to my temporary presence in their lives.

Observations may range in type from unstructured to structured (Cohen, et al. 2000). Unstructured observation does not entail the use of an observation schedule but aims to record in as much detail as possible the behaviour of participants, with the aim of developing a narrative account of that behaviour. It has the potential to uncover unexpected topics or issues. In structured observation a clear focus is used to assist the observer to know exactly who and what is to be observed and which aspects of the setting are to be observed (Bryman, 2001). In this study, like many studies in natural surroundings of the school (Cohen, et al. 2000), unstructured observations were all conducted within classrooms aimed at forging a naturalistic emphasis on teachers and students in the social setting of technology classrooms. As much as possible I wanted to see through teacher and student eyes.

Different degrees of researcher involvement were employed. Three membership roles predominate in observational research: the complete member researcher, the active member researcher, and the peripheral member researcher (Adler & Adler, 1987, 1994). Two styles were used in this study: peripheral member researcher and active member researcher. Peripheral membership roles are where the researcher observes and interacts closely enough with participants to establish an insider's identity without actively participating in the activities. Active membership roles may also be employed when the researcher becomes very involved with participants and the researcher becomes a participant. Often recordings are not made and notes remain unwritten until after the event.

The presence of a participant observer may result in reactive effects where people's knowledge of the fact that they are being observed may make them behave less naturally. Typically though, the longer a participant is around, the more likely people will become accustomed to the researcher's presence and begin to behave more naturally (Bryman, 2001). In this study two years of

involvement helped me become 'part of the furniture'. In consequence, ease developed between teachers, students and myself.

Dangers of bias are inherent in participant observation. Though difficult to eliminate, researcher awareness of bias is a step towards rejecting pre-conceived ideas and prejudices (Bell, 1987). Additionally, involving others in observations and comparing notes afterwards provides a check on interpretation of events. In this study another researcher frequently accompanied me in classrooms and we conversed and compared notes afterwards in an audit and review process.

Techniques employed in participant observation include videotaping, audiotaping and field notes. Audiotaping allows for the voices of the participants to be recorded, is less distracting and more mobile than videotaping. Field notes are flexible and unobtrusive and though not able to record everything they produce a permanent record of events.

In order to learn about the details of any situation a process from broad observations to specific observations can be used (Denscombe, 1998). First, getting a general feel for the situation as a background scene-setting device maybe used. A move to increased focussed observation can then be employed to more closely scrutinise specific things. Special observations maybe undertaken when attention needs to focus on unexpected things and at issues and problems identified by participants.

Though recording observations may be onerous, it is necessary for later analysis. Lofland (1971, in Cohen, et al. 2000) advise that notes need to be recorded as quickly as possible after observation to avoid forgetting information. Full notes should be written so that reasonably vivid pictures of any described event can be later recalled. Notes may also be recorded at the same time as observing, rather than just after the event, to increase the authenticity of what is being observed. On the spot and after-the-event notes were recorded in this study.

Document review

Documents maybe collected for analysis as an additional data source to supplement information obtained through interviews and observation and to support trustworthiness of findings. Document is an umbrella term used to refer to a wide range of written, visual, and physical material relevant to the study at hand (Bell, 1987; Merriam, 1998). It covers a wide range of kind and source (Bryman, 2001). A broad interpretation of document is taken for this study, as all recorded work produced by teachers and students during the course of the period under study are included. These documents are research-generated documents; documents prepared by participants once the study has begun (Merriam, 1998).

Documents can be divided into primary and secondary sources. Primary sources are those that come into existence in the period under research (eg. student work, teacher's planning). Secondary sources are interpretations of events of that period based on primary sources (Bell, 1987). In this study primary sources were used.

Documents are derived from different sources and locations (Bell, 1987). In this study they were derived from three locations – personal and school (both local sources), and state (national source), although personal documents were the most heavily sourced. Personal documents were both written (eg. teachers' planning, worksheets and assessment recordings; workshop recordings; student work) and visual (photographs of student work; student diagrams, drawings and artefacts; teacher diagrams, charts and drawings). School documents included policies and school plans, and state documents included national curriculum documents and Education Review Office records.

Particular documents are chosen because of their quality, including reading and analytical quality, being natural and being relevant to researcher concerns (Bryman, 2001). Four criteria were used to assess the quality of the documents. Criteria included authenticity in origin, as documents were gathered in situ; genuineness, as they were not forged; representative, as the evidence was typical of their kind, and their meaning was comprehensible (Scott, 1990, in Bryman, 2001). The documents were deconstructed and categorically analysed through examining words and visual images (Denscombe, 1998).

In review, interpretive case study research uses multiple methods. In order to understand the case in its totality and to provide an intensive, holistic description of the case, breadth and depth of data collection is warranted. Multiple methods undertaken in a recursive, interactive process add to the richness and trustworthiness of the data, which are generated and gathered through multiple sources.

3.3.3 Data analysis

Qualitative research tends to be associated with words rather than numbers as the units of analysis. It relies on transforming information from observation, interviews, reports and recordings into the form of written words and is associated with description. The specific, intricate description of events and people provides the reader with sufficient detail to judge whether the researcher's interpretation of the phenomenon is justifiable and relevant for other circumstances (Denscombe, 1998). For the qualitative researcher a vast amount of time is usually taken to analyse results from large amounts of data. Rather than isolating variables, viewing things in context and stressing the relationship and interdependence of data are important. A naturalistic approach is taken to data analysis whereby social "realities are wholes that cannot be understood in isolation from their context, nor can they be fragmented for separate study of their parts" (Lincoln & Guba, 1985: 39). The analysis is rich in the context of the case and settings in which the case presents itself (Merriam, 1988, in Creswell, 1998).

An inductive approach to data analysis characterises qualitative research. As hypotheses are not generated a priori, relevant variables for data collecting are not predetermined. What becomes important to analyse emerges through inductive reasoning about the data. A qualitative approach to analysis also emphasises an emergent research design approach. Data analysis begins early and is an ongoing research activity, where results from early data analysis guide subsequent data generation and collection efforts (Maykut & Morehouse, 1994; Merriam, 1998). Data collected requires transferring into readable forms (eg. transcribing interviews) for analysis. Coding may be employed to assist with source identification and to preserve anonymity.

A researcher's journal and observer comments may be used and from the beginning ideas, questions and thoughts can be recorded. A form of note making may be employed where observer comments are written beside field notes (Creswell, 1998). This shows the first steps in qualitative analysis 'discovery' (Taylor & Bogdan, 1984 in Maykut & Morehouse, 1994) and is a step towards more formal analysis. Other general data analysis strategies include writing reflective passages throughout the study and drafting summary sheets of field notes (Huberman & Miles, 1994). Working with other researchers also facilitates data analysis, as feedback on ideas and insights are fostered adding to the credibility of the study. In addition, the checks and balances involved with team-based data analysis increases the trustworthiness of analysis (Lincoln & Guba, 1985).

Holistic analysis of the whole case, as well as an embedded analysis of specific aspects, may be undertaken (Yin, 1989, in Creswell, 1998). Analysis may begin with an analysis of themes and issues and an interpretation of assertions about the cases. Themes and issues from the literature may assist in this process. Two stages of analysis can be undertaken – the within-case analysis and the cross-case analysis (Merriam, 1998). For the within-case analysis, each case is treated as a comprehensive case in and of itself where a detailed description of each case is conducted. Cross-case analysis can then be undertaken to explore relationships and patterns to assist in synthesising findings from the individual cases. Next integrating data and interpreting meanings of the cases yields an understanding of the people and settings being studied (Creswell, 1998; Maykut & Morehouse, 1994). Attempts can be made to build a general explanation and draw abstractions across the cases. This two-stage method of data analysis leads to categories and themes that abstract data from all the cases (Merriam, 1998).

After all data has been generated and collected and the analysis completed, the research is written up. In writing about the research additional analytical work is undertaken as analysis-through-writing can clarify themes and patterns. Thinking about how to report the substance and sequence of the findings requires rethinking the data and may reveal new insights and understandings (Maykut & Morehouse, 1994). This finally leads to the reporting of the 'lessons learned'

(Lincoln & Guba, 1985) and the making of naturalistic generalisations (Creswell, 1998) from the case.

In review, an inductive, naturalistic data generation and collecting process focussing on an emergent design approach coupled with holistic and thematic analysis underpins this interpretive research.

3.3.4 Ethical considerations

Qualitative researchers face many ethical issues requiring serious consideration as meanings constructed for the study arise out of the trust and rapport developed between the researcher and research participants (Ball, 1984; Walsh, Tobin & Graue, 1993). Mutual respect and confidence between researcher and participants is needed for good research. Open and honest interaction assists with this development (Banister et al. 1994). Ethical principles underpinning social research include: whether there is harm to participants; whether there is a lack of informed consent; whether there is an invasion of privacy; and whether deception is involved (Diener & Grandall, 1978 in Bryman, 2001).

The researcher has responsibility to anticipate and guard against consequences for research participants which can be predicted to be harmful and to consider carefully the impact of the research experience (Bryman, 2001). Informed consent, confidentiality and protection from harm are examined and negotiated throughout the research, not just at the beginning stages, as the research design and participants involvement may alter throughout (Alton-Lee, 2001; Banister, et al. 1994; Bryman, 2001; Cohen, et al. 2000). Data derived from participants and used in research must be known and agreed by them (Bell, 1987). Data collection and use should not be surprising to participants. No deception should be used (Bryman, 2001).

When young students are involved in the research ethics are particularly important (Alton-Lee, 2001; Bell, 1987; Carr, 2001; Cohen, et al. 2000). For example, informed consent should be gained from both the adults responsible for students and the students themselves. Students should be given a real and legitimate opportunity to say they do not want to take part. If they wish to

withdraw, they should not be questioned, their actions not recorded and no aspect or reference should be included in the research report (Cohen, et al. 2000). Fine and Sandstrom (1988, in Cohen, et al. 2000) comment that age should not diminish rights, although students' level of understanding must be taken into account in the explanations shared with them.

Methodological and ethical issues are inextricably interwoven in qualitative, interpretive research. The key lies in establishing good relations (Cohen, et al. 2000).

3.3.5 Ensuring trustworthiness of data generation and analysis

Alternative criteria from the traditional criteria of reliability and validity for judging and evaluating qualitative research may be discerned. The simple application of reliability and validity to qualitative research presupposes that a single absolute account of social reality is feasible (Bryman, 2001). In quantitative research the search for validity and reliability rests on the assumption that it is possible to replicate good research (Banister, et al. 1994). Guba and Lincoln (1989) are critical of this view and argue that there can be more than one and possibly several accounts of the social world and therefore it is necessary to specify alternative terms and ways to establish and assess the quality of qualitative research. Creswell (2001) agrees, positing that verification is a more suitable term than validity. Verification is a distinct strength of qualitative research in that the account made through extensive time spent in the field, the detailed thick description and the closeness of participants in the study all add to its value. Qualitative research should be authentic and trustworthy (Guba & Lincoln, 1989; Maxwell, 1992, in Bryman, 2001). A number of verification procedures contribute to the authenticity and trustworthiness of the research. For authenticity, procedures should ensure that the account:

- is factually accurate in that it is about what actually happened;
- has captured the meanings, interpretations, terms, intentions that situations and events have for the participants;
- has explained the theoretical constructions of the research; and
- has generated theory useful for understanding other similar situations (Bryman, 2001).

Several procedural aspects verify the trustworthiness of research. These include using multiple methods of data collection and member checking for enhancing credibility; building an audit trail and working with a research team for enhancing dependability; and finally working in depth to enhance transferability (Lincoln & Guba, 1989). Each is discussed.

The combination of different methods of data collection increases the likelihood that data will be understood from various points of view and ways of knowing. Qualitative researchers understand and welcome the opportunities for others to supplement their account. There is always a gap between the meanings that appear in the research setting and the account written, and that gap is space for a reader to bring their own understanding of the issue to bear on the text (Banister, et al. 1994). In triangulation, researchers make use of multiple and different sources, methods and theories to provide corroborating evidence. This process involves substantiating evidence from different sources to shed light on a theme or perspective and adds to the study's credibility (Cohen, et al. 2000; Creswell, 1998; Miles & Huberman, 1994). Convergence of themes, patterns and ideas derived from a variety of data sources lends strong credibility to the findings (Lincoln & Guba, 1989).

Member checking is an essential part of qualitative research and refers to the process of asking research participants whether an accurate description of their experience has been written. Participants can check data and interpretations, correct factual errors, add further information and summaries. Seeking participant feedback enhances credibility (Cohen, et al. 2000; Guba & Lincoln, 1989). Working with a research team also assists in confirming the adequacy of the analysis, assesses whether proper procedures have been followed and assesses the degree to which theoretical inferences are dependable and justifiable through peer or external audit (Creswell, 2001; Lincoln & Guba, 1989; Miles & Huberman, 1994).

Working in depth produces thick description (Geertz, 1973), that is rich descriptions of the details of a culture (Bryman, 2001). Thick description allows others to make decisions regarding transferability (Lincoln & Guba, 1989;

Merriam, 1998) as participants and contexts are described in detail and others can decide whether findings can be transferred because of 'shared characteristics' (Erlandson, Harris, Skipper & Allen, 1993, in Creswell, 2001).

In retrospect, qualitative, interpretive research draws on the interpretive skills of the researcher. The interpretation is bound up in the self of the researcher; therefore the findings are a creation of the researcher rather than a discovery of fact (Denscombe, 1998). Guba and Lincoln's (1989) criteria provide strategies for ensuring the study's authenticity and trustworthiness; establishing and assessing research quality and verifying the findings.

3.4 The research design

This section describes this study's research design including the participants, how data were generated, the kinds of analysis and how trustworthiness of data and interpretation were affirmed.

3.4.1 Data collection and timeline

To address the research aim three main phases of data generation and collection were undertaken. Phase One (1998) examined existing and emerging approaches in teaching and assessing technology in the classroom. Phase Two (1999) concentrated on developing ways to teach and assess in technology, and Phase Three (1999) on testing out assessment procedures and ways of implementing these. The phases are outlined in Figure 3.1.

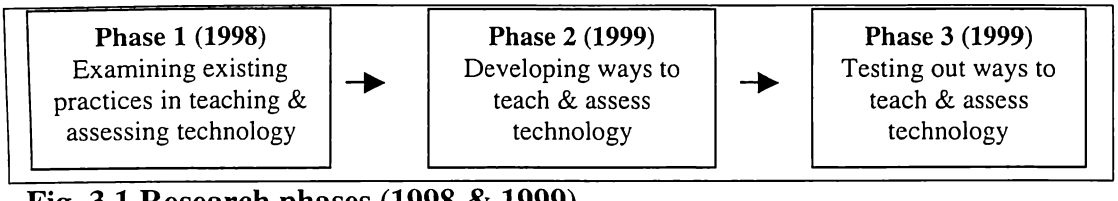


Fig. 3.1 Research phases (1998 & 1999)

In phase one, undertaken between March and September 1998, nine primary teachers were interviewed to ascertain their views of planning, teaching and assessing technology education. The teaching, learning and assessment of complete units of technology education were observed for eight of the nine teachers (the 9th Joan, was an assistant principal and did not have a class).

Teachers were interviewed throughout the units and at the end. Along with undertaking general classroom observations, between five and six students in each class were observed more closely, were interviewed throughout the process and at the end. In phase two and three, undertaken between March and December 1999, teaching, learning and assessment of two complete units of technology education were observed for seven teachers. This was one less teacher than in 1998 as Ann had moved to another school too distant to remain involved. Teachers were interviewed throughout the units and at the end. Like 1998, between five and six students in each class were observed more closely. These students were interviewed throughout the units and at the end of each unit. Teachers also participated in seven professional development days. Data collection methods and the timeline are summarised in Appendix 1.

3.4.2 Multiple perspectives

The importance of relationships and interactions between teachers, students, subject matter and assessment in technology education are important in enhancing student learning. The perspectives of the key players in these interactions in this study were considered. As case study is a social process (Burgess, 1982) teachers' own accounts were important. Not only did I value their explanations; there was the expectation that these teachers would contribute to the shape of the study. Their individual perspectives, personal constructs and explanations of situations were actively sought. The particular meanings that teachers gave to their subjectively structured world were taken into account (Cohen & Manion, 1994). The research was collaborative as the teachers were considered to be participants and not objects of the study. There was a commitment to feeding back information quickly to teachers so their interpretations were accessed. Mobilising responses of teachers strengthened the case. The focus was on interconnected and interrelated relationships and processes. The key players in this study (teachers, students and the researcher) are now introduced.

The teachers

Nine teachers were involved. Three had positions of responsibility, Burt and Ally being Senior Teachers and Joan an Assistant Principal. Five were Scale A teachers and one (Sarah) held a long-term relieving position. They held a range of

qualifications, eight a Diploma of Teaching and one (Ernie) a Post-Graduate Diploma of Teaching. Four had Bachelor of Education degrees and one a Diploma of Education. In addition, three held other Bachelor qualifications.

Years of teaching ranged from a first year teacher to a teacher of 28 years. Three had taught all primary class levels from Years 1-8; three from Years 4-6 (middle primary school classes); one from Years 3-6; one had experience in Years 1-5; and one was teaching her first year in a Year 3 class. Two teachers had taught outside New Zealand, with all of the rest New Zealand only teachers. Other work employment varied and included advertising, accounting, electronic engineering, horticulture, farming and selling. Table 3.1 sets out background details.

Table 3.1: Teachers' backgrounds

Teacher	Academic Background	Teaching Position	Teaching Background	Other employment
Rachel	Dip T B Ed	Scale A	Teaching Year 3, First Year Teacher	
Burt	Dip. T, B Soc Sc	Senior Teacher	Taught Years 4, 5 & 6, 5 years teaching experience	Advertising – a cartoonist
Penny	Dip T B Man St	Scale A	Taught Years 4, 5 & 6, 4 years teaching experience	Account ant
Ernie	PostGrad DipT	Scale A	Taught 7-12 year olds in England for 5 years, Years 5-6 in NZ for 1 year	Electronic engineering
Ann	Dip T Dip Ed	Scale A	Taught Years 1-8, 10 years teaching experience	
Tina	Dip T B Ed	Scale A	Taught Years 1-5 in Australia, England, NZ, 28 years teaching experience	Horticulture
Ally	Dip T Dip Hort B Sc	Senior Teacher	Taught Years 3-8, 8 years teaching experience	Farm worker
Sarah	Dip T B Ed	Long-term reliever	Taught Years 1-8, 5 years teaching experience	Soft furnishing sales person
Joan	Dip T B Ed	Assistant Principal	Taught Years 1-8 but mostly 1-3, 16 years teaching experience	Lecturer - reading & language

Technology education teacher development experiences

A range of involvement with technology education professional development was evident, although no teacher had had extensive involvement. Five teachers (Sarah, Ally, Burt, Tina and Joan) had had moderate professional development

involvement, as they had been part of the yearlong Ministry of Education professional development contracts in 1996 or 1997. Two (Rachel and Penny) had minimal involvement and Ann had no involvement, nor had Burt in New Zealand. All teachers were eager to learn more about teaching technology and saw that involvement in this study would afford valuable teacher development opportunities. Three teachers (Ann, Tina and Joan) professed particular interest in assessment in technology. Teacher development experiences, technology attitudes and research involvement attitudes are summarised in Table 3.2.

Table 3.2: Technology teacher development experiences, attitudes toward technology and the research project

Teacher	Technology Teacher Development Experiences	Attitudes Towards Technology Education & the Research project
Rachel	Minimal Beginning teacher courses	Interest in information technology Eager to learn more Positive towards research involvement
Burt	Moderate Yearlong Ministry course	Seen as a personal strength Eager to learn more Positive towards research involvement
Penny	Minimal After-school workshop & staff meeting	Eager to learn more High interest in the subject Positive towards research involvement
Ernie	English curriculum experiences in skills-based workshops No NZ involvement	Eager to learn about NZ curriculum High interest in the subject Positive towards research involvement
Ann	None	Keen to learn about assessment in technology Positive towards research involvement
Tina	Moderate Yearlong Ministry course	Keen to learn about assessment in technology & policy formation Positive towards research involvement
Ally	Moderate Yearlong Ministry course	Highly interested Encouragement of practical skills very important Positive towards research involvement
Sarah	Moderate Yearlong Ministry course & In-school development	Eager to learn more Positive towards research involvement
Joan	Moderate Yearlong Ministry course	Keen and interested in assessment in technology and policy development Positive towards research involvement

For more details related to the teachers' schools, their backgrounds and technology education experiences see Appendix 2.

The students

A large number of students were involved in technology classes throughout the two years, 248 (109 girls and 139 boys) in 1998, and 215 (118 girls and 97 boys) in 1999. For overall class details see Appendix 3. Though I gained general impressions in classroom observations and gathered class sets of work, I could not follow all students. Instead I focussed on a small number of students in each class, more closely observing their progress, conversing with them each day I was in their class, interviewing at the conclusion of each unit and examining their work in-depth. In each class I researched between 4 and 12 students' technology learning. Higher numbers were in classes where students worked on their technology in pairs or groups. In percentage terms this equated to 23% of students in 1998 and 22% in 1999. Selection considerations included gender, age and class level balance, and willingness to communicate – a high level of performance in technology was not a selection criterion. For example, in Penny's 1998 Year 4/5 class I researched three girls and three boys, three were Year 4 and three Year 5, two were 8 years old, three 9 and one was 10. All of these students were volunteers recruited during classroom observations.

During participant observations I sat in vacant seats or on the floor with students and worked with students around me. Once we became familiar I asked if they would like to talk about their technology learning. All responded positively. Sometimes other students initiated conversations with me. Students were also interviewed more formally at the conclusion of teaching units. Both the teacher and I asked permission for interviewing. All agreed. These interviews were conducted in a quieter place than the classroom – either outside or in another vacant room in the school. Often students were in pairs or groups as they had worked on activities together. They always had their work with them, as this served as a focus for the interviews. Additional students who requested interviews were also interviewed.

The researcher

Three researchers were involved with the Learning in Technology Education (Assessment) Project in Year Two, 1999 and hence were involved with data collection, generation and analysis. My background is outlined in Chapter One,

section 1.4.2. Alister Jones, the director of the Project was involved in professional development days and data analysis for Ministry of Education reports. Ann Northover sometimes visited classrooms with me to generate and analyse data. Her presence allowed for the triangulation of the participant observation data.

3.4.3 Multiple data generation methods

Data were gathered through individual and group interviews, participant-observation, field notes and document reviews.

Interviews in this study

Interviews in this study were considered as conversations with a purpose (Lincoln & Guba 1985; Maykut & Morehouse, 1994; Merriam, 1998). Nine teachers and many students were interviewed throughout the study. Individual interviews formed a large part of this study as they were easy to arrange, individual's opinions and views were prime, specific ideas were located with specific individuals and only one person needed guiding through at a time. Additionally, data could be kept confidential.

Group interviews, though harder to manage were particularly useful for interviewing students when they had worked on technology projects together. There was an emphasis on a defined topic where students had been involved in the same situation (their learning and their project). Students were able to qualify and modify views and voice agreement. They could bring to the fore important ideas and issues and they could challenge each other's views. Finally they could develop ideas in interaction and discussion with others. This meant that group interviews were more naturalistic, as students could negotiate the meanings of researcher questions and build on each other's answers (Bryman, 2001). The interviews became more like conversations as the children were used to working with their classmates.

On-the-spot conversations between the researcher, teachers and students were also held to seek teacher and students perspectives in naturally occurring situations (Bryman, 2001, Carr, 2001). In attempting to understand student and

teacher thinking, conversation was treated as action, as situated discursive practice (Cohen, et al. 2000). Therefore, examining how teachers and students mutually shared and structured each other's participation and understandings in problem-solving processes was important for this study.

Teacher interviews

Four sets of semi structured interviews were held with teachers over two years. The first set was undertaken at the beginning of Phase 1, 1998. The questions for this set were piloted with a teacher known to the researcher. Piloting assisted in gaining interview practice, finding out which questions were confusing or needed rewording, which questions gave ineffective data and which questions, suggested by the teacher, should have been included in the first place.

Following the pilot the interview was re-organised and then undertaken with all participant teachers (Appendix 4 details the interview questions). Interviews were audio taped and transcribed verbatim by a transcriber and given to teachers for endorsement. These initial interviews were used as a basis for gauging teacher perceptions regarding concepts they held about technology and assessment in technology (see Jones & Moreland, 1998; Moreland & Jones, 1999 for details). Though a schedule of areas to be explored was prepared, the interviews were an open discussion and informal in manner. They began with teachers being asked to describe information about themselves as teachers and their previous technology teacher development experiences. This was an ideal way for assisting teachers to feel comfortable in the interview situation. Next experiences using the technology curriculum document and previous experiences related to teaching technology education were discussed. This was followed by a discussion of assessment views and practices in technology.

The second 1998 interviews were conducted at the end of Phase 1 after teachers had taught a technology unit. These concentrated on teachers' views and interpretations of the teaching, learning and assessment that had occurred during their unit. They began discussing their unit overall. This was followed by discussions related to the technology task and any significant technology aspects. They talked about their interactions with students and student learning.

Assessment aspects were discussed as well as any significant and unexpected occurrences. They were finally asked about changes they might make. This reflective aspect gave them opportunity to clarify their thoughts and experiences as well as offer their perspectives (Merriam, 1998). Probes were used to follow up when there was a sense that more was to be learned and when there was a sense the teacher was onto something significant.

Interviews were conducted during lunchtimes, class-free times or after school; whichever was most suitable for the teachers. Duration was approximately 45 minutes. Audiotaping and transcribing was conducted. Teachers received transcripts for verification.

The third set of interviews was conducted after the first teacher development workshops and participant observation of classroom units in Phase 2, March – June 1999. Each teacher was interviewed to monitor views of technology education, assessment and classroom experiences. Teachers reflected on the emerging models they had tried in their classrooms. Preferences for the next teacher workshop were discussed. Again these interviews were conducted in times most suitable for teachers. Duration was from between 45 minutes and one hour. Audiotaping and transcribing was conducted and teachers received transcripts for verification.

The final set of interviews was conducted towards the end of Phase 3, July to December 1999, after the final teaching unit. Reflections on technology education and assessment in technology education were discussed. As well classroom experiences, changes they had made to their technology education practices and views, and models for technology education were discussed. Like all previous interviews, these were conducted at suitable times for teachers and typically lasted between 45 minutes and one hour. Audiotaping and transcribing were conducted. Teachers received transcripts for verification.

Student interviews

There were three sets of student interviews. The first set occurred during phase one in 1998. They related to finding out student's perceptions of technology and

what they had learned. The interviews began with the researcher asking the student, or students if students had worked together, about what they had done and learnt in the technology unit. All students had items of work they had produced during the unit with them for reference. The semi-structured interviews were conducted around the following ideas:

Tell me about your work.
What is good about it? Why?
Tell me about your drawing? How did drawing help you? How about constructing? What can you tell me about your testing?
Did you have any problems?
Did you have some things that went well?
How did you know when you had finished?
What did you think you learned?
Do you want to talk about anything else in technology?

These interviews were low-key and never longer than 20 minutes for older students. For younger students they often lasted just 10 minutes. They resembled a conversation, as students also asked me questions, mostly about the tape recorder and the notes I was taking. They listened to themselves on playback and saw and read the notes I was taking if they wished. All students chatted freely and none refused to answer. Often interviews were conducted in the classroom while other students were carrying on with other work. However, if students wanted to go to a quieter place we did so.

The second and third set of interviews were also conducted at the end of the units in Phases 2 and 3 in 1999 and followed a similar format to Phase 1 interviews. Again students had their work with them to act as a prompt. During these interviews students were asked to describe what they had done and learnt during the unit. They were asked to evaluate their progress, to describe any successes or problems, to outline any future changes they might make, to describe how their teacher had helped them and their understandings of technology.

Issues related to interviewing young students were evident. To assist them to feel comfortable, confident and at ease all interviews were conducted with individual student consent and in places and times suitable for the students. Their rights and comfort were paramount. They were always asked if they wanted to talk about their technology work before the interview commenced and were afforded the

right to stop the interview whenever they wished. As well they were asked if the interview could be taped. Students were all eager to talk about their work and always wanted it taped so that they could listen to themselves afterwards. Students knew me well from my ongoing, long-term presence in their classroom and appeared to like talking about technology with me. They showed confidence by chatting freely and were at ease and keen to tell me about their work and progress made. Certainly keeping focussed on their work was the key – they were conversing about something with which they were familiar and were eager to share their results. Often students came to me requesting an interview. This I always did for it showed my interest in their work and their confidence in me as a trustworthy person. Teachers also told me of students who let them know that they wanted to be interviewed. I also conducted those interviews.

Sometimes students lacked the language to explain their thoughts. Always basing interviews on their work assisted, for this acted as a focus and a stimulus. Also by conducting repeat interviews over time with the same students they soon knew the question types. This helped them know beforehand the likely ideas we would be talking about together. The open-ended nature of the interviews also gave control to the students, who were free to follow any ideas they had about their work and could explain it how they wished. The questions I asked were always genuine questions focussed on their technology learning and based on my real curiosity about their technology progress. It did not matter if they could not always explain well, for we would find some other way to share ideas. For example, sometimes we drew and sketched ideas together and at other times questions were abandoned or asked in different ways. Additionally, interviewing more that one student at a time assisted in overcoming any language difficulties as they explored ideas together, bounced ideas of each other and often used each other's language.

Participant observation in this study

My role was that of participant-observer as I aimed to get insights into technology classrooms. It was clear to teachers and students that I was extremely interested in their actions and conversations during sessions as I was in close contact with them for long periods of time. Every attempt was made to ensure that participants understood what the research was about so that my role was

never deceptive (Bryman, 2001). A building of mutual trust between teachers, students and myself was a prerequisite for conducting observations. Mostly I was able to take a peripheral-membership role where I observed and interacted closely enough in classroom situations without active participation and where I was able to fully function as a researcher.

Sometimes it was difficult not to participate as young students expect adults in classrooms to assist them. In these circumstances I took a more active membership role, that of 'helper'. Students often requested my help and where possible I gave it. I developed a system that signalled to students when they could freely approach me. This was when the tape recorder was switched off and my hands were free of my field notebook. Students saw me as a researcher when the tape recorder was on or when I was working in my notebook, for on those occasions they did not ask for my help. Sometimes it was necessary to become involved especially when I thought students might harm themselves, for example with hot glue guns or craft knives. At other times I was compelled to be come involved as a failure to participate might have indicated lack of commitment and hence lack of credibility (Bryman, 2001). For example, teachers sometimes indicated to students that I would help them. On those occasions I felt obliged to assist and was pleased to do so. This indicated an acceptance by teachers and students and assisted in exploring student perspectives.

My classroom involvement was extensive involving nearly four hundred hours of contact. The classroom observations allowed for the general context of the environment to be explored as well as allowing for the consideration of the variety of influences that might be affecting student performance in the technology tasks.

As well as classroom observations, observations were carried out during teacher workshop sessions. In the workshops my role was far more participant than observer, for I was directly involved with conducting them. This meant that workshop field notes were somewhat sketchy and I relied heavily on making mental notes, sometimes referred to as head notes (Lofland & Lofland, 1995, and Sanjek, 1990, in Bryman, 2001). Mental notes are the record of observation that a researcher retains in their head (Sanjet, 1990) used when it is difficult for the

researcher to take notes at the time. In this study they were recalled and included in the field notes as soon as possible after the events and were often written in collaboration with other researchers present in the workshop situations. This added some measure of trustworthiness to the recordings.

Field notes were used extensively throughout classroom observations so that a wide range of data could be collected from a variety of situations and from a variety of students. The strength of using field notes was their flexibility. For example, sometimes I was unsure of what was going to happen next in classrooms, or I wasn't sure which groups of students I would be following, or I didn't know beforehand where the important actions would be. This meant I needed to maintain an open mind to which observations would be conducted and I could move easily when necessary. If students inquired into the content of my field notes, they were shown them. They were never hidden and notes were recorded very openly with students freely reading them if they so desired. There were occasions when I was even instructed to "write that down, that's good". I made sure I complied with such requests.

Full field notes were made as soon as possible after each observation, often at the end of the day. Two columns were employed in the observation protocol - the first for descriptive notes, the second for reflective notes. The descriptive notes described activities undertaken, conversations, and any relevant notes and charts made and used during the sessions. The reflective notes included reflections about lessons, teachers, students, activities and included some summary conclusions (refer Appendix 5 for an example). Reflective notes were often made at the same time as observations, although very brief jottings. I also wrote memos to myself about what I was learning. The following example is an excerpt of a field note observer comment. The excerpt indicates some early reflective thoughts about Rachel's teaching:

> Perhaps the task has not been specified clearly enough at the beginning. Rachel kept adding conditions and criteria as the afternoon progressed, so students seemed to be getting mixed and confused messages. I'll think about this. (Field notes, 6.8.98)

This excerpt demonstrates engagement in the first important steps in qualitative analysis: 'discovery' (Taylor & Bogdan, 1984 in Maykut & Morehouse, 1994). It was the first step towards more formal analysis. It indicates that generation, collection and analysis of data was not a linear process in this study, rather data interpretation and analysis began as soon as first data were collected.

Tape recordings of classroom exchanges were also made, but this created the problem of transcribing a lot of speech. However, these recordings did assist in capturing the actual dialogue that took place. It also meant I could make briefer field notes, as I knew the exact dialogue would be recorded. Students and teachers did not wear individual microphones. Rather I used a directional microphone to record conversations in the immediate vacinity. This was less intrusive for participants. It also meant flexibility for me as I could move quickly with the tape recorder to activities of interest. The disadvantage was the poorer quality of recordings, but with back-up field notes I captured enough quality data for analysis and interpretation.

A process from broad observations to specific observations was used to understand the details of classroom situations. Getting a general feel for the situation as a background scene-setting device was first used. Then increased focussed observation was employed to more closely scrutinise specific things. Special observations were also undertaken when attention needed to be focussed on unexpected aspects, for example student difficulties in working iteratively. Observations were also undertaken looking at issues and problems identified by participants as important, for example teachers' identification of their technology questioning techniques.

Though recording observations was onerous, this was required for later analysis. Four lecture notebooks were filled with notes made during one hundred and fifty five lessons and over two hundred and sixty hours of observation. Notes were recorded as quickly as possible after observation to avoid forgetting information, they were written as fully as possible to bring to mind a vivid picture of the described events. I also recorded notes at the same time as observing rather than just after the event to increase the authenticity of what was being observed.

Documentary data in this study

Documentary data on teaching, learning and assessing technology were also collected in order to support the trustworthiness of data. All documentary data were from primary sources. Official state documents used included national curriculum statements; the most heavily used being the technology curriculum. School documents were confined to Education Review Office records for gaining school descriptions.

The most heavily sourced documents were personal documents generated by teachers and students during the study. Teachers' written material including their unit plans and recordings of student summative assessment were collected. Other data sources included photocopied student work. Photographs were also taken of completed artefacts and used as a data source. Finally copies of text and pictures produced by teachers and students throughout the technology units were collected. Documentary data produced during units were sometimes recorded as field notes when it was not possible to photocopy originals (for example, whiteboard notes).

All documents used in this study met four quality criteria. First, they were authentic in origin, as they were gathered in situ. Secondly, they were genuine for they were not counterfeit or falsified. Thirdly, they were representative being typical of their kind, and finally, their meaning was comprehensible.

3.4.4 Management of data

All teacher interviews were transcribed verbatim by a transcriber from the university. I checked transcripts through a comparison with the audiotape and notes I had taken during interviews. Field notes were stored as written. Teacher and student work was collated in class sets with individual student work sequenced in order of production. It was stored in A4 or A3 folders.

In this study pseudonyms are used for both teachers and students to protect anonymity of data sources. Teachers' chose their own pseudonyms and students were assigned pseudonyms by me. Coding was used to assist with data reference and indicated types of data, source and date. For example, the transcript of an interview (I) with Ally (A) on 31st of August 1998 was coded I/A-31.8.98.

However, this coding was not used in the thesis write-up, only pseudonyms were used to personalise data sources.

3.4.5 Ethical considerations

Ethical considerations of informed consent, potential harm, confidentiality and open disclosure were employed throughout. Negotiating and gaining on-going access to each teacher's classroom and to students was a privilege I was mindful in keeping. I must have added extra pressure to the teachers' already saturated working days. To have a relative stranger scrutinise all actions, constantly question and tape every word, photocopy work, question their students and then go away and write about everybody must have seemed a daunting prospect. Teachers lead relatively secluded adult-free lives in their classrooms. Certainly the teachers did not work in total isolation from other adults, as adults visited frequently throughout the teaching day and parental classroom involvement was encouraged. However, to allow someone classroom access knowing they are there to investigate, dissect and study you for long periods is something quite different. My contact was ongoing over a long period of time (two years). Observations were coupled with follow-up interviewing and then all gathered data were analysed and written about. Presentations have been given and papers produced. What was a relatively private pursuit, that of teaching in their own classrooms, has become very much public. Maintaining confidentiality, gaining on-going consent and reducing potential harm became significant. Confidentiality was maintained through the use of pseudonyms and anonymity was guaranteed. However, in a small country like New Zealand, absolute and total anonymity is difficult to preserve (Alton-Lee, 2001). Inevitably some participants may become known. Author's sensitivity to reduce potential harm and maintain confidentiality is therefore an underpinning principle in published papers and public work. Teachers and students placed their trust in me and I therefore have an unqualified, timeless responsibility to them.

Initial consent to carry out the research was obtained from Boards of Trustees (BoT) and principals of the schools concerned. The aims of the research, the methods of data collection and data analysis were outlined in written and verbal form to both (see Appendix 6). Once BoT consent was obtained individual

teacher consent was obtained. First information about the study was conveyed to the teachers at initial school group meetings. At these meetings details of the research project were given, as was information about the likely additional workload with research involvement. Ethical considerations were also outlined in oral and written form. Teachers were given the right to withdraw from the research at this stage. None did.

Written consent was then obtained from the teachers (see Appendix 7). Any teacher had the right to withdraw from the research at any time. Free, informed consent was sought throughout the research. Nothing was used without teachers' consent. No quotes from interviews or sessions, or written comments, were used without permission. The teachers had ownership of the raw data they generated and all transcripts were returned to them for approval and comment. Anonymity of the teachers, students and the schools was preserved and their privacy was protected. The teachers and students were allocated pseudonyms and school names were not revealed to assist in preserving anonymity.

Consent to use student work was always sought from teachers and students and either could refuse to give permission for work to be used at any time. No teachers or students refused permission. In fact the opposite was usually the case with many students freely giving me their work to use. I accepted every offer. No originals were kept. Work was never removed for photocopying without student and teacher permission and originals were always promptly returned. Completed artefacts were photographed and students were given copies of photographs.

3.4.6 Strategies to ensure trustworthy data collection and interpretation

The criteria for trustworthiness proposed by Lincoln and Guba (1989) were employed in this study. They include multiple methods of data collection and member checking to enhance credibility, building an audit trail and working with a research team to enhance dependability, and working in depth to enhance transferability.

Enhancing credibility by using multiple methods of data collection and member checking

Data collection methods to enhance credibility included interviews, observations and document collection. Substantiating evidence from different sources extended understandings of the different themes and perspectives through the process of triangulation. Over the two years themes and ideas from different data sources converged leading to strong credibility of the findings. Cross-case analysis was made possible and the confirming findings added to the study's credibility. Comparisons between different data sources made it possible to verify findings and to provide detailed thick description necessary for demonstrating authenticity and trustworthiness of the research.

The analysis was member checked by teachers. After classroom observations in 1998 I asked teachers about various events, what technology students were learning and how they had enhanced that learning. These comments were recorded as field notes and compared with and used to inform my interpretation of technology teaching, learning and assessing that had occurred in the lessons. Individual case studies were written. Early in 1999 each teacher checked and commented on their draft case study. Later in 1999 they were given a draft of all 1998 case studies to check, compare and provide comments (Moreland & Jones, 1999). During 1999 teachers and I undertook discussion sessions after each lesson, commenting on teaching, student learning and assessment practices. As well teachers commented on the models, especially their progress in using the planning format. As a group the teachers also contributed to the content and structure of the professional development workshops, especially contributing to the development of the framework for planning. Conference papers presented during the research were also given to teachers for comment.

Enhancing dependability through working with a research team and an advisory group

Peer checking was achieved by another researcher observing in the same classroom at the same time as myself during 1999. Both of us took field notes thus increasing the depth of observation by providing two perspectives. Field notes were checked and compared, as was the analysis. Working with a research

team also facilitated the dependability of data analysis, as feedback on ideas fostered insights, adding to the study's credibility. The checks and balances involved with team-based data analysis increased the trustworthiness of the analysis (Lincoln & Guba, 1985). In addition, the ongoing analysis for the Learning in Technology Education Project was peer checked and the analysis supplemented through four advisory research days organised as part of the research contract.

Enhancing transferability by working in-depth

Prolonged engagement in the field contributed to the provision of detailed thick description and to get close to the participants in the study. This enabled me to 'see as other's see' and to provide a genuine, factually accurate account of what actually happened. Prolonged engagement allowed me to explore the same themes and ideas over a number of interviews and classroom situations. The teachers, students and myself created shared experiences inside and outside the classroom and inside professional development workshops. This meant I was able to learn more about teachers and students and to find common themes and ideas in their behaviours and conversations. Describing participants and situations in detail assists others to make decisions regarding transferability. The multiple cases of 1998 provide detailed descriptions of the teaching, learning and assessment practices in technology classrooms (see Chapter 4 and 5). Analysis of the 1999 teacher development workshops provides detailed descriptions of the effects of the workshops (see Chapter 6). The compilation and cross-case analysis of the 1999 cases provide detailed descriptions of the enhanced teaching practices and student learning achieved (see Chapters 7 and 8).

3.4.7 The analysis and kinds of analysis

To provide a concise account of how meaningful and trustworthy conclusions were reached this study employed a combination of analysis methods. Even before the study began suitable themes for analysis were considered. Figure 3.2 shows the initial analytical framework used. The themes relate to students' and teachers' concepts of technology and technology education and their views of assessment. These themes assisted with framing the study and making decisions on how to go about gathering data from the outset.

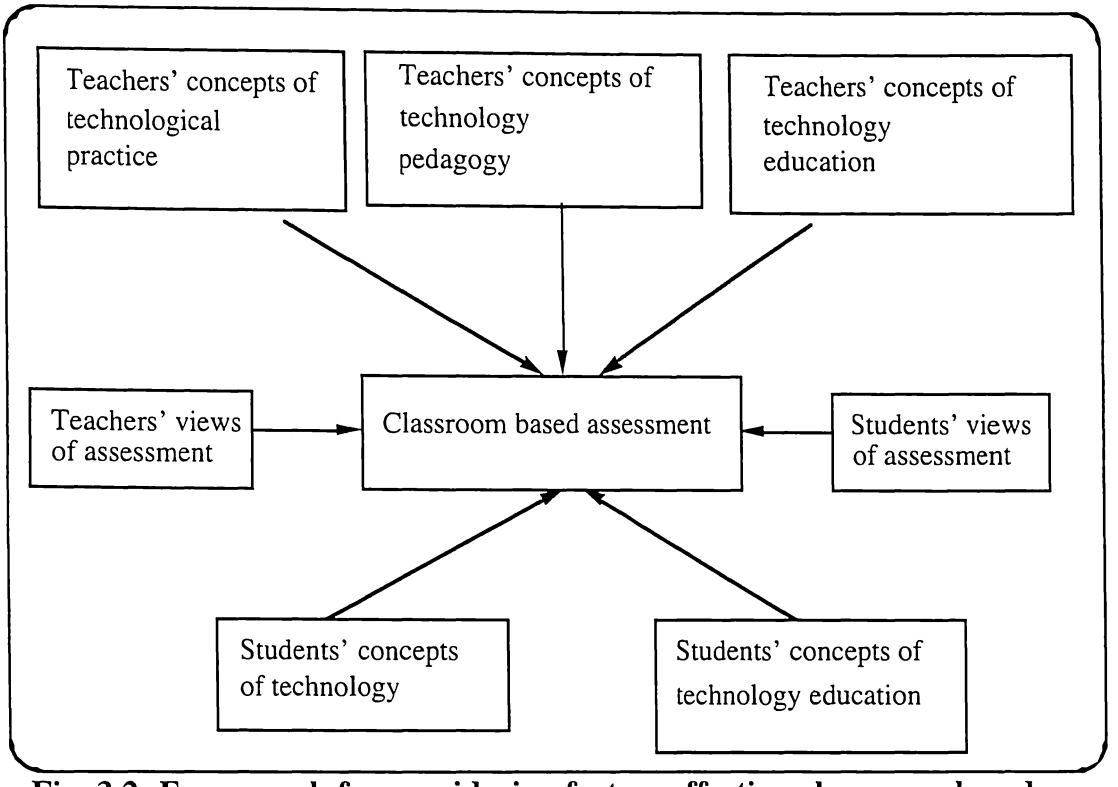


Fig. 3.2: Framework for considering factors affecting classroom-based assessment

Building on this initial thematic categorisation, themes and issues from 1998 interviews, observations and documents emerged. Additionally, themes and issues from relevant literature contributed to the analysis units. Then, when writing about the research more analytical work was undertaken as analysis-through-writing clarifies themes and patterns. Thinking about how to report the substance and sequence of the findings required rethinking data revealing new insights and understandings (Maykut & Morehouse, 1994).

Three kinds of analysis were identified to showcase the data gathered, generated and presented during 1998 and 1999. First, a thematic approach derived from individual case studies and literature was used in Chapters 4 and 5 to describe how teachers and students separately and together viewed and experienced technology education. Second, narrative reporting (Bassey, 1999) was utilised for Chapter 6 to describe the stages and effects of the teacher development programme. Finally, a cross-case analysis was adopted in Chapters 7 and 8 to describe the changes in teaching, learning and assessing technology. Each method is discussed in turn.

Themes from case studies: Chapters 4 and 5

In 1998 I interviewed all teachers and observed all the technology sessions I could. While I had themes for exploration in the interviews, lesson observations were less category-bound. In the lessons I wanted to find out as much as I could about teachers and students while they were involved with technology. Like Ball (1984: 77), I wanted to get a "feel for the place" writing down anything that came to mind and not necessarily knowing how much would be of relevance. Ball (1984) argues that this openness provides one of the important bases of the value and power of participant observation research as it captures patterns of behaviour as they occur in real life. However, even with this open approach, selections were being made and distortions must be admitted for I was not able to notice, remember or record everything, and I also had a beginning analytical framework from which to work.

A two-stage analysis was undertaken for Chapters 4 and 5 – a within-case analysis and a cross-case analysis (Merriam, 1998). For the within-case analysis, each teacher and their classroom were treated as a comprehensive case in and of itself. Once individual analysis was completed the second stage was undertaken through cross-case analysis where relationships and patterns were explored to synthesise findings from individual cases. Integrating data and interpreting the meanings of the cases yielded a more holistic understanding of the people and settings being studied (Creswell, 1998; Maykut & Morehouse, 1994). Attempts were made to build a general explanation and abstractions across the cases (Merriam, 1998). The findings from this two-stage data analysis method were initially presented in *Case Studies of Classroom Practice in Technology, Working Paper 523* (Moreland & Jones, 1999).

Descriptive reporting: Chapter 6

The second kind of analysis, narrative reporting (Bassey, 1999) was employed for Chapter 6. It provides "a sense of immediacy of an event unfolding before the reader's eyes" (Zeller, 1995 in Bassey, 1999: 88). This best describes the stages of the teacher professional development programme and decisions made in regard to the content, structure and effects of the programme. The chapter is organised in sections with each section representing a period of time during which each

significant stage of the programme was conducted. The sections appear in chronological order and so the stage-by-stage report shows how questions were asked and answers sought, how teachers responded to the models, how the models were modified and re-tested, and how teachers changed their views and practices in relationship to the models and programme. Data collection, analysis and interpretation for Chapter 6 are intermingled in this narrative account.

Descriptive report writing was also employed to describe the tangible outcomes of the teacher professional development programme. Description was used as a supporting strategy to enrich the narrative details of the intervention and to contribute to a better understanding of teacher and researcher perspectives related to the intervention.

Cross-case analysis: Chapters 7 and 8

The third kind of analysis used in Chapters 7 and 8 was a cross-case analysis. The cross-case method of analysis differed from Chapters 4 and 5 as individual cases were not extensively analysed and reported before generalising across the cases. Instead, themes and issues that had emerged from ongoing data analysis were used as the basis for cross-case analysis. Making sense beyond specific cases became the goal (Miles & Huberman, 1994). This allowed for the development of more sophisticated explanations by viewing teaching, learning and assessing technology across cases. However, one teacher's case (Burt) is presented to provide a holistic detailed account of changes teachers made to their practices as a result of the intervention. Chapter 7 presents an analysis of findings from teachers and their classrooms, while Chapter 8 presents an analysis of findings from student work and progress they made. Separating the perspectives allowed distinct and explicit meanings to be explored and presented. The views and behaviours are presented separately for they provide a rich picture of technology education from two different perspectives.

3.5 Summary of Chapter 3

In review, an inductive, naturalistic data generation, collecting and analysis process was utilised. An interpretive research methodology compatible with the

research questions and the epistemological underpinnings of the study was adopted. Data were generated through interviews, participant observation and documentary analysis. Trustworthiness of data generation and analysis was assured through the use of Guba and Lincoln's (1989) criteria. Three different kinds of analysis are used for the study and provided the framework for the following five data chapters. These are: a cross-case thematic study of teachers' existing practices in technology education and the effects on student learning (Chapters 4 and 5); a narrative account of the teacher professional development programme and its effects (Chapter 6); and a cross case analysis of the changes made in teaching practice and student learning (Chapters 7 and 8).

4. EXISTING PERCEPTIONS OF TECHNOLOGY AND TECHNOLOGY EDUCATION: 1998 FINDINGS

4.1 Introduction

Rich and detailed interview, observation and documentary data were generated in 1998. As outlined in Chapter 3, a within-case analysis followed by a cross-case analysis was undertaken. Three categories grouped data related to the initial research questions - What are primary teachers' emerging planning, teaching and assessment practices in technology education and how do these influence students' learning in technology?

First, initial teacher views of the nature of technology and technology education were examined, as teacher knowledge of subject content and subject pedagogy is critical for successful teaching and learning (Black & Wiliam, 1998; Jones, et al. 1994; Sadler, 1998; Shulman, 1987). Second, teachers' 1998 classroom practices about planning and teaching specific technology units were examined, as transformations of teachers' subject knowledge to planning and associated pedagogical strategies suitable for classroom experiences are significant (Bell & Gilbert, 1994; Paechter, 1992; Shulman, 1987). Third, data generated from 1998 classroom visits were examined to analyse teacher-student experiences and formative interactions.

This chapter presents initial teacher views about technology and technology education. Chapter 5 presents data on 1998 teachers' planning and classroom practices including their formative interactions with students. The chapter division cleanly separates initial 1998 interview data from 1998 classroom data. In Chapter 4 teacher perspectives are compared and contrasted. Their views are presented in two sections: 4.2 Perspectives of technology and technology education and 4.3 Technology assessment views and experiences. An overview of Chapter Four is provided in 4.4.

4.2 Perspectives of technology and technology education

Section 4.2 reports on teachers' 1998 technology and technology education perspectives in three categories. First previous experiences in teaching technology are described. Secondly, views of technology are presented and finally views of technology education are outlined.

4.2.1 Previous experiences in teaching technology

This section assists in introducing the teachers as technology teachers and covers five aspects. These are: the influence of previous classroom experiences, teachers' use of the curriculum document, technology teaching as a practical problem solving process, previous units teachers have taught and influences on topic choice. Each aspect is presented in turn.

Influence of previous classroom experiences

Teachers' previous technology teaching experiences impacted on their 1998 attitudes towards teaching technology and views of technology. Background experiences exerted a strong influence.

Ann was very positive towards teaching technology as previous experiences in teaching technology had been enjoyable and technology had given students new learning opportunities. For example:

> A lot of the girls had never touched lego-technics before. It's a stereotyped idea but it was true and they found it quite difficult to use but they were enthusiastic and they were very pleased with their results. (Ann)

Like Ann, Ernie, Tina, Penny and Ally were very positive towards teaching technology. All had tried to teach in a variety of technological areas and believed teaching technology was a personal strength. For example:

> I've always felt that I had strength in technology, or what I saw to be technology and if you have strengths you want to keep developing, keep motivated and it's something my children love to work with. (Ernie)
> My reaction towards technology is a positive one. I am quite at home with it. (Tina)

Rachel, a first year teacher, found it difficult to incorporate technology into her programme as she was trying to come to terms with other learning areas. Technology had been given little attention.

> I haven't concentrated on technology at the moment. Like in terms of my first term, my focus was maths. ... I haven't honestly really thought about it that much yet. At the moment it's probably been setting up my routines and my maths. (Rachel)

Burt, a teacher from England, had extensive experiences working with the English technology curriculum where his teaching focussed on students acquiring technology skills. These experiences dominated his views of technology and technology education, which were strongly skills-focussed. Though he believed the New Zealand curriculum was lacking in emphasis on the teaching of skills, he preferred working with the New Zealand curriculum as teachers had more freedom of choice than in England.

Joan's role as an Assistant Principal meant she had never taught technology in the classroom. Some of her difficulties with understanding technology education centred on her lack of actual classroom experience. She was bereft of reflective practice opportunities, which was a barrier to a deep understanding. Despite an apprehension to teaching technology Joan saw the curriculum document as positive. She also believed it important to gain an understanding so she could work in a supportive role with others.

In sum, background experiences influenced teachers' 1998 attitudes towards teaching technology. Especially influential were previous classroom-teaching experiences. The more teaching they had undertaken the more confident they appeared.

Use of the curriculum document

All used the technology curriculum document to assist with planning and were familiar with the three technology strands. However, this did not mean they found planning and teaching the three technology strands easy. In fact they had difficulty incorporating all three strands in their classroom practice. Burt was an exception illustrated when explaining a toy unit he had taught. He thought that societal aspects were addressed when students examined toys from the past and researched their development, knowledge aspects when students examined structures and mechanisms of toys, and capability aspects when students planned and developed their own toys.

All tried to incorporate some technological procedures in their teaching. For example, Tina expected her students to compare their classroom pizza making process with that of a commercial operation. With a sweet making unit, Sarah's students examined the effect of processing on the basic components of sweets, as well as understanding the chemistry and behaviour of those components. Some teachers, Sarah, Tina, Burt, Ernie and Ally, expected students to utilise existing knowledge and be involved in research before beginning to design products. Burt and Ernie believed students should examine existing technologies in order to make refinements and improvements.

Though all teachers used the curriculum document to assist with planning they believed it did not provide the level of support necessary for sound classroom teaching, nor did it provide enough assistance for articulating specific learning outcomes. Rather it provided assistance to only work at the broad, achievement objective level.

Teaching technology as a practical problem solving process with a design, make and test emphasis

Previous classroom units focussed on practical problem solving, with designing, making and testing at the core. Technology was taught with a problem solving perspective, which involved students building knowledge, skills and ideas to solve a problem. All teachers placed a heavy emphasis on designing. For example, all Ann's technology units included a design element with students drawing in the early unit stages. Included in drawing was an evaluative aspect where students were encouraged to redraw their designs once construction had begun.

> They have to do a pencil drawing of something but then they can do their model, their initial model. Then they go back and refine the drawing. .... And they get better and better at it. ... They start thinking things through with more logic and become more imaginative with their solutions. (Ann)

Additionally, creativity was valued and teachers encouraged the production of a variety of solutions. A variety of solutions was acceptable and indeed anticipated.

> From what I understand I don't think there is a right and wrong way of designing things. So there is no right or wrong and they come up with all sorts of answers for how they think. ... Some of them are commonsense and some are quite far-fetched. (Ann)

In aiming to get a variety of creative solutions from students, Tina expressed difficulty in making decisions about when to intervene with students' work.

> The enigma is do you put them through the design process or do you interfere in that process slightly. I confess that I do. In all situations it does have to be satisfying for kids who make it or otherwise it's incredibly frustrating. How far do we intervene with young children and the design process? (Tina)

Students' involvement in task management and the co-operative way they solved problems was also an essential part of the problem solving process. Aspects related to students' reviewing their work, and making adaptations in the light of such review were evident.

Previous units taught

Teachers' experiences in teaching in different technological areas ranged from extensive to none. Ally and Sarah had taught in all technological areas, Burt all areas except biotechnology, Rachel in only the area of food and Joan, in no technological areas. The rest had taught in several areas. Some teachers combined several technological areas in a single unit. For example, when Ally's students created pet houses, materials, control, information, structures and mechanisms were covered, and in bread-making biotechnology and process and production were included. When Sarah's students were involved with water treatment processes they covered biotechnology, electronics, production and process.

A wide variety of units had been taught. For example, Penny had covered the technological areas of structures and mechanisms, materials, food and biotechnology with topics such as designing a times table machine (in conjunction with a mathematics programme), designing and producing a milk product, and designing a slipper for Cinderella (in conjunction with a reading programme). Tina's units were packaging pikelets (food and structures), building compost (biotechnology), designing and producing pizzas (food, process and production), designing a water wheel and designing a system for filtering water (both materials and structures and mechanisms). Ann had taught materials and structures (students created models of pet houses) and food (students created different milk products). Ally covered topics such as building pet houses, deconstructing electronic devices in order to understand their workings, and designing and marketing a bread

product. Sarah had taught food, production and process (sweet making processes), materials, structures and mechanisms (designing and constructing bridge models, creating fasteners), and biotechnology, electronics, production and process (water treatment processes). Teachers had been able to match topics with technological areas reflecting a broad understanding of particular technological areas.

Influences on topic choice

A wide range of factors influenced topic choice. These included selecting topics that would interest and motivate students. As Ally commented:

> I try to look at what will interest children and if an idea sparks from there. The electronics one I did because I had a group of children who were very interested. (Ally)

Also influential was the availability of resources. For instance:

> The students can be motivated with basically the resources that are around us, like we have a milk factory and the school has got heaps of resources about milk, so that was because we had the information. (Penny)

The need to provide a balance of technological areas was considered important. As Ernie commented:

> You've got to ensure getting a good balance of areas. It varies from teaching situation to teaching situation. (Ernie)

Additionally, examples in the curriculum provided inspiration. For example:

> I looked through the curriculum and there were a few ideas there and I thought oh, I could do that. (Rachel)

Personal knowledge gaps also affected topic choice, with avoidance the solution when teachers were unfamiliar with a topic. For instance:

> But if I actually had to explain how a washing machine or something works, or, what's behind the mechanics of it, that intimidates me.... I tend to stay with things that I am comfortable with or what I am interested in, and so maybe that's a reason why I don't go into that. (Penny)

Teachers also balanced different aspects for topic choice. For example:

> You try to feed the interest of the children, even though we have to do certain things and we've still got to be using the curriculum. (Ann)
> I like to keep my children extended and so I like to keep them motivated and open to topics that I think will work for them. At the start of the year, I also give them a topic list and and I say ... which ones would appeal to you and why. And have you got any others to add so that also takes precedent. Our school asks for certain things, so they always have prescribed bits and pieces. But really for me I also need resources for topics. (Burt)

In sum, a range of influences affected topic choice.

4.2.2 Perspectives of technology

Two aspects were evident in teachers' views of technology. First, the view of technology as a practical problem solving process with students designing, making and testing was common to all. Secondly, disparate views demonstrate the idiosyncratic way technology was perceived.

A practical problem solving process incorporating design-make-test activity

All teachers believed technology was a practical process where students should be engaged in designing, making and testing/evaluating activities. Technology involved students in finding answers to practical problems in a hands-on 'doing' manner. Of importance were procedural (physical manipulation) aspects. Technology was a process with little emphasis placed on developing students' understandings of technological concepts. Conceptual aspects were marginalised. For example:

> Technology is a way of organising certain materials and working with problems to create a solution. A technological problem will involve the manipulation of materials to solve a problem pertinent to children's lives. Technology involves design and process with a specific goal in mind. (Tina)

Problem solving with a practical focus was influential. Technology involved a process of thinking through problems and realising practical solutions. Ally commented:

> I expect them to use the knowledge that they have, find out more knowledge, the knowledge that they are going to need, design something, create it, make it, and then evaluate it, possibly make changes and then re-evaluate it. (Ally)

Additionally technology was related to aspects of daily life and the real world. In examining technology products some teachers, for example, Ann, Rachel and Burt, believed it important to look at technologies of the past and imagine how they might be in the future. Adapting and modifying existing technologies was an element of teacher perceptions. Most consistently held though was that technology was a practical, problem solving process.

Teachers believed there was a sequence to the whole technological process. The sequence began with designing, was followed by making, which was further

followed by testing. A design-make-test focus was foremost for Penny, Ernie, Tina, Ann and Joan. Tina and Penny illustrate this view:

> Straight away I think of the design factor. ... By design I mean the divergent ways to finding solutions. I mean there is a sequence in the whole technological process and you have an idea or you have a need and you design around that. Design is probably a highlight for me because of the creativity. (Tina)
> The first thing I think of is designing, like I have this thing about trying to find solutions. ... I like the idea of not having a right or wrong in terms of a set solution. (Penny)

Rachel, Burt, Sarah and Ally also believed in a focus on designing, making and testing and additionally included modification as part of the process. For example:

> It is all very well having ideas, but you also have got to be able to put them into practice and see how they work and modify and adapt and move on and that's technology doing that. Just modifying something is a technological advancement and I think it is putting theory and practice together. (Ally)

Ernie and Tina mentioned a further refinement of the design process related to needs identification, a procedure they believed should occur within the design process. For instance:

> You're identifying needs and then the children actually have to develop some sort of system to solve their needs or meet that need. ... Looking into more realistic sorts of problems, whether it's actually creating a need for the children to solve or whether it's sort of taking skills, which you develop. ... It's actually got a design element rather than just sort of making things. (Ernie)

However, despite some differences related to the technological process components, the common aspect was that a design-make-test focus was inherent. These procedural aspects were prominent. Conceptual aspects were not evident.

Idiosyncratic views

Beside the common view that technology is a practical problem-solving process involving designing, making and testing, teacher technology concepts included an assortment of idiosyncratic ideas. These demonstrate the variety and diversity of technology views. Perceptions were that technology relates to the historical development of artefacts, technology is about invention, technology relates to economic and consumer viability and technology is a risk-taking, creative process. The following examples illustrate the differences.

Burt's concept of technology included notions of historical development when, for example in a clothing fashion design unit, students examined clothing from different periods of history, before designing their own items.

Ann's concept of technology incorporated invention notions.

> Thinking through how things work, inventing things, being able to explain. (Ann)

Economic and consumer influences were inherent in Tina's understandings of technology. She thought school technology was divorced from real-life technology as student experiences were unlike those of practising technologists.

> Out in the wide world you have to make it economically viable...that's something we miss in school because we are isolated. ... The dilemma for me is we should do the whole process. ... Ideally children would price the expense of making pizza and sell it - considering the economic aspect of their production, and also satisfying consumer need. (Tina)

Joan, Sarah, Ann and Tina emphasised technology as a risk-taking venture and a creative process. For example:

> It's just that it encourages kids to think outside the square, which I think it should do. (Sarah)
> Encouraging children to problem solve and think for themselves and going outside the safety zone of what is right and what is wrong and what they have to achieve. So it's a whole different way of learning and its very much part of the real world. I see it as quite a key area. (Joan)

In looking across these views, a range of perceptions not consistently held by everyone is evident. Again though, technological conceptual aspects were absent. A procedural focus was noticeable.

4.2.3 Technology education perspectives

Teachers' perspectives of technology education are separated into six categories. These include technology is an important learning area, knowledge of technological areas, technology is suitable for integration with other learning areas, technology is a separate learning area to be studied in its own right, teachers' confidence to teach technology relates to professional development experiences, and technology education is heavily centred on technological capability. Each is presented in turn.

An important learning area

Teachers believed technology education was an important curriculum addition and that it should be included in the general curriculum as a compulsory learning area for all students. Reasons included the notion that it could provide open tasks where students could personally set goals and take different problem solving pathways. It gave students opportunities to develop creativity and risk-taking ability. It also led to high student motivation, as they became involved in exciting work. As Sarah stated:

> I see the need for technology education because it encourages the thinking process to expand more than anything else, which it should do and I think that anything that does that is going to be useful. (Sarah)

An economic justification was given by Tina and Rachel, who believed student involvement was important for their long-term future as it could assist them to be more informed members of the workforce. They commented:

> I recognise it as wanting a skilled population. They want people valuing divergency in an economical kind of way. (Tina)
> It's definitely needed in terms of the workforce, leading to a more informed workforce to look ahead. (Rachel)

Finally, teachers believed that student technological understanding was vital, as technology was all around, commonplace and part of everyday life. However, it was often taken for granted, so teachers wished students to be more technologically aware. As Burt and Ann remarked:

> It's just one of those things that is just sort of so evident in daily life that we tend not to notice it, and I think that it's important that we should actually be aware of it. (Burt)
> I think the children need to understand where things are coming from and where they are going. ... Everything in our lives, like for example for school, they need to think things through. For example thinking what they can use to go in their lunches, how they can keep them fresh. Just every day things, ... because it's very commonsense and it's very much this is our life. (Ann)

Technology education was viewed as an important learning area for fostering students' personal, economic and educational development.

Knowledge of technological areas

Teachers knew of the seven technological areas and had focussed on some of these in previous teaching. Ally and Sarah were the only teachers claiming they had taught in all areas. All teachers acknowledged strengths in teaching some areas. For instance, Burt was more confident teaching in the areas of materials

technology and structures and mechanisms, and Rachel in information technology. Teachers also acknowledged difficulties with some areas. For example, Ernie professed lack of knowledge in food technology, Penny in biotechnology and Ann in electronics. However, all were positive towards using the curriculum document.

A subject suitable for integration

All the teachers thought technology suitable for integration with other learning areas and believed that this was a positive approach to use. As Rachel commented:

> I really like teaching technology and I think it can interrelate with the other curriculum areas fairly nicely. (Rachel)

They thought technology readily connected to other learning areas especially when using a common theme for organisation. For example, Ally believed technology to be suitable for incorporating science and maths when she used an animal theme. Burt thought a puppet theme tied English, Art, Maths and Technology together.

> I think it ties so much into any areas. For example we are talking about puppets, which is English and it's Art, but it's also about moving parts. We're looking at the body, we're looking at hinges and joints and all those bits and pieces and we are looking at advertising and then you start looking at production processing and those sorts of things. So they inter-link so much. (Burt)

With attempts to tie different learning areas together Burt was the only teacher to express doubts about the dilemmas this could cause.

> It's finding the focus and I think that's where my biggest problem actually is. Actually making sure that this is exactly technology and that I can actually look and say well hey this is what I need to assess in technology. Not getting off on a tangent somewhere else because I'm after that teaching as an integrated unit. (Burt)

None of the other teachers suggested that there were any difficulties in retaining subject integrity when teaching across different learning areas.

A separate learning area

As well as believing technology was suited to integration, teachers also believed it should be treated as a separate learning area. Specific time was allocated for teaching technology. They usually time-blocked two to three weeks, when technology would often be a daily, afternoon focus. Technology, Science, Social

Studies and Health usually rotated in these afternoon times. With ten-week terms operating this meant technology was taught approximately three times a year. When teachers focussed on technology as the main learning area, they acknowledged difficulties in defining their technological focus. As Burt articulated:

> That's why I'm screaming out for help. ... I try to make sure. I tried to familiarise myself with the document but there are still grey areas. I hope the units are technology. (Burt)

Examining the technology curriculum did not alleviate teacher quandaries. For instance, teachers were puzzled about why the teaching-learning examples given in the technology curriculum were *technology*. As Penny said:

> I'm looking at it and thinking well, why is this listed under a technology unit? It would be all right if it was a thematic unit where it branched off. So now I need to try and understand why it's in there and not in design. (Penny)

Though clear that technology was a separate learning area, they were not confident or sure that what they defined was technology.

Professional development and confidence to teach technology

Teachers' confidence to teach technology was influenced by professional development involvement. The more extensive professional development they had been involved with, the more confident they were. Those with yearlong Ministry of Education technology course experiences were more willing to tackle technology in classrooms. Rachel was particularly affected as a beginning teacher with no professional development experiences in technology. In consequence she believed technology did not get the entitlement given to reading, writing and mathematics as core subjects. In the overall curriculum it was an added extra. Her marginalisation of technology was clearly demonstrated in her conversations with other teachers. Teacher technology talk had not happened. She stated:

> In terms of talking to my other friends that have decided on teaching, I never actually heard them say Oh what are you doing in technology? It's never discussed. Whereas it's, oh what are you doing for writing, or, how is the maths going? Technology is never mentioned. It's never, ever been mentioned. It's just something that is bottom on our long-term planning. I've never thought about it but it's just not something that you go and borrow someone's technology unit. ... At varsity I don't ever remember hearing about the curriculum document and I never got it until half way through my second term of actually teaching. I had to ask for it, so obviously in my year people never got the document. (Rachel)

As a contrasting example Tina was very positive after working in a yearlong programme with opportunities to become familiar with the curriculum document.

> I am quite at home with it. There is a huge demand in there though if you are going to do it all. It is about what is effective and what isn't. (Tina)

On the whole, the more involvement with teacher development, the more confident they were in teaching technology in their classrooms.

A weighting towards technological capability

Though endeavours were made to include all three technology strands in their previous teaching, their procedural interest led them to focus on the technological capability strand of the curriculum. The 'doing', practical aspects were afforded heavy weighting. Teachers concentrated on designing and making. For example:

> It wasn't so much the first strand, that understanding strand. I tend to avoid that and just go straight into my favourite thing about this designing stuff and identifying the need. (Penny)

Teachers found the strands of technological knowledge and technology and society difficult to include. Particularly difficult was including technological knowledge in relation to each technological area. Technological knowledge explanations were vague and usually links to design were evident. For example, when Ally was explaining knowledge aspects of a pet house unit she stated:

> I guess if they're making a cage, they need to design it. So some of them are going to be able to measure accurately and have a little help and they'll go and research that and have that little bit of help. They'll have to think about materials used. So they'll have to draw on what they've already found out themselves or they may go and ask a builder. They're really just drawing on the general knowledge they have. (Ally)

When Ann outlined the components of her technology units, no technological knowledge or societal aspects were evident. Again, design aspects come to the fore. She said:

> What sets aside technology from reading, language and science and social studies? The fact that I think my interpretation of it is that the children are able to experience, and design things on their own, and being able to make designs that they think are going to work, and think things through in a different way. Whereas in science they do experiments, say if we are going to grow something. But they are not encouraged to design something on their own and try it out. It's working processes to me, which is different to science and different to social studies. ... I just feel that with the technology it's working through design. (Ann)

Difficulties with articulating knowledge and societal aspects were self-acknowledged and were evident when teachers tried to distinguish between science and technology. For example:

> But that understanding, I was still not sure how that fits with science. I know that it goes really closely with science but what makes it technology and what makes it science? (Penny)
> We looked at the changes that happened when we do things in food technology like when we mix ingredients ... and then we apply heat so what happens, so that's technology. Its also science and that's where its hard to pull apart science and technology because its both those things, and its by doing the science things that sometimes technology results, you know new technology results. (Sarah)

All teachers' had difficulties specifying technological knowledge and technology and society aspects. To the fore were procedural aspects, especially those related to technological capability and design.

4.3 Technology assessment views and experiences

In their initial interviews teachers revealed views and experiences of technology assessment. Six categories are presented: assessment integral to teaching and learning, influences on assessment, deciding what to assess, comparisons with assessment in reading, student self assessment and reporting to parents.

4.3.1 Assessment integral to teaching and learning

Teachers were cognisant of the need to undertake assessment in technology and were aware of formative and summative assessment. They saw assessment integral to the teaching-leaning process and not an adjunct to it. For example, Joan commented on teachers working alongside students to gain an understanding of their learning.

> To me if kids can talk through what they are doing, why they are doing it and the processes that they are thinking through. Then if you are a good listener you'll pick up what the kids are thinking. ... Then the professionalism of the teacher comes through in making a judgement at the end of the day. ... Has learning occurred? (Joan)

Teachers gathered and interpreted student progress information while students were undertaking technology in classrooms. Assessment was not added on as a separate task. Methods included keeping anecdotal records, undertaking observations, making head notes and working alongside students. For example:

> I gathered information as part of a feedback session. It was part of the process of making a decision and was kind of integrated. I didn't actually pull something out like a worksheet or books. It's through interaction with kids, and talking to them. (Tina)
> I do a lot of anecdotal sort of stuff, where I will just sit and observe and watch and see what's going on and I'll take notes on specific things. For example, their results, or the planning stage, or the researching stage, or whatever it might be, and it might even be a trip. I keep a lot of stuff in my head and I work alongside the kids to help them along. (Ernie)

Teachers saw the need to assess in a sustained manner. One-off assessment was not deemed appropriate. For example, Sarah spoke of being vigilant over time, so she could make valid judgements and give appropriate assistance to different students.

> I would be looking for the moment when a child realises that the idea that they had before is changing. I'd be able to move in and move them on by questioning, by setting them in a direction, by whatever method works for that child and their learning style. ... I know what I'm looking for, for each child individually. During the unit I'll be looking for that. I'll think this unit will suit everybody but those ten kids there. ... What I'm looking for in them is something different and during the unit I'll either be moving them towards where I think they need to be going or, letting it take them where they need to go. (Sarah)

Ann also spoke about the need to assess in an ongoing manner.

> I've got a little book that I carry round with me quite often and make notes on children on how they're working. If somebody sort of shines in some way I make a note about that in the book and that book is useful in making day to day assessments. I also use it for my summative assessment. And I look at kids' work. (Ann)

No teachers gave formal technology tests or examinations. All gained assessment information throughout technology units while students were working on their tasks.

4.3.2 Influences on assessment

All found technology assessment difficult. Uncertainty accompanied every move. As Penny stated:

> I've been thinking about their learning. ... They can show me that they've achieved something specific, but in the broader sense, I don't know. It's just like telling me what they should have in their lunch box, you know, in terms of healthy eating, but outside the classroom or whatever, I think. ... How can they actually apply that to other experiences? I don't really know. (Penny)

Teachers were unsure of their assessment practices and expressed doubt about assessment appropriateness. For example:

> I think that some objectives fitted better than others. But I don't really know. (Ally)
> I wondered if my assessment was right. Like I wondered if I should have been assessing them all the way through the process. They did so much work in the pet house unit and I just evaluated them on the final feeding machine.... Maybe I should have done some more work on when we did the dog kennels on the ground and scale and what they added and what they didn't add and how they changed their original ideas. (Ann)

To overcome difficulties different practices had evolved. For example, to handle the wealth of student data generated when undertaking an extensive problem-solving process, Burt concentrated on assessing particular instances or events

undertaken within the technological process. For example, he sometimes assessed planning stages and other times, final products.

> I might look at the planning stage itself. I might just look at how they planned and where they have gone for resourcing. How they have compiled their plans? Or it might be the final product. Did your machine, contraption, device move? Did it improve? Those sorts of things. (Burt)

All others placed a heavy reliance on curriculum achievement objectives to guide assessment practices. This was despite achievement objectives describing two years of learning and their unsuitability for direct transference to specific classroom units. For example, Tina pre-selected achievement objectives at the beginning of a unit and subsequently used these for summative assessment. Ann chose a single technology objective as a focus for each unit and then commented for each student in relation to it. Penny chose a curriculum objective then altered it to include a context for more specific focus. Articulation difficulties were evident:

> I'm just trying to think ... like identifying a need, that type of thing. So is able to identify or explain something, like being specific. ... I can't even word it. ...Yeah, I can't explain it. ... It ties in with the curriculum anyway but it is more specific to a kitchen appliance or a household appliance. Identify the need of a household appliance and can provide adaptations to it to make it faster or ... sorry, I can't. I'm not very clear on that. (Penny)

Penny, Burt and Ann relied on School A assessment guidelines, as their school had a set format for recording technology information. However Ernie and Rachel, also from School A, were not so sure of school guidelines, Ernie as he was new to teaching in New Zealand and Rachel as she was new to teaching. Both had other priorities. School A requirements included specifying technological areas, strands and accomplishment level. Of some contention was the requirement to report against one strand each term. Though Penny, Burt and Ann did this, it seemed at odds with strand integration.

> I was sort of thinking and I am trying to understand the assessment procedures but I had always thought that we were meant to try and link the strands together. So I don't know. ... I haven't thought it through yet. (Penny)

Teachers also relied on methods and practices they used in other curriculum areas to overcome technology assessment difficulties. As Sarah stated:

> Having not done enough units in technology and with no policy guidelines and any implementation plans, it's just been having a go. So, nothing really formalised had been done. So I've had to go with what I do everywhere else. (Sarah)

In sum, a variety of practices were employed to overcome technology assessment difficulties. These included adhering to school-wide requirements, using practices from other curriculum areas, focussing on technology achievement objectives and focussing on single instances or events. With teachers being uncertain about assessment in technology, practices wavered under different influences. Teachers felt insecure and doubtful. No methods were employed that focussed at a specific conceptual or procedural level or on the whole task.

4.3.3 Deciding what to assess

With little guidance teachers had difficulties making decisions about what to assess and whether students had made progress. Teachers tried to focus on technological aspects but often focussed on students' social and managerial skills, such as how well they shared tasks and worked together. Technological conceptual and procedural aspects were marginalised, especially conceptual aspects. For example, Penny had assessed students' ability to design a product in relation to an identified need, group dynamics, their ability to work together, their completion of tasks and presentation quality of work. Ernie had assessed feasibility of ideas, use of knowledge and experiences to solve problems, how they organised and solved problems and their methods of working. Ann looked at student confidence in sharing ideas, enthusiasm, ability to include more complicated design ideas and degree of creativity employed.

Sarah and Joan considered the need to assess across the three strands for each unit, believing all strands were integral to technology education - each strand was not meaningful without the others. However, they also focused on social and managerial aspects. For example in the unit on sweet making, Sarah assessed the managerial aspect of selecting and employing successful group problem solving strategies.

No teachers focussed on student progress from one unit to the next. Rather they focussed on student progress within a unit. Progression was not well understood. Not only were teachers unsure of where to next take students, they were unsure of students' backgrounds and previous positions when they moved into their class. For example Burt had significant problems identifying his students' technology

background. This discontinuity meant he was compelled to rely on progress identified within his class over the year, rather than follow progress over several years. Even here he was unsure of his ground.

> I've no idea what they did in technology before. So basically I'm trying to do things where I can say well this is what we did the first time with this problem and then six months later down the track we can do a similar problem. I could show improvement or a result or whatever and I would hope that some of the knowledge would come through. ... But it is hard to know if it is useful sort of material and that's why we are looking for advice and guidance. (Burt)

To summarise, social and managerial aspects and some broad technological aspects dominated teachers' assessment focus. Only two teachers tried to focus on strand interrelationship for assessment, the rest focussed on single strands. No holistic aspects were focussed on; rather assessment was atomistic and piecemeal. Aspects related to progression were almost non-existent especially when looking at student progress between classes, units and over time.

4.3.4 Comparisons with assessment in reading

All teachers, bar Penny, believed assessing reading was easier than assessing technology. This was because reading had clear benchmarks in place and set standardised formats such as running records, which all teachers knew about and used. Teachers were more confident and knowledgeable about reading and assessing reading. Guidelines were very clear and teachers had verified assessment tools at their disposal. There was more detail with which to work, and they could look at specific reading behaviours, such as decoding skills, ability to obtain meaning, fluency, and comprehension. Assessment was structured, well researched, and had tried and tested methods that teachers staked their judgements on. In addition reading was taught and assessed frequently, so teachers were very experienced in assessing student progress.

In contrast, technology assessment was vague, provided little teacher guidance and was based on individual ideas and any self-selected curriculum achievement objectives with which teachers had little experience. Burt commented on the extensiveness of the reading records that accompanied students when they moved from class to class and the paucity of detail in the records that described their technology progress. He accessed valid and reliable assessment methods and tests

in reading. In technology he relied on things that he trialled himself. He was not confident that his technology assessment practices were reliable or valid.

> In reading, kids come with lots of information about what they are doing but that doesn't happen in technology. We can't see progress in technology. I don't know what to look for the same. .... It is so much harder. I would hope that the methods I am using are the right ones for technology. ... I'm sort of trialling things that are right for me, but do they mean anything? So it is difficult, difficult to know what is right. (Burt)

To intensify matters technology was likely to be taught only once per term. Progression in technology was therefore difficult to judge due to infrequent teaching and long inactive periods. Attempting to make comparisons over prolonged time gaps was problematic. Exacerbating the time lapse were difficulties in making comparisons between different technological areas. Not only did teachers teach technology infrequently; they rarely taught a technological area more than once to their students. This meant they tried to compare unlike technological areas. Teachers' lack of opportunity to gain accumulated expertise through assessing similar technological experiences compounded difficulties. Also there was little in place to assist teachers. Therefore, teachers had to rely on their own knowledge and experience.

> Anything at all that you want for assessment in reading is there. You can't really go wrong. With technology there is nothing, absolutely nothing. So it's really going on teacher knowledge, background knowledge of things, I think. Your confidence and understanding of the document; experience with using the document. I don't know, but at the end of the day, it is down to your gut feeling and your own professional knowledge. (Joan)

Penny was the only teacher to find assessing technology easier than reading because she thought that reading assessment was so detailed it was problematic. Technology was narrower as students were all involved with similar activities at the same time. Therefore, technology assessment could focus on a few aspects. On the other hand, students involved with reading were on many different levels with a multitude of divergent aspects to assess.

As technology education was a new learning area in its infancy, there were few guidelines, or dependable and reliable aides for assessment compared with reading. Therefore teachers did not have the confidence to assess in technology education that they had in assessing reading.

4.3.5 Student self assessment

All teachers viewed student self-assessment as important. Self-assessment was included in students' ongoing technological processes and more formally at the end of a technology unit. Teachers expected students to reflect on their work and make changes in the light of review. They wanted students to be involved in self-review as an ongoing occurrence throughout the technological problem solving process. As Ann said:

> I want them to be able to explain, to make and try ideas out and then fix them. Yes and analyse what they have done and then change what they have made initially and make it fit the criteria. (Ann)

Self-assessment was particularly focussed on at the end of units where students were required to look back over their accomplishments. Teachers gave students work sheets that directed students' attention to particular aspects. For example, Rachel's students assessed how well they achieved their intended solution. Burt's students assessed how well they met the programme objectives, their use of materials, the improvements that could be made to their devices, the degree of match between solutions and designs, and their reasons for changing plans. Ann's students focussed on aspects such as enjoyment of the task and degree of satisfaction with results. This more formal self-assessment served to conclude units and was the final task students undertook.

All teachers viewed student self-assessment as an important component in technology education. It was afforded consideration throughout the technological process and at the conclusion of units.

4.3.6 Reporting to caregivers

Teachers had few experiences in reporting to caregivers about student technology progress. Few school guidelines existed on ways to report technology to caregivers. Reporting was therefore very dependent upon individual teacher's interpretation and personal confidence in attempting the task. Ernie, Tina, Rachel, Ally, Joan and Sarah had not reported to caregivers at all. Penny, Ann and Burt had reported to caregivers, but were not confident in doing so. They were unsure if what they had done was appropriate. For example:

> Am I leading them in the right direction? Am I giving parents false expectations and false ideas about what technology is? And that's why there really is a need for technology development. (Burt)

If given the choice of reporting to caregivers they avoided it. For example Ann said she would only report on children's technological progress if caregivers asked.

When they explained aspects for reporting, students' social and managerial aspects were to the fore. For example, Rachel stated she would concentrate on the students' co-operative skills, Tina would concentrate on managerial skills such as:

> How they react when they meet frustration because they are going to. ... How they cope with that whole process. (Tina)

A concern was that caregivers would not understand the curriculum. So teachers might spend interview time explaining it. Teachers evaded technology talk with caregivers because they thought barriers to caregivers understanding technology were too great. For example:

> I would have to spend all my time talking about what technology is all about, and so maybe I just avoid it. ... I wonder if I avoid it purely because I wouldn't want to get into the discussion, only having 10 minutes to talk about their child. (Penny)

Reporting to caregivers about student technology progress was a neglected task. Only three teachers had undertaken caregiver reporting and even they would evade the task if possible. Confidence levels were low.

4.4 Summary of Chapter 4

This section summarises the 1998 views gained through interview of the nine teachers involved in the research project. Several aspects of commonality emerge. These include a broadening understanding of technology and technology education, the establishment of technology as a stand-alone learning area, self-acknowledgement of knowledge gaps and difficulties with assessment.

- ***A broadening understanding of technology and technology education***

Teachers' awareness of the technology curriculum, including strands and technological areas, had broadened since the 1994 research in New Zealand classrooms (Jones, et al. 1994). Technology was a separate learning area and a

developing technology subject subculture allowed teachers to choose technology tasks appropriate to particular technological areas and their students.

Teachers had a reasonably consistent view of the nature of technology. It included aspects of design, innovation, problem solving, creativity, creating new and improved products, was part of the real world, and was practical. They identified key technology aspects such as meeting needs, design-make-test process, risk taking and aiming for multiple outcomes. All teachers saw technology as a hands-on subject requiring the practical involvement of students. In consequence, all tasks included hands-on, making aspects. Particularly prominent were drawing, construction and testing in relation to creating artefacts. Students were expected to experience these and teachers concluded that if these were present, they were teaching technology. This is broader than earlier (Jones & Carr, 1993a; Jones, et al. 1994) but still represents a restricted view of technology and technology education. Detailed technological knowledge understandings were absent. The influence of subject subcultures and background experiences were evident. In particular, teachers had difficulties articulating differences between technology and science.

- ***Technology as a separate learning area***

Despite teachers' expressing difficulties in understanding technology and technology education, technology education was established as a separate learning area in both schools. It was allocated separate teaching time and was included in school plans. Both schools expected teachers to teach technology at least two times each school year. However, technology's status was tenuous, as it had not gained a firm foothold in the schools. For example, only three teachers had reported to caregivers about technology and School B did not have a technology assessment policy.

Teachers knew they needed to teach different technological areas. Experience in the areas ranged from extensive (Ally and Sarah in all areas), to moderate (five from 2-5 areas), to minimal (Rachel one, and Joan no areas). All had used the curriculum to assist with planning and for trying to distinguish between areas. They knew strand integration was important when teaching technology. However,

strand integration was problematic as it complicated the teaching process and made assessment particularly formidable. A self-acknowledged barrier was their narrow knowledge of significant underlying technological concepts and principles in each technological area. Choosing suitable specific content for teaching was perplexing and uncertain.

Nevertheless, despite the barriers in implementing technology, all were very positive in their enthusiasm, expressing support for opportunities to foster creativity, problem solving, risk taking and a more comprehensive understanding of the made world.

- ***Acknowledgment of personal knowledge gaps***

Coupled with a broadening understanding of the technology curriculum was the realisation of teacher knowledge gaps of all technological areas. They acknowledged difficulties articulating technological concepts and principles. Though technology held a less tenuous position in terms of allocated teaching time compared with earlier studies of technology education in New Zealand (Jones & Carr, 1993a; Jones, et al. 1994), teacher knowledge and teacher talk remained transient. Technology was not spoken of with ease or familiarity and continued to remain outside the parameters of usual teacher talk. Technology was viewed as puzzling. In teaching technology, all teachers exercised considerable effort. No one saw teaching technology as effortless. Rather it was seen as tough and somewhat mystifying.

- ***Difficulties with assessment***

Although teachers were able to discuss technology in broader ways than teachers were in previous years this had not translated into broader assessment practices. All acknowledged assessment difficulties. They relied on other learning area methods to guide their technology practices. In formative assessment they talked with students to understand their thinking and to assist them to move on. Prior views were often sought to establish beginning points and to use as a comparison. Anecdotal records were kept to note aspects of significance. Student worksheets were highly thought of as a means to gather student self assessment data. In

summative assessment, checking each student against pre-selected achievement objectives was common practice.

Uncertainty stalked every assessment move. Teachers knew they should integrate the strands in teaching, but did not know how to transfer and translate this to assessment practices. This ambiguity perplexed teachers. In consequence, assessment focussed on definite, separate activities or itemised achievement objectives. Additionally, either conflicting, or inadequate, school-wide guidance exacerbated difficulties. Teachers' lack of confidence in assessing technology was most evident in reporting to caregivers. Only three teachers had talked to caregivers about their child's technology progress in formal reporting interviews.

Assessment difficulties were highlighted when teachers were asked to compare reading assessment with technology assessment. Eight of the nine teachers commented that reading assessment was easier. This was because they taught reading every day, had established tests, knew a lot about reading, knew where students were going in reading and schools had strong, school-wide practices in place. In technology all they had was the curriculum document, which they believed did not give them enough guidance and detail for assessment. As well they had little technology teaching experience to call upon. They were unsure of the goals in technology and a sense of school-wide technological progression was lacking. Consequently they did not assess with any degree of confidence.

Penny, the one teacher who thought it was easier to assess technology than reading, thought so because reading assessment was so detailed she had difficulties handling, sorting and selecting from the wealth of information available. On the other hand, students were involved with the same activities at the same time in technology, so assessment had more commonalities.

- ***Concluding remarks***

At the heart of teacher troubles was their lack of secure knowledge of technology and technology education. Teachers tried to use the technology curriculum to assist with planning, teaching and assessment but found it not specific enough. Technological principles, concepts and processes received minimal attention, as

teachers did not have a detailed knowledge of them. Their planning, teaching and assessment lacked technological focus. Instead social and managerial aspects were targeted. This was not surprising given an existing subculture in primary classrooms where such aspects are considered important to students' development. No teachers had focussed on holistic aspects of assessment where student learning and progress throughout the whole technological process was considered. How well students had brought all the relevant aspects together in undertaking and solving technological problems was not addressed.

All were experimenting with different technological ideas and practices. Technology had yet to be embedded into their teaching with ease. In becoming competent, confident practitioners, they were at a stage where teaching required considerable effort. The learning area presented significant challenges and all found it complex and requiring effort. None however, viewed their uncertainties as insurmountable. All saw technology as a subject worthy of inclusion in the New Zealand curriculum. As Ernie concluded:

> It seems to be very much dismissed as a subject. ... But it's one of those subjects that the more you look into it the more important it actually becomes as a subject. ... Technology is about developing life skills in a way, because you're actually developing skills that you're going to need when you leave school and go into the world of work. ... It's something kids need to be involved with. (Ernie)

Chapter 5 continues the examination of teachers' involvement with technology education during 1998. From teachers' views of technology and technology education described here in Chapter 4, the shift is to teachers' classroom experiences. Their planning, teaching and assessing of technology education undertaken in 1998 is detailed and analysed.

5. PLANNING, TEACHING AND ASSESSING TECHNOLOGY EDUCATION: 1998 CLASSROOM FINDINGS

5.1 Introduction

Chapter Four described teachers' 1998 perceptions of technology and technology education. These included a broadening understanding of technology and technology education, the establishment of technology as a stand-alone learning area, self-acknowledgement of knowledge gaps, and difficulties with assessment. This chapter details classroom practices undertaken by the teachers in 1998. As explained in Chapter 3 a two-stage analysis of data was undertaken – a within-case analysis followed by a cross-case analysis. This chapter presents the findings. Joan is excluded as being an Assistant Principal she did not teach technology.

Section 5.2 examines the background to teachers' units including an overview of teachers' classes and their programme planning. Section 5.3 focusses on technology classrooms and examination of teachers and students working together. Teachers' application of technology understandings is addressed. Pedagogical aspects include the influence of task description, the adoption of a linear discrete process, expectations of transfer, technical skills application, integrating technology with other learning areas and teachers as self-reflective practitioners. Assessment aspects examined include teachers' understandings of progression, student self-assessment, formative interactions and summative assessment. Section 5.4 presents the chapter summary.

5.2 1998 planning

This section examines teachers' technology planning. An overview of classes is presented, followed by an analysis of teachers' formal planning including teachers' use of the technology curriculum, lesson sequencing and assessment considerations.

5.2.1 Overview of each class

An overview of each class includes year levels taught, class sizes, gender and ethnic make-up and students age-range. The class range included one Year 2/3, one Year 3, two Year 4, one Year 4/5 and three Year 5/6 classes. All primary class levels were covered except Year 1. A gender balance was evident and there were 22 different ethnic groups across the classes. Penny's class was the most diverse with 11 ethnic groupings and Burt's the least with 3. The student age range was 5.6 to 10.8 years (refer to Appendix 3 for details). Altogether a range of classes with students from a variety of backgrounds were involved.

5.2.2 Teachers' programme planing

This section addresses two aspects. First, topic choice is examined, and secondly, planning documents are analysed.

Technology topics

Topic examination details the range of technological areas, the specific technology unit chosen and the expected teaching time. Heavy focus on the technological area of Structures and Mechanisms was evident with six of eight teachers choosing this area. Additionally five of the six combined it with Materials technology; Burt being the only one to focus just on Structures and Mechanisms. Ally's focus on Materials was combined with Food and Information and Communication. Ernie was the only teacher choosing Electronics and Control as a focus.

A range of topics was chosen including electric map games (Ernie), time clocks (Burt), The Greek restaurant (Ally), fitness equipment (Sarah), Mazes (Rachel and Tina) and moneyboxes (Penny and Ann). Rachel and Tina both chose Mazes as they utilised a local science and technology centre interactive exhibition. Penny and Ann also chose the same topic, as they were co-teaching the unit. Unit duration ranged from a moderate 2 weeks, with 6 sessions, to an extensive 4 weeks, with 14 sessions (details in Appendix 8). Teachers gave a variety of reasons for topic choice with three common categories - targeting particular

technological areas, linking to previous teaching in other learning areas and student suitability. Table 5.1 tabulates these reasons.

Table 5.1: Reasons for topic choice

	Targeting particular technological areas	Linking with another learning area	Engaging for students	Other reasons
Rachel	√		√	Science & technology centre maze exhibition - unique opportunity for students
Ernie	√	√ Science unit-electricity	√	
Burt	√	√ Science unit-weather devices	√	
Penny/Ann	√	√ Maths unit-money	√	
Tina	√	√ Maths unit-symmetry, Language unit-Alice in Wonderland & links to mazes	√	Science & technology centre maze exhibition - Unusual technology
Ally	√	√ Language unit-Greek legends	√	Opportunities to teach in an integrated way
Sarah	√	√ Science unit-muscles & bones, Physical Education/Health unit-personal fitness	√	

Seven of eight teachers linked technology to previous units taught. Of these three built on a science foundation, two on mathematics and two on language. Rachel was the only teacher not to directly link with previously taught units, instead taking the opportunity to use an environmental experience. All eight believed topics chosen would be particularly suited to their students, as they were topics that would engage student interest. Finally, all were influenced by their objective to target particular technological areas, either in consideration of school requirements, or due to the need to cover a different technological area than taught previously. No teachers chose topics for covering particular technological knowledge or procedures.

Teachers' planning documents

Examination of planning documents reveals that all teachers completed a written plan and used the curriculum document for planning. Only two identified specific learning outcomes. All outlined a lesson sequence and considered summative

assessment. Finally, a variety of other aspects were included. Each point is considered.

Formal planning undertaken

All teachers formally planned by completing a written plan of their intentions and all identified level/s focus. Planning formats and plan contents all differed, except for Penny's and Ann's. Their planning was the same as they were combining classes for co-teaching the same unit 'Moneyboxes'.

Based on the curriculum document

All teachers used the technology curriculum to assist with planning selecting particular technology strands for focus. Three, Rachel, Sarah and Ernie, selected Strand B (Technological Capability) and five, Burt, Penny, Ann, Ally and Tina, all three Strands (Knowledge and Understanding, Capability and Society). For articulating more detailed achievement objectives the curriculum again influenced choices made. Rachel and Sarah chose one achievement objective and Ernie two from the capability strand at a particular level, while Penny, Ann, Burt and Tina featured achievement objectives from all strands at particular levels. No teacher chose all achievement objectives. Teachers rewrote or paraphrased the level achievement objectives. For example, Ernie recorded these objectives from Level 2 technological capability:

> With reference to identified needs and opportunities:
> - discuss solutions and strategies, select and develop a suitable option
> - make preferred solution
> - show and describe examples of their intentions, progress and outcomes
> - describe how satisfied they are with progress and outcomes.

Penny, Ann, and Burt also based objectives heavily on the curriculum but contextualised them. Table 5.2 shows examples from their planning.

Table 5.2: Altered achievement objectives

	Achievement objective	Altered Achievement objective
Penny Ann	Level 2 Achievement Objective 1 *explore and discuss the use and operation of technologies in everyday use* (Ministry of Education, 1995, 32)	*explore and discuss the origins and use of* Piggy banks *in everyday use*
Burt	Level 3 Achievement Objective 5 *gather and collate information on needs and opportunities in the local environment* (Ministry of Education, 1995, 37)	*gather and collate information on needs and types of* time devices *in the environment*

Specific learning outcomes

Only two teachers, Tina and Sarah, had identified and outlined specific learning outcomes. Tina recorded three: (i) understand aesthetic, cultural and historical aspects of maze building; (ii) co-operate and work under consensus; and (iii) set and follow design criteria and understand the positive and negative ramifications of design. Sarah outlined two: (i) how a fitness machine works the body especially bones and muscles and (ii) how and why a machine needs to be designed to meet specific needs.

Intended lesson sequence included

All teachers outlined their intended lesson sequence. Four teachers (Burt, Ernie, Ally and Sarah) compiled brief lesson sequence outlines, while the others (Penny/Ann, Tina and Rachel) compiled detailed sequences. Details included activities students would undertake within each lesson, possible questions to ask students as well as technological principles and ideas pertinent to the unit. For example, Penny/Ann emphasised the need for children to consider ease of use, durability, size, appearance, safety in construction, security, and who they're designing for; Tina featured aesthetics, safety, stiffness of material, stability, strength, and durability; and Rachel highlighted durability and user appropriateness.

All teachers followed similar linear structures in lesson sequences (see Appendix 9). First there were introductory and exploratory activities, then designing and constructing activities and finally testing and self-assessment activities. Though appearing linear where teachers would move directly from one stage to the next, teachers commented that each session would build upon previous sessions. Prior thought was given to relationships between the planned activity sequence. For example:

> It's a good idea to give them these activities first (exploratory activities). They'll realise all the problems and begin to see ways to solve them. They can see how to synthesis their ideas together. They can see what will work and what won't. It gives them a chance to think things through. (Sarah)
> I wanted them to start thinking that Piggy banks have a function, there was a reason why they were invented and they do have a purpose ... If they can understand that they can start putting ideas into their design. (Penny)
> We're going to talk about Greek, Roman and Celtic mazes and we'll talk about religious mazes too. It's all to give background, the history, links to society aspects, leading into the why of mazes. (Tina)

Typically teachers' lesson sequences and activities included a design-make-assess process and emphasised technology education as a practical pursuit, with students' hand manufacturing an artefact. Penny/Ann, Tina and Rachel's planning indicated careful forethought with a sequential linking of activities. In contrast to other teachers they matched activities to particular achievement objectives for assessment.

In summary a range of lesson planning sequences was evident with some teachers undertaking very detailed planning. No teachers planned using detailed conceptual and procedural aspects specific to particular technological areas.

Summative assessment considered

All teachers considered summative assessment when planning. For example, Rachel, Ally, Penny/Ann, Sarah and Tina identified their summative assessment focus. Rachel's focus was on student planning, production, co-operation and reporting. Ally was going to focus on special design effects for invitations and menus, student questioning and use of information. Penny/Ann were focussing on understandings of moneybox origins and uses, gathering resources, making, assessing and modifying moneyboxes, and identification of favourable consumer features. Sarah was going to focus on 3D modelling. Tina identified achievement objective 2a, specific skills (setting and following design criteria, redesigning and reassessing constructions, understanding positive and negative effects of design), and how well children could understand, set and adapt design criteria.

Tina, Rachel, Burt and Penny/Ann also identified aspects for students to summatively assess. Tina expected students to assess against criteria they set and Rachel specified students would assess against durability and age appropriateness criteria. Burt and Penny/Ann were more detailed designing assessment worksheets. Burt included a final design drawing and set questions to answer, including was your design successful, most/least liked, changes I would make. Penny/Ann's worksheet had questions about the workings of moneyboxes, improvements needed, changes in moneybox construction from design and customer evaluation. Other teachers included student assessment in their plans as an intention but did not develop focus or content during planning.

However, no teacher's summative assessment focus was on how students would bring all aspects of the task together or on specific conceptual and procedural aspects.

Other aspects

A variety of other planning aspects was addressed. Sarah, Burt and Tina included links to other learning areas; Sarah, Rachel and Tina linked to essential skills; Penny/Ann, Ally, Rachel, Burt, and Tina identified technological contexts; and Ernie, Sarah, Ally, Rachel and Tina identified resources.

5.2.3 Summary of planning

From the range of primary classes commonalties were evident in planning. Seven of the eight teachers linked technology to other learning areas exemplifying ideas that technology was suitable for building on other learning areas. All believed topics chosen would suit their students and all were influenced by their objective to target particular technological areas. Area targeting reflected their understanding that areas helped to define technology education and students should experience a range.

All used the technology curriculum to assist with planning, even though it did not provide the detailed guidance they required. All included some thought about summative assessment indicating the importance they placed on it. All lesson sequence structures emphasised hands-on exploration, designing, making and testing. Teachers' also organised student activities in a design-make-appraise sequential process reflecting practical, design views of technology.

Overall though, planning was distinctive and personal with each developing their own unique method relying on practices in other learning areas and personal judgements. As Sarah stated

> Having not done enough units in technology and with no policy guidelines or any implementation plans, its just been having a go. So nothing really formalised has been done. So I've had to go with what I do everywhere else. (Sarah)

With no school-wide direction or agreement, teachers were given total responsibility for making planning decisions. There was a sense of 'going it

alone'. Teachers could choose appropriate tasks and target particular technological areas but lacked detailed understanding of different areas and the curriculum for creating detailed, specific student learning goals. With no secure school guidelines and little accumulated practice from which to draw, planning was undertaken with doubt.

5.3 Teachers and students in technology classrooms during 1998

The aim of examining technology classroom practice was to gain an understanding of teachers' teaching practices and student technological learning. Each time teachers taught technology sessions were observed. Unstructured interviews with teachers after most sessions were conducted. Questions were in response to that day's classroom happenings. Sometimes teachers instigated aspects to talk about. Pertinent material, such as charts, student worksheets, whiteboard diagrams and lists compiled from class discussions, was gathered and copied. Student work was gathered, photographs of finished products taken and conversations with students were undertaken while they were working. At each unit's end more structured student interviews were undertaken. Teacher and student conversations were taped and transcribed. The extensive classroom-based data gathering and analysis led to the findings now presented. The findings are presented in three sections: understandings of technology, pedagogical aspects and assessment aspects.

5.3.1 Understandings of technology

Teachers' classroom work reflected several understandings about the nature of technology. These included notions that technology is a practical pursuit, has multiple solutions to problems, is design and is purposeful. Findings are presented. Student work in technology education also reflected several understandings about the nature of technology. Where applicable, their understandings are reported alongside teacher understandings.

Technology is a practical pursuit

All teachers viewed technology as a subject requiring the practical involvement of students. As a consequence, all tasks included hands-on, drawing, making and

testing components. Particularly focussed upon were drawing, construction and testing in relation to creating artefacts. There was an expectation that for students to be involved in technology, they would experience these aspects. For example, in Tina's maze unit, 9 of the 12 sessions included practical components such as drawing, constructing and tangible testing. In Ally's restaurant unit, 11 of the 14 sessions included drawing and/or making, and in Sarah's fitness equipment unit 10 of the 12 sessions included drawing, construction and/or tangible testing.

The dominance of technology as a practical activity affected opportunities to foster student conceptual development. This was particularly evident with Sarah, who had students making fitness machine models. In doing so Sarah did not realise young students would have difficulties with understanding relationships between modelling and real things. She assumed students would know the differences and take these into account, believing students would view models as smaller scale replicas of real things and would transfer knowledge gained in real situations to their model making. For example, she took students on a gymnasium visit expecting them to gain understandings about fitness machines and apply these to their model making. No students did this. Additionally, she did not realise young students saw model making as different from making real things. No students measured, worked to scale, or used transferable construction techniques. By sidelining conceptual modelling aspects, students only focussed on procedural model-making aspects.

This practical dominance was also strongly reflected in student technology views. Boys and girls from 6 years to 11 years saw technology as a hands-on, doing activity. Construction aspects and making their ideas were prevalent. For example:

> I think technology is structuring and building. It's about making an idea. (Rawiri, 10 years)
> Science is chemistry, physics and biology. Technology is none of those things. With technology the first idea that comes into my head is two cogs turning round and one cog moving another. It's doing stuff. (Paul, 10 years)
> It's like these drawings. You have lots of ideas and you have to choose the best one and make it. (Dana, 9 years)
> Technology is how to make moneyboxes and to see how we can do things for ourselves. (Sam, 8 years)
> Technology is how to construct things, how to make things. (Mary, 8 years)
> I think it's making mazes. (Summer, 6 years)

Teachers and students viewed technology as a practical activity. Teachers had a broader view than students; teachers saw more complexity in practical activity with designing, making and testing involved. Students tended to focus more narrowly on construction aspects.

Technology has multiple solutions to problems

Teachers believed that technology was about students creating multiple solutions to problems, that technology does not produce one correct answer and is innovative. A large variety in solutions meant more appropriate technology education. When teachers involved students in creating artefacts, they expected and encouraged a variety of solutions. They anticipated that no two artefacts students produced would be alike. The search for divergence was reflective of creativity, an aspect understood to be inherent in technology.

> ... I have this thing about trying to find solutions. ... I like the idea of not having a right or wrong in terms of a set solution. (Penny)
> They're all so different. ... I wanted to see how well they would co-operate and how they came up with a solution. There is so much difference there. I wanted them to see there is not one way of doing something. (Sarah)

To encourage divergent solutions, teachers often set technology tasks so students could contribute toward task goals as student input led to task flexibility with multiple solutions the end result. Problem solving was thus encouraged.

> I believe that this unit did achieve the aims that technology offers. The children gathered information, took risks, thought about various possibilities, constructed solutions to problems, worked on trail and error, used teamwork and used a variety of resources. (Rachel)
> I'm proud of the huge variation that we have of the task in the end result. ... There was a lot of creativity put into the first plans but some of it was unrealistic. But that is part of the learning process. ... they have learnt to redefine their thinking through planning. They have modified their materials. They had problems to solve. Their whole context was problem solving. They have been able to interact to solve their problems. (Tina)

When teachers involved students in creating artefacts, they expected, encouraged and accepted a wide variety of solutions. As technology was about innovation and creativity, technological problem solving involved developing many answers.

Technology is design

All teachers believed design was inherent in technology and actively pursued this aspect. When students' designed they were to illustrate ideas through drawing.

The design process included creative drawing, making and testing. Teacher instructions to students confirm this.

> You need to have a clear plan of your maze. Think in your head how you are going to do it. Go with your partner to design and draw your maze. This afternoon you are going to make them. (Rachel)
> Today I'm going to give you some paper and you are going to do creative design. We have to plan out design and know what we are going to design and what the fitness machine needs. (Sarah)
> We want to see how we can design and make something to help other children with maths. You need to present at least three different ideas, sketch out those ideas, so then you can choose one to make. (Ernie)

Drawing was a major aspect in the development process and was expected to connect to construction. Drawing was carried out in two positions in the development process - beginning and concluding stages. In beginning stages students were expected to use drawing for exploring and developing possible construction ideas. In concluding stages students were to show final constructions by drawing the completed artefact. Sometimes they were to reflect on their progress by drawing future alterations to constructions. Always teachers saw drawing as a way to connect stages together.

Though some students realised connections between drawing and construction, not all did. Many did not understand that drawing could be a construction guide and even a blueprint for it. Many students perceived it a way of jotting down ideas showing their current thinking. Once construction began, new ideas could be included and previously drawn ideas could be abandoned. In fact, many students threw away plans once they began construction for they were of no further use. For instance, three boys constructing a sand maze abandoned all plans and added a sign stating that:

> We are just working off the top of our heads. Our design was too hard. (Daniel, Regan, Kevin, 7 years)

Teachers' well-established concept of technology as design was not as securely established in student technology undertakings.

Technology is purposeful

All teachers viewed technology as a purposeful activity with the need to identify the rationale for producing artefacts. Activities were undertaken where students

made decisions about the artefact's target group. They were to find out about anticipated users and to create their artefact for the intended individual or group. This intentional identification occurred early in the process. Teachers expected students to identify and establish needs and requirements for the people who were to use the artefact, even if it was for student's own use. Technology was viewed as purposeful with particular aims. The following teacher instructions to students are illustrations.

> You need to think about the moneybox you are going to design. You need to think about the things that are important to you and prioritise what is important for your moneybox. (Ann)
> You need to be aware of the maze you are going to make. Is it suitable for a younger child? Can your marble go through? (Rachel)
> Today we are going to do a new design for a fitness machine. You need to think about children's needs and their fitness needs. What do you have to consider? (Sarah)

Identifying needs of target groups established a foundation for justifying the designing and making of the artefact. Students were required to be cognisant of the tie between artefact the user. As teachers stated:

> You're identifying needs and then the children actually have to develop some sort of system to solve their needs or meet that need. ... It's looking into more realistic sorts of problems, whether it's actually creating a need for the children to solve or whether it's sort of taking skills, which you develop. (Ernie)
> I wanted them to start thinking that piggy banks have a function, there was a reason for why they were invented and they do have a purpose and even though they look fun they were important to people. (Penny)

Most students understood that their products were intended for particular groups of people or individuals. They talked about ties between artefacts and users. For example, Nicole and Michelle were aware the maze they were making for Michelle's rabbit, Peter, needed to be the right size for him

> We won't have any problems with Peter fitting because we measured the rabbit and we measured the doorways. (Nicole, 7 years)

Laura (8 years), in making her fitness machine, viewed it suitable for children because it was a small size and light. Dean and David (11 years), in making time measuring devices stated that:

> Our job is to make a device to measure 4 hours and 5 minutes that can be used over and over. (Dean) Yes, it must be exactly 4 hours and 5 minutes and it has to work. (David)

Simon talked about the purpose of his moneybox.

> It is for children. It had to be a toy as well as a moneybox and a workable moneybox. The money has to be able to go in and not get stuck. I'm working on how to get the money out at the moment. (Simon, 9 years)

Both teachers and students understood that technology is purposeful.

5.3.2 Pedagogical aspects

Teachers' classroom practices showed particular pedagogical aspects. The influence of task definition on student learning was not clearly understood. The technological process often adopted linear and discrete stages despite teachers knowing about an iterative process and desiring it. Teachers found it difficult to account for transfer. They underestimated the influence of student technical skills. They attempted to integrate technology with other learning areas. Finally, teachers were self-reflective practitioners. These aspects are presented.

The influence of task definition

The influence of task openness on student learning and subsequent assessment opportunities was not clearly understood. Teachers sometimes defined tasks tightly, for example by limiting criteria, by restricting materials, or by specifying narrow working guidelines. When this occurred, students produced almost identical outcomes, worked in almost identical ways and thought convergently. This was despite teachers wanting students to attain a range of solutions, to work in different ways and to think divergently. For example, Ernie expected his students to devise a variety of mathematical games. He made a mathematical, electrical circuit game and showed this to students at the unit's beginning as a possible way to solve the problem. All students subsequently produced almost duplicate versions, for they used Ernie's example as a model. Ernie expressed disappointment in the conformity of student solutions. Ally's students were expected to create different menus and invitations for their Greek Restaurant. This did not happen as the class agreed to a particular format and material restrictions, thus limiting individual choice. Examples of other invitations and menus were not examined for gleaning supplementary ideas, and opportunities to learn new graphic skills and refine existing graphic skills were not provided. Students therefore produced almost duplicate copies of menus and invitations, undertook both tasks in the same manner and demonstrated a high degree of class similarity in their finished solutions, despite Ally expecting creative, divergent student thinking and a wide variety of solutions.

At other times, tasks were defined openly and had few guidelines. Student learning was affected in a number of ways. First, students were unsure of task requirements sometimes attaching unnecessary bits and pieces to constructions. For example, two students added cardboard elevators to their marble maze. When asked for an explanation Matt said:

> We're just adding all sorts of stuff. It doesn't matter. (Matt, 8 years)

Two girls drew dozens of bows and smiley faces all over their maze. They said:

> We've just learnt how to draw smiley faces and bows. We put them on everything. It's all right. (Nina, 7 years)

Second, students were unsure of next steps, waited for teacher instructions and at times disengaged altogether. For example, Colin disengaged from his moneybox making task, not sure of his direction and therefore finding the task difficult.

> I wouldn't want to do this again. It was hard and I couldn't do some and I didn't know where I was going. (Colin, 8 years)

Third, students unsure of task goals were not sure when they had finished, sometimes waiting for teachers to tell them. As instances:

> I think I have to draw a maze. It has got all sorts of shapes. It might have circle. I don't know when I'll be finished. I don't know when it's done. (Harry, 6 years)
> It will be finished when it is. (Ian, 7 years)
> I think it will be when the paper is all filled up (Charlie, 6 years)
> Because when the teacher says everything is all right (Sue, 7 years)
> It will be finished when the teacher and I think it is. (Sally, 10 years)

It appeared that open task definition with few guidelines left students unsure of task requirements, what needed attention and when tasks would be completed.

Like students, teachers became confused about learning focus with open tasks. They were unable to articulate technological outcomes inherent in the task or where to place the emphasis for students. As one teacher said:

> I feel lost and I am no longer sure that I am teaching technology. (Ally)

Rachel talked about student confusion with 3D paper maze-making because of her confusion:

> I think I needed to say at the beginning why I wanted them to make the maze. I needed to set the objectives clearer because they got into it and didn't know why we needed them. We did talk about the co-operation but they didn't understand the mazes, didn't make comments. (Rachel)

When teachers altered task parameters while students were undertaking the task, they were undiscerning of the consequences. They did not realise the effects of the changes on students. Students dealt with this changing nature of tasks in a number of ways. First, they ignored the new criteria preferring to stay with the original task. As Ali said when talking about his fitness machine:

> I'm not going to add-in any new ideas I saw at the gym either. I like it how it is. (Ali, 8 years)

Second, some students superficially took changes into account. As an example, a student who had made a static machine model glued on fixed cardboard wheels after the task had been redefined as the construction of a mobile machine.

Third, some students became so confused they disengaged completely. For example, Rachel initially defined a task as designing a 3D maze with pathways through which marbles could pass. Later, designing the maze for play by younger children was added. Even later, notions related to the durability of the construction materials were introduced. The continual changing of task parameters without student negotiation, meant the goal posts kept shifting - the task became a different task each time another variable was added. Consequently, students were confused resulting in some task non-completion. In interview, Rachel stated that she realised in her formative interactions with students she hadn't specified enough variables. The task was too open. By adding criteria, she expected students to have clearer ideas of what they should be designing and constructing. However, this rather ad-hoc way of working meant students got lost. It was not surprising they could not complete their plans.

Finally, some students embraced the new variables by talking about their artefact as if they had included them, when they were clearly not evident. For example, after mobility had been added as an extra criteria in making models of fitness machines one student said:

> I'm not going to have moving parts because it will be too hard. I'll just explain how it works to others. (Anna, 9 years)

Teachers did not give the degree of task openness, and the effects this had on student learning, due consideration.

Process adopted linear and discrete stages

When students were developing products, teachers often undertook a process based on planning and drawing, construction and finally testing. For instance:

> They (the initial sessions related to exploratory activities) will give them something to hang their ideas on. They have started to use the knowledge they gained from the daily fitness programme and the science unit. That's why they're integrated in this way. I like to let their thinking take flight and some came up with ideas of testing and modifying and adapting. By sharing, it got more children involved in thinking. (Sarah)

Though teachers understood iteration between stages was important, students had some difficulties realising that stages were related, as teachers did not always make links explicit. Therefore, stages followed each other successively and discretely. As a result, iteration between stages was weakened. For example, many students discarded drawings once construction began because they saw no further use for them. Drawings expressed initial ideas and were not a link between drawing and construction. Often drawings could not be used as construction blueprints, as the drawings were too complex to construct. This was despite teacher intention of students to use drawings as blueprints. Unfortunately, as teachers had not cued students to consider this aspect, students failed to realise it. For example:

> We had problems because we can't make it (i.e. follow their drawing). We can't fit in the small pieces of wood. We'll just do something else. (Laura and Rebecca, 7 years)
> I don't need this (the drawing). I know what I am going to do. I suppose I might use it as a check. (John, 9 years)
> I couldn't do it (use the plan as a blueprint for construction). I had too many things to make. I just did a bit. I hadn't thought about how to join the bits together. It was hard. (Lindsay, 8 years)

Ann, Penny, Burt and Tina tried to make links between drawing and construction more explicit resulting in better realisation by students that stages relate to each other. It meant more likelihood of students thinking ahead while drawing to difficulties they might have with construction. When constructing, students tied drawing to it. These teachers cued students to think ahead to construction aspects, to image with materials in mind and assisted them to apply the knowledge of materials and their properties at drawing stages. As examples students said:

> We know where we are going. The plan is to help you see things. It can improve your ideas because when you plan you can think of a series of ideas. A plan can be a step by step knowing what you are doing. (Hannah, 10 years)
> The design shows the idea I had in mind. It saves me trouble because I don't have to remember it. People expect to see what's on your paper. If you just have it in your head it is easy to change your mind all the time. (Lucy, 7 years)

> A plan is to think about what you're going to make. If you don't have a plan you won't know what to do. It helps you think. You keep looking at it as a check. (Michelle, 7 years)

Testing was usually the last technological process stage. Students rarely had chances to put testing results into practice, having to accept the idea that review was a concluding, thinking activity rather than a practical, recurring pursuit. Testing was viewed as an add-on rather than part of an iterative process. For example, Ernie's students tested their electric circuit games with students in other classes and obtained their reactions and responses. However, this valuable feedback was not acted upon, as Ernie's students were not given opportunities to use the ideas to change their games. Product evaluation was an add-on and product appraisal superficial. An iterative cycle of design was minimised and testing had little real consequence.

Some teachers (Penny, Ann, Burt, and Tina) attempted to build testing into construction stages. They encouraged students to regularly trial solutions while constructing. For example, Penny and Ann cued students to continually test moneyboxes for ease of depositing and removing money, during the building of the moneyboxes. Where teachers accounted for iteration, students had more success realising effective practical solutions. As one student said before the final testing of her water clock:

> I'm confident that it is going to work because we have tested it so many times and it is quite stable. (Hannah, 11 years)

Students did not understand the iterative nature of tasks when teachers did not assist them. The learning process then became linear and discrete. Where teachers assisted students to understand an iterative way of working by highlighting connections between different stages, students more likely realised relationships between different stages and undertake a more interconnected process.

Expectations of transfer

All teachers, bar Rachel, used a theme approach to their technology teaching whereby they carried a unifying idea through from another curriculum area to technology. Ernie taught a science circuits unit before teaching a technology electronic games unit. Ally taught a language unit about Greek myths before

teaching a technology unit about creating a Greek restaurant. Penny and Ann taught a mathematics money unit before teaching a technology unit about moneyboxes. Burt taught a science weather devices unit before teaching his time-measuring devices technology unit. Sarah taught a science muscles and bones unit, and a physical education personal fitness unit before her technology fitness machines unit, and Tina taught a maths symmetry unit and a language unit about Alice in Wonderland before teaching her technology maze unit. Their reasoning was that students would transfer knowledge and understanding gained in the previous units to the next. Every teacher underestimated the difficulties associated with this. Teachers assumed that conceptual and procedural knowledge acquired by students in other learning areas would be readily and freely transferred to technology tasks. Leaving transfer up to the learner became problematic.

For example, Rachel expected students to construct mazes as box structures using the idea of nets, a geometrical concept that she had taught in mathematics. No students utilised this concept. Another example was of Tina who expected students to transfer the mathematical concept of symmetry to the technological task of drawing symmetrical mazes. Of the class of 28 students only 8 were able to incorporate this notion into their drawings. As one student said:

> I'm not sure what I have to do. I think I have to draw a maze. It will have all sorts of shapes. It might have a circle. (Hazel, 7 years)

Teachers also assumed that within technology tasks students would effortlessly transfer knowledge from former technology sessions to later technology sessions. However, teachers did not make provisions for this to happen, for example, Ally used a graphic designer to demonstrate graphic techniques to students and expected them to independently utilise and transfer this graphical knowledge to their technological context without any cueing or guidance from her. Students found combining ideas from different sources difficult. Though teachers organised task sessions in an order that could enhance learning and evident in their planning, conditions for transfer were not readily taken into account and so often opportunities for students to make links were lost.

One exception was Burt who realised his students had difficulties and he moved to close the gaps. He realised that students were struggling to solve problems related to measuring time accurately. This was despite having previously worked on time in mathematics. So he assisted students to make links between the subject areas. He reminded them of the learning they had accomplished in mathematics and demonstrated how this knowledge could be utilised in the technology situation. Burt was required to repeat this articulation and demonstration a number of times for different students in different ways. An understanding of transfer issues ensured he moved to bridge student gaps and his formative interactions assisted students to solve their problems.

Most teachers did not realise the difficulties students would have in transferring learning from one situation to another. They expected students would do this with ease and with little direct teacher assistance.

Underestimating the application of technical skills

All teachers did not realise the importance of students requiring and utilising particular technical skills. Though cognisant of skills needed, they did not teach them in an easily accessible way. For example, Penny and Ann knew their students required drawing skills. They set an activity where students drew illustrations of existing moneyboxes from several viewpoints, to show various perspectives. With guidance, all students were able to do this. Then Penny and Ann expected students to show these viewpoints when drawing their own moneybox plan. No students did this. All drew from a side-on perspective.

No teachers built in activities to develop engineering skills. So when students came to build, they encountered many difficulties. Some looked to other students by observing what they were doing and then trying it themselves. Some sought overnight home help returning with ideas. Others went to teachers. This often meant long queues of students waiting for assistance. Teachers became technicians, often undertaking the work for students in order to speed up the process and reduce queues. As Ann said:

> I didn't realise the difficulties we would have with the paper mache and sculpture mould and I needed extra assistance with the construction so then I would have been free to teach. (Ann)

Teachers did not foresee the limiting effects student technical skill deficits would have on student learning. All teachers underestimated the importance of attending to technical skills.

Technology integrated with other learning areas

Teachers included other learning areas in their technology units. Any opportunities were exploited to the best of teachers' abilities. This is consistent with their views that technology is an ideal vehicle through which curriculum integration can occur. For example, Ally included social studies, language, mathematics and art in her unit. Burt included language, science and mathematics and Sarah included health and physical education, language and science. At times other learning areas overwhelmed the technology tasks. Technology activities and goals were submerged and even lost. Teachers became concerned as to whether they were still teaching technology. For example, much of Ally's unit became focussed on language and art. As she commented:

> While I am working I have this question – is this technology? I keep going back to the document and I'm still questioning myself. (Ally)

Technology education lost focus when teachers attempted to combine technology with other learning areas. Their teaching of technology education could not withstand the inclusion of aspects from other learning areas, as they did not have a secure enough understanding of technology education to retain subject integrity.

Teachers as self-reflective practitioners

Just as teachers considered it important for students to look back over their learning, they also considered it vital to examine their own teaching and students' learning. All teachers reflected on their technology teaching, students' learning and their successes and failures. Reflection was undertaken throughout the unit and at its conclusion. They considered the successfulness of individual sessions, how well they achieved their own goals as well as the accomplishments of students. Often they altered their teaching in the light of review. For instance, Rachel recognised her students' muddle in undertaking a maze task and so restated the task to help clarify it for them. She stated that she realised the problems they were having in understanding requirements of the task. So with

redefinition students were more certain of task goals. Being a reflective practitioner assisted Rachel to notice and understand what had happened. She responded and addressed student difficulties. In another instance, Sarah included discussions about prototypes, an aspect she had not thought they would cover. However, she realised students were having difficulties understanding differences between models and real artefacts. Therefore, she discussed models as a means to get ideas into 3D form, which may lead to developing prototypes for testing. In future students might consider building prototypes after making models. She said:

> Students thought about how they could test their model and how they would change their idea for making a prototype. So they learnt new language for a start and then they had to think beyond their model...I hadn't planned on moving into technology and society like this but we did because we talked about copyright and prototypes, testing and commercial realisation. (Sarah)

Teacher review at the end of units helped them understand changes they would make next time they taught technology. For example, Penny stated:

> I really enjoyed this teaching but there were some children I didn't see early enough and they got lost in the task. I was so disappointed that not all of the students saw the links between plans and construction. Next time I might ask that they have their plans with them so that they are more likely to realise that there is a connection between the two. (Penny)

Teacher self-review ensured teachers were reflective practitioners mindful of becoming more adept and competent in the teaching of technology education.

5.3.3 Assessment aspects

Developing progression in student understanding

Progression in technology was an aspect with which all teachers had difficulty and they were unsure of where to take students or what to do next. They were unsure of what they would concentrate on to assess technology progression. For example, Ernie attempted to articulate progression aspects he would examine. His hesitancy was apparent:

> Well, I mean, you might want to define the product yourself and let the kids actually solve the problem and assess how they did that. But then again you might want to assess something slightly different. You might want to actually look at how did the children tackle the problem, how did they go about working, how did they organise the problem, how did they work co-operatively. You might want to look at their different ways of working perhaps. There are different elements that you can assess and I think one of the problems was the fact that I hadn't actually decided before what I was going to assess. There are so many variables. I mean you have to decide to sort of take a snapshot rather than looking at a whole process. I think that will come in time. (Ernie)

Teachers' task selection was based on ensuring students had experiences in a number of different technological areas, rather than on developing progression in student technological understanding. Though teachers were able to organise tasks reflective of technology these tasks were somewhat isolated experiences, rather than cumulative and purposeful. For example, in Ally's Greek restaurant unit, she set a task of designing appropriate invitations. Designing suitable menus followed this. Finished invitations and menus were almost identical, not an unexpected result given that Ally focussed on the same goals, and no progression elements. There was no sense of moving students on; rather the menu task was a repetition of the invitation task. As Burt articulated:

> I can't see progress in technology. I don't know what to look for the same. It is so much harder. I would hope that the methods I am using are the right ones for technology. I'm sort of trialing things that are right for me. But do they mean anything? So it is difficult, difficult to know what is right. (Burt)

Additionally, no teachers examined how students put all individual elements of technology tasks together. The inter-relationship between conceptual and procedural aspects and an overall, holistic approach were not considered for progression. Rather teachers focussed on individual elements as a way to assess student progress. As teacher knowledge of technological concepts, procedures and technical skills was not detailed, progression, in terms of increasing the complexity and number of variables and their inter-relationship that students might consider in a technology task, was not considered.

Student self-assessment

Most teachers undertook relatively formal student self-assessment at unit conclusions, where students analysed their own progress. This was viewed as a way to gather student information about their learning throughout the unit and as a way to assist students to think reflectively throughout the whole process. It was typically a concluding activity and students were not given opportunities to use any insights gained through their self-evaluation. Thus, student self-review of progress was a final activity rather than an on-going component of the technological process. Opportunities for students to respond to self-evaluation, to utilise their reflective thinking, were minimised.

Teachers usually devised self-assessment worksheets and sometimes included new elements students had not previously encountered. This mismatch confused students. Examples of student reaction follow.

> I didn't like the self-assessment much because some of the things in it don't match my model. (Anna, 7 years)
> The self-assessment was a bit hard because I didn't know to think about support structures. (Larry, 8 years)

Self-assessment worksheets focussed on students' attitudes and judgements about their accomplishments. They often included future changes students might make and a drawing of their final product. For example, Burt's students drew their final clock design, rated its success, wrote what they like most and least, and recorded changes they would make. Rachel's students identified materials used and the user group; rated how well they developed a suitable option, their use of resources, their communication to the class and how satisfied they were with their achievement; and identified what they liked best, their problems and what they could improve. Sarah's students rated how well their fitness machine model included safety features, stability, support structures, an interesting feature, mobility, fitness features, instructions for correct use and labelling. Tina's students recorded whether they built by following their plan and criteria, reasons for diverging from plans and criteria, materials they would use next time, improvements they could make and a yes/no categorisation of functionality.

Student self-assessment was viewed as an important means for gathering information about student progress. Self-assessment worksheets minimised conceptual understanding, focussing more on processes students had undertaken and their attitudes towards the task.

Formative interactions

Teacher-student formative interactions focussed on several aspects. These included praise and task completion, social and managerial aspects, broad procedural and conceptual aspects, and technical aspects. Sometimes teachers chose not to give guidance at all. Each aspect is considered successively.

Emphasis on praise and task completion

Teachers did not identify detailed and specific procedural and conceptual technological learning outcomes of tasks. Therefore, interactions were frequently praise-based and related to task completion, rather than related to enhancing specific conceptual and procedural student understandings. Instances of teacher interactions, where students and teachers critically discussed work in terms of the strengths and weaknesses, were under-utilised. This meant detailed guidance for ongoing work was absent. Students were not clear of desired goals, or of how well their work matched the goals. For example, Tina accepted all student attempts at drawing mazes without discrimination. In effect this meant students were not required to reflect on their work, as to whether they had met task objectives, how well objectives had been met, or what they might do next. Opportunities to build on relevant conceptual, procedural and societal aspects were lost. For example, Ally praised students for staying on task and completing work when designing invitations forfeiting opportunities to develop graphic skills.

> Neat. Wonderful. I like that idea. That looks good.
> I knew you people would come up with good ideas. (Ally)

Teachers interacted with students with a particular focus on praise and task completion. As well, the number of interactions were minimised as teachers believed intervention by them could be counter-productive to students' developing creative thinking.

Focus on social and managerial aspects

Teachers often focussed on general social and managerial aspects in their interactions and in the feedback they gave. Intensifying this emphasis was the strong subcultural influence in primary schools of expected ways of working where students are encouraged to work in collaborative as well as independent ways. For example:

> Before you make the game think about how you're going to go about making your game, who is going to do the jobs in your group, what jobs you will need to do. (Burt)

Later, during constructing, many of Burt's interactions were focussed on these managerial aspects. For example, when talking with David and Daniel (both 9 years):

Burt: Have you decided on how you're going to do the jobs?
David: Yes:
Burt: Are you going to do the jobs separately, or together?
Daniel: Separately.
Burt: Good. So if you are cutting up what is David going to do?
David: I'll draw the picture.
Burt: You're happy about that, are you?
Both boys: Yes.

As another example Rachel talked to two students, Jess and Sandy (both 7 years), who had completed a paper maze. Interactions centred on social skills:

Rachel: How well did you talk about making your maze?
Jess: Good.
Rachel: What was the best part for you?
Sandy: Co-operating.
Jess: Yeah, working together.
Rachel: Good.

Often students became confused about the purposes of tasks, believing social and managerial aspects were more important than technological aspects. For instance, students thought it more important to draw co-operatively with their partner than to create a drawing that would show their initial product ideas. Students became unclear of desired task goals. When teachers provided corroborating comments about how well students were working, further importance was attributed to these goals at the expense of technological goals.

Emphasis on broad procedural and conceptual aspects

Teachers were able to identify broad conceptual and procedural learning outcomes in their technology tasks, though these learning outcomes were not detailed and did not address underlying technological principles. For example, Burt emphasised the assembly of components and accuracy in measuring 4 hours and 5 minutes in students' clock-making task. But he placed no emphasis on aspects such as stability and equilibrium of structures, mechanical properties of materials such as elasticity, strength and brittleness, structural loads and concepts of bending and buckling, factors of safety and aesthetic sensitivity, and factors related to mechanisms such as ideas about motions and levers. Additionally, he did not highlight design aspects related to ensuring mechanisms would perform functions required of them. Yet he had specifically targeted structures and mechanisms as a focal point. Therefore his conversations with students were

pitched at a broad, imprecise level. For example, Hannah and Amy (9 years) had built a structure for a water clock and had yet to put in a water flow hole.

Ernie: How are you going?
Hannah: Not so good. We haven't got our hole yet.
Ernie: How are you going to decide on the size of the hole?
Amy: We're going to use a nail.
Ernie: What if it is too big?
Hannah: Oh, we'll need to test different sizes.
Ernie: That sounds wise to me.

In another instance, Ally's students visited a restaurant to gain ideas for their own restaurant venture. Before the visit, Ally asked students three things they would like to find out. Student responses related to table waiting and health aspects for waiters and waitresses – a small slice of procedures important in restaurant management. Students were not guided towards other aspects such as food preservation, heating and storage, food regulations, use of labour and time saving devices, lighting systems, marketing, use of graphics, or types of technologies used.

However, the general identification of unrefined technological concepts and procedures did assist teachers to interact formatively in a broad way. For instance, Penny and Ann targeted general features of moneyboxes and suitable construction materials throughout sessions with their 7- to 9-year-old students. Many conversations focussed on these aspects.

(1) Penny: You are going to make yours in the shape of a teddy bear and it is going to be strong and for children?
Lucy: Yes.
Penny: How are you going to make it strong?
Lucy: I don't know.
Penny: Well, would paper be any good?
Lucy: No, but I could use paper mache.

(2) Ann: How do you know if your slot for money is the right size?
Alice: Test it out with money.
Ann: That's right. Test it. Would you use 5-cent pieces?
Alice: Yep, but 50-cent ones too cos they are the biggest money.
Ann: Is all money coins?
Alice: No, but it can fold down to fit.
Ann: What happens to your moneybox with lots of money?
Alice: It gets heavy.
Ann: So you might need to think about a strong moneybox.

Ernie included general features of mathematical games and their suitability for particular age and gender groups of students in his conversations. An example

follows with Ernie talking with Kahu and Dan (both 9 years) about designing games for a target group:

> Ernie: Why will you play the game with the kids you made it for?
> Kahu: So to test it's not too easy and not too hard.
> Ernie: Right. This is as important as making the game work because if the children you designed it for find it too easy have you been successful?
> Dan: No. Should it be for boys and girls, or just boys?
> Ernie: Is it for boys, or girls, or both?
> Dan: So far it is for boys, but we haven't really asked.
> Ernie: Well, you could ask girls what they think of a game that's got jet engines all over it.

Tina targeted general features of mazes and broad procedural aspects in conversations with students. For example she talked with two students, Dave and Regan (both 7 years), when they were planning their maze for subsequent construction:

> Tina: What about the size of the water trough for your sand maze?
> Dave: Well, we'll just have to change our design when we build it so it fits.
> Tina: Good. You'll modify as you go. I like the steps for different levels in your maze. How are you going to make them?
> Dave: With cardboard and hard sand.
> Tina: Have you matched all your criteria?
> Regan: Yes, I think so. We think we can build it. It has dead-ends. It has curves and is tricky. It has detail and has forks. The walls will stand up.
> Tina: Have another look just to check. Think about how strong your maze will be.

By focussing on broad conceptual and procedural aspects, teachers assisted students to also focus on them. Teacher feedback often targeted these general qualities and also focussed on helping students improve these qualities. Lacking though was detailed, specific feedback helping students to identify their strengths and weaknesses, ways to reach next steps and how to take them. Also lacking was a consistent emphasis on detailed conceptual and procedural aspects. Teachers ranged between praise, task completion, social and managerial aspects and broad conceptual and procedural aspects.

Emphasis on technical aspects

Conversations between teachers and students often targeted technical aspects, especially in construction sessions and when teachers became technicians. For example Sarah's 7- and 8-year-old students needed to hot glue their constructions. They needed help and so Sarah became stranded in a corner with the hot glue gun. The following conversation shows the dominance of glueing concerns and absence of conceptual and procedural aspects:

(1) Sarah: Whereabouts do you want it? Jane: Here (points) Sarah: Now hold it till it sticks.
(2) Sarah: Show me where. Kelly points, Sarah glues.
(3) Jessica: I need glue here. Sarah: OK. Hold it out so I don't get glue everywhere. That's the idea.
(4) Sarah: OK, what do you want? Xavier: I need glue here and here. Sarah: OK, hold them there for a minute.

Sarah expressed discomfort about spending so much time glueing:

> I was so frustrated spending my time glueing or dishing out materials. I think it is a real problem for construction in technology at the primary school level. (Sarah)

Students' technical and engineering difficulties were a prime focus in many constructing sessions. Teachers spent a lot of time on pursuits like cutting, bending, sawing, hammering and joining materials, mixing paper mache and paints, and finding suitable materials. Though other interactions sometimes took place, like questioning students about their intended directions, encouraging them to stay on task, assisting them to test and make changes, these interactions were afforded less significance. Students' technical problems became all consuming. For many students difficulties were insurmountable, for they had no procedures, skills or knowledge at their disposal to solve their problems. They became reliant on adults. For example Ben (7 years) couldn't join the base of his moneybox to the sides as he had not incorporated any means to form attachments, nor did he have any knowledge of different methods to accomplish such joining. His solution was to repeatedly visit the hot glue station until eventually the adult there dispensed so much glue the sides fixed together. In another instance, Morgan was unable to make her original idea of a paper mache moneybox due to inability to manage paper mache. She commented:

> My original plan was totally impossible. I thought that it was going to be easy to make. But even if you plan things they're not as easy as they look and sometimes it doesn't work out the way it should. You can't always do it. (Morgan, 8 years)

An analysis of technical knowledge and skills students might need was not undertaken. A balanced approach to developing conceptual, procedural and technical aspects wavered as teachers' had not foreseen student technical gaps.

Choosing not to give guidance

Sometimes teachers did not give guidance about technological processes students were utilising, as they thought it might hinder student thinking. They wanted students to develop some autonomy in solving problems for themselves, rather

than relying on teacher advice. Students were encouraged to independently utilise their existing skills or knowledge, use best-guess principles, or acquire whatever they could from around them to solve technological problems. For example Ally talked to students about their fitness machines. She did not give specific advice:

(1) Ally: How is it going to work?
Bruce: I'm not sure.
Ally: Does it tell how far you've walked?
Bruce: I don't know.
Ally: There's your next problem.
(2) Ally: What will this fitness machine do?
Lisa: Nothing, I'm not sure really.
Ally: You need to design fitness equipment for something.
Lisa: OK.
Ally: Away you go then.

The idea that teacher intervention might hinder student independent thinking was perhaps tied to idea that student-driven problem solving was critical for realising innovative technological solutions.

Summative assessment

Though indicating difficulties all teachers attempted to make appropriate summative assessments. The complexity of learning demonstrated in extended technology tasks exacerbated difficulties. Influential in decision making, were current school practices and policies. For example:

> We are told at the beginning of the year, which strands of each curriculum we need to assess . . . and we must have a comment for each child for it (Penny)

Teachers were unsure of aspects for focus. So they focussed on a variety of aspects including social and managerial aspects, the technology task as the learning outcome, achievement objectives as one item of assessment, and summative assessment at a unit's end and focussing on pieces of learning. Each is discussed.

Focus on social and managerial aspects

Like formative assessment, a bias towards social and managerial aspects was reflected in summative assessment. Teacher comments included social skills such as listening to others, taking turns and co-operative ability, and managerial aspects such as finishing on time and managing materials. For example, Rachel's summative comments for 29 students included 24 reflecting social and managerial

aspects. Ernie commented on ability to communicate ideas. Sarah commented on ability to self-reflect and ability to take turns when reporting to others; and, Ally commented on group co-operative skills, and helpfulness.

In interviews at the conclusion of teaching, all teachers commented that technological problem solving afforded opportunities for developing social and managerial skills. As several teachers commented:

> It has been good for them because of lots of problem solving and lots of group work. They had to work together. (Ally)
> It was successful for them because the students were enthusiastic and have shown good thinking, problem solving and co-operative skills. (Ernie)
> I think that kids have progressed particularly through the use of lots of discussion and because the reflective process was in-built and the whole context was a problem solving one. They have had achievable tasks, have been able to interact to develop their ideas and they have had time. (Tina)

Student development of social and managerial aspects was given strong emphasis in summative assessment.

The technological task as the learning outcome

Teachers identified suitable technological tasks for students but had difficulty identifying suitable technological learning outcomes. They tended to focus on task completion as the learning outcome for assessment. For example:

> I looked at whether they had made a plan and adapted it. (Tina)
> They have achieved most of the things I set out for them to do. They have all built a clock. ... They have got a product that is quite workable. (Burt)
> Could they complete a plan of action? (Ernie)

This focus meant teachers had difficulties in making student learning statements useful for future teaching and learning. Absent were detailed concepts of technics (techniques associated with practice), technological praxis (how the knowledge base is used) and technological knowledge. Assessing at the level of organising principles was not apparent.

Achievement objectives representing one item of assessment

Teachers used the broad curriculum achievement objectives as one item for assessment. As was typical in other learning areas, they pre-selected particular achievement objectives from the curriculum to base their assessment judgements and comments upon. They chose their objectives from an appropriate level and

strand. As each level represents two years of learning, rather than one assessment item, and as student learning was assessed summatively against these level statements, no detailed analysis could be obtained and little sense of progression could be indicated. For example, Tina selected the achievement objective: identify and discuss ideas about their modification and adaptation of maze technology and some of her summative assessment comments follow:

> Student 1 - Wonderful plan, brought materials, couldn't build to plan
> Student 2 - Sound maze plan, plan modified twice, maze structure very simple
> Student 3 - Very careful planning and construction, successful in that design was kept simple and realistic.

Ernie selected a capability achievement objective: with reference to identified needs and opportunities discuss solutions and strategies; select and develop a suitable option; make preferred solution; show and describe intentions progress and outcomes; and describe how satisfied they are with progress and outcomes. A selection of comments related to Ernie's assessment of student achievement follows:

> Student 1 – Initial plan and final product very similar, when encountered difficulties able to think of alternative solution, could list improvements to be made and state successful features.
> Student 2 – Could solve problems using limited materials, suggested 2 improvements after testing, gave 2 reasons why game was successful
> Student 3 – Able to show through diagrams and explain why game was successful, decided game was inappropriate for specified age group and altered age group accordingly

Sarah also selected capability objectives but employed a sliding scale check system for assessing student achievement. One tick indicated the student had attained an understanding of the objective, two ticks indicated a good understanding of the objective and three indicated a very good understanding (see Appendix 10).

Broad summative statements meant information about student technology achievement was not especially useful to the teacher, or to other teachers in subsequent years, or indeed the students themselves because of their widely defined and non-specific nature. In essence statements about each student's learning were relatively ineffective.

Occurring at the end and focussed on itemised learning goals

Teachers used a summative assessment procedure at the end of units and this was the only time teachers summatively assessed. They assessed against pre-selected objectives often employing a checklist type method, a common practice in other learning areas. They did not judge students' technological practice overall. No teachers attempted to assess how students brought all aspects together. Making holistic judgements was not part of teachers' summative strategies. Teachers did not sum up all the learning that had occurred. Instead, particular aspects or events were selected for attention. This meant that assessment did not match the learning students had undertaken. Therefore a skewed, partial view of performance resulted. Teachers only described slices of what students had undertaken and achieved. Summative assessment was the final task teachers undertook and closed their technology teaching.

5.3.4 Summary of teachers and students in technology classrooms during 1998

All teachers focused on the idea that technology is a practical, problem solving pursuit. They encouraged the development of multiple solutions, as technological solutions require diverse, varied answers. A high degree of divergency in solutions meant successful teaching and learning had taken place as creativity had been fostered. Technology as design was influential. Design often equated to drawing ideas and was typically undertaken in the early stages when students were encouraged to graphically record ideas. Finally, technology as purposeful was incorporated into teaching. All teachers expected students to understand whom their technological solution was for.

In their pedagogical approaches teachers were not fully cognisant of the influence of task definition, often underestimating the different effects open and closed tasks had on the learning of students. Also misjudged were the effects of changing task descriptions once tasks had begun.

Teachers saw different technology teaching stages as iterative and inter-related, though students found iteration difficult. This resulted in students dealing with the technological process as linear, discrete and without connections. Students had

problems carrying ideas through from one stage to the next. This was particularly evident in not realising connections between their drawings and constructions, with many discarding drawings as soon as construction began. All teachers underestimated how hard it would be for students to work iteratively. Though teachers' planning showed careful scaffolding of tasks, with tasks building on each other, teaching often lacked the support needed for students to make connections. Similarly, teachers usually underestimated students' ability to transfer ideas between contexts and learning areas. Transfer issues were not comprehensively addressed.

Also underestimated were student difficulties in applying technical skills. Skills were not often specifically taught for, so many students were unable to construct their ideas. In consequence teachers became technicians themselves, often as an expedient measure to alleviate queues of students.

Finally, technology integrated with other learning areas was a pedagogical approach taken by many. This was due to the perceived number of learning areas contributing to technology, the chance to connect different learning areas together and the opportunities to build on previously taught units in other learning areas. Often the result was a loss of technology focus, an elevation of focus on other learning areas and teacher and student confusion. Technology was submerged with technology learning outcomes minimised.

With technology understanding and definition difficulties, assessment also lost a definite technology focus. Teachers had problems developing progression notions, particularly at the detailed conceptual and procedural level. Rather progression was defined at the sweeping achievement objective level. Few worthwhile opportunities to interact precisely about student accomplishments and future directions developed. Student self-assessment was likewise defined at a broad level, often focussing on social and managerial aspects, with students afforded little opportunity to think in detail about their own progress. Additionally, student self-assessment was usually a formal procedure undertaken at the end allowing students no opportunities to apply any ideas gained through their review process.

Formative interactions focussed on several aspects often vying for position. The result was student confusion about the main task purposes. Praise and task completion were major feedback foci, as were social and managerial aspects. These were afforded significance to the detriment of detailed conceptual and procedural technological aspects. Critical discussing of work in terms of strengths and weaknesses was under-utilised. Often absent was detailed guidance for ongoing work. Though there were formative interactions related to undertaking and completing particular tasks, descriptive feedback of organising principles and detailed conceptual and procedural aspects of different technological areas was absent.

Some broad conceptual and procedural aspects were identified assisting teachers to focus on these in formative interactions. However, feedback was pitched at a broad, imprecise level. A dominant emphasis on technical aspects developed during construction sessions when teachers became technicians assisting students with their constructions.

Summative assessment occurred at unit's end, was the final task teachers undertook and served to close the technology unit. Social and managerial aspects were to the fore with teachers judging student progress against these. As teachers identified suitable tasks, the task itself also became a summative focus. Whether students had completed tasks was assessed, such as completing an aimed-for artefact. Summative practices were influenced by school-wide assessment policies, where using achievement objectives and levels was common. Achievement objectives became one item of assessment, so no detailed analysis was obtained as objectives are so broadly defined. Treating achievement objectives as one item of assessment also meant that teachers assessed atomistically. No teachers attempted to make an overall progress judgement related to how well students brought all aspects together. Rather, summative assessment focussed on particular instances and itemised learning. All summative assessment practices resulted in teacher difficulties making statements useful for future teaching and learning.

5.4 Key findings of Chapter 5

In summarising Chapter 5 a number of key findings are itemised and presented. They include:

- Broadened concepts of technology and technology education;
- Teaching technology education presented major difficulties;
- Ability to identify suitable technology tasks;
- Misunderstanding the effects of open and closed tasks;
- Expectations of transfer;
- Formative assessment not well-understood;
- Interactions based on praise, task completion and social and managerial aspects;
- Formative assessment focus on activities and broad achievement objectives;
- Summative assessment focus mixed;
- No holistic assessment;
- Teachers as self-reflective practitioners; and
- The need for an intervention programme.

- ***Broadened concepts of technology and technology education***

Teachers had broadened their understandings of technology and technology education from earlier research (Jones & Carr, 1992; Jones & Compton, 1998; Moreland, 1998). Though concepts were still not detailed enough to account for many conceptual and procedural aspects, teachers had identified key aspects such as meeting needs, designing, constructing, testing, multiple solutions and student risk taking. Both schools had developed a technology education subculture where technology was treated as a separate learning area, technology policies written and budgetary allowances made. Teachers understood the different technological areas and were developing confidence in teaching across them. They also understood the three technological strands and knew all should be included in a unit. However, Strand B, technological capability, received the most weighting. Technology education was viewed as a practical subject aimed towards multiple solutions. Student creativity in developing innovative solutions was highly valued.

- *Teaching technology education presented major difficulties*

Despite a broadened understanding, teaching technology presented major difficulties. Teachers' confidence wavered when difficulties arose. Quandaries prevailed. Other more dominant learning areas often influenced, so technology became lost. However, teachers willingly acknowledged their knowledge gaps especially in reference to technological areas, technology concepts in each area and in using appropriate technology language. Technology was not an integral part of the talk of classroom teachers and the community. A shared language of technology had not developed to any degree of specificity, which Black (1998) states is vital for assessment. Significant planning, teaching and assessment problems were evident. Despite teacher difficulties, students showed relatively high levels of engagement and enjoyment through the units.

- *Ability to identify suitable technology tasks*

Teachers' views of technology, their planning and classroom actions showed strong ties to technology as a creative, practical problem solving process where designing, making and testing artefacts was central. Teachers' developing technology concepts had led to an ability to identify suitable technology tasks for students. However, concepts were not yet robust enough to retain subject integrity. Coupled with ideas that technology is a learning area particularly suitable for integration with other learning areas meant technology changed shape and focus, often disappearing altogether. Details of the different technological areas, including the associated knowledge bases, were not well articulated or understood. Therefore, teachers showed confusion in identifying technological learning outcomes and progression in learning within chosen technology tasks.

- *Misunderstanding the effects of open and closed tasks*

Pedagogical difficulties included misunderstanding the effects open and closed tasks had on student learning. The complexity of students undertaking and solving technology tasks was not well understood. Misunderstandings meant teachers did not foresee problems students might encounter, and thus they were unsure of what was occurring and how to best assist. When closed tasks were defined students produced similar artefacts, tasks were undertaken with little variety and divergent ideas were not developed. When tasks were defined openly, students were unsure

what they needed to include, were unsure of what to do next and were not sure when they had finished.

- ***Expectations of transfer***

All teachers underestimated student difficulties transferring understandings and skills from one learning area to another and from one technological activity to another. This resulted in a linear, discrete process with few connections made between activities and learning. In consequence student learning became piecemeal and disjointed.

- ***Formative assessment not well-understood***

Formative assessment appropriate for technology was not well understood. Teachers could not articulate detailed technological and procedural aspects or desired technological goals for their particular students. They found it difficult to know the detailed actions to take, as they were unsure of students' current positions and where students were going. Teachers did not hold a well-developed sense of technological progression as they held in other subject areas, for example reading, for which there is an established assessment culture in primary schools. Impacting on teacher assessment practices in technology were the existing assessment subcultures in schools, school-wide policies, teacher experiences and teacher subject expertise. What teachers relied on for assessing in technology became largely dependent on what they already did and knew in other curriculum areas.

- ***Interactions based on praise, task completion and social and managerial aspects***

Teachers had difficulties identifying detailed conceptual and procedural technological aspects so formative interactions did not focus on these and interactions at the organising principle level were absent. Instead, teachers focussed on praise, task completion and social and managerial aspects. With such a range of focus, students became confused about task purposes.

- ***Formative assessment focussed on activities and broad achievement objectives***

Formative interactions and technology planning often focussed on activities and broad achievement objectives rather than on specific learning outcomes. With this generalised focus it became almost impossible for teachers to provide feedback at the detailed conceptual and procedural level. Additionally, learning outcomes identified were often not technological, so feedback was not in technology terms and therefore learning in technology was not enhanced. Formative assessment lacked detailed and specific focus to help students identify their technological strengths and weaknesses, next possible steps and how to take them. Lacking was a consistent emphasis on conceptual and procedural aspects.

- ***Summative assessment focus mixed***

Like formative assessment teachers had difficulties retaining a reliable and valid technological focus. All teachers acknowledged summative assessment difficulties. Practices from other learning areas and school-wide guidelines influenced technology practices. Task completion, social and managerial aspects, the task as the learning outcome and achievement objectives as one item of assessment became the focus. Often the focus was not consistently held. Specific technological conceptual and procedural aspects were not addressed. Effective information for students and teachers for enhancing future student learning was not gleaned. Summative assessment was therefore biased, as teachers did not sum up technology learning.

- ***No holistic assessment***

No teachers attempted to assess how students brought all the technology task aspects together. Making such holistic judgements was not an assessment strategy. Instead, particular aspects or events were selected for attention. This meant assessment of student learning was not well matched to the learning undertaken. The result was therefore a biased, partial view of performance, describing only certain slices of what students had undertaken and achieved.

- *Teachers as self-reflective practitioners*

Though all teachers were gaining practical experiences in teaching technology, they had yet to develop the understanding required to be competent, confident teachers in all technological areas. A deep understanding of pedagogical content knowledge had yet to develop. Doubt was ever present, especially in deciding on suitable learning outcomes, appropriate technology pedagogy and relevant assessment practices. In becoming effective technology teachers they were in the early stages. However, teachers' reflected on their own practice, scrutinised it in detail and recognised their gaps. They wanted to learn more about technology to enhance and refine their teaching and were willing to be involved in the research project for the following year, as this would assist them in their technology classrooms.

- *Need for an intervention programme*

From these findings an intervention programme was devised for 1999. It aimed to assist teaches to develop more suitable learning outcomes, more appropriate technology pedagogy and more relevant and valid assessment practices. Of importance were ways to assist teachers to focus on holistic aspects of learning in technology and ways to focus teacher attention on detailed, specific conceptual and procedural aspects in different technological areas. Additionally, enhancing assessment practices, especially a focus on descriptive feedback needed attention. Chapter 6 describes the 1999 intervention programme and outlines teachers' reactions to it. It presents data related to the second research question:

> What can assist teachers to develop their teaching, learning and assessment practices in technology?

6. THE PROFESSIONAL DEVELOPMENT PROGRAMME

6.1 Introduction

This chapter describes Phase 2 of the research, which examined the ways teaching and assessment in technology were developed (Fig. 6.1).

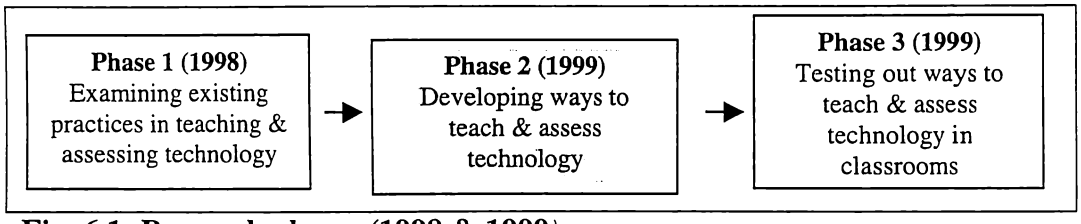


Fig. 6.1: Research phases (1998 & 1999)

The chapter is about the intervention teacher development programme used to enhance teachers' views and teaching practices (Jones & Moreland, 1998; Moreland & Jones, 1999). 1998 case studies, technology research findings, successful professional development criteria and teacher change enablers assisted in developing a yearlong intervention programme. The programme scheduled classroom practice between a series of workshop days. This chapter solely focusses on intervention strategies and workshops rather than teachers' work in classrooms. Teachers' classroom work is described in the following chapter, *Enhanced Classroom Practices in Technology: Findings from 1999.* Although classroom practice data informed workshop planning, they are kept together in Chapter 7 because one of the interesting stories is the development of teacher classroom practice. As described in Chapter 3 a narrative style is used to present the findings chronologically.

Research teachers for 1999 reduced to eight, as Ann had left School A at the end of 1998 for another school too distant to remain involved. Rachel, Penny, Burt and Ernie remained at School A. Tina changed teaching positions, moving from School B to an Assistant Principal's position at School C, a co-educational, city, primary school, while Joan, Ally and Sarah continued at School B.

The professional development programme was externally funded. The key aims were to enhance teachers' planning, teaching strategies and assessment strategies, especially their formative interactions. These aims would lead to appropriate identification, enhancement and assessment of technological learning of primary students (see Appendix 11).

With a pivotal purpose to enhance student technology learning, a strong focus was placed on teachers' planning, teaching and assessment strategies and formative interactions. Developing interplay between these aspects was important. An interactive planning process was expected to move teachers away from defining technology education with an activity focus, to focussing on student learning. Activities themselves would not develop student learning, rather learning would be assisted by students and teachers working towards intended learning goals developed from within the activities. As Rhine (1998) highlights, activities would no longer be expected to do the teaching on their own. Instead, teachers' interactions would be guided by their planning assisting them to make informed instructional decisions. By clearly articulating the technological task aspects, formative interactions with students would more likely centre on them.

A less significant focus was how formative strategies influence summative assessment. Planning strategies aimed towards assisting teachers to articulate intended learning outcomes in concise technological terms. Teachers were encouraged to think of the task as whole rather than in isolated aspects. This was to help explore the holistic nature of learning in extended technology tasks. Finally, teachers' formative interactions, especially descriptive feedback, were targeted to enhance student technological understandings.

Section 6.2 describes key principles for professional development programmes. Section 6.3 outlines and describes the time-line, the content and organisation; the significant strategies employed in the programme and teachers' comments and reactions. Section 6.4 summarises the chapter.

6.2 Key principles for the professional development programme

Educational change is dependent on what teachers do and think (Fullan, 1991). It is conditional on teachers' interpretations of guidance and what they do in classrooms. Fortunately these teachers were committed to learning more about technology education, all being volunteers and willing to enhance and refine their teaching (Section 3.4.2, The teachers). They believed technology was important so wanted to develop more expertise in teaching the subject. McGee (1997), citing Ramsay, Harold, Hawk, Kaai, Marriott and Poskitt's (1990) study, describes several teacher characteristics necessary for successful change. The characteristics include openness to new ideas, willingness to share ideas with colleagues and preparedness to take risks. All participating teachers possessed these dispositions. None possessed inhibiting characteristics that work against change. That is, none were cynical about change and new ideas; none believed they were experts with nothing to learn; none lacked teaching commitment; and no one held a conservative view that things should always stay the same (Ramsay, et al. 1990, in McGee, 1997).

The programme was based on key success principles. These included time for trialling ideas and reflecting, providing support and guidance, and building a spirit of co-operative inquiry. Each is discussed.

6.2.1 An extended time for trialling ideas

The yearlong timeframe was crucial for it provided time to build a strong supportive relationship between researchers and teachers to plan modifications, trial ideas and reflect on success (Treagust & Rennie, 1993). Time ensured a long period for analysis, reconceptualisation, discussion and dissemination of results. It gave opportunities to step back from the work and reflect. Time allowed for opportunities to present the research to teachers and other colleagues, which granted scope for powerful rethinking and synthesis (Bell & Gilbert, 1994; Shulman, 2001). Presenting work to others enhanced the research process, as this encouraged deeper thinking about findings and a richer understanding. Sharing ideas through presentation tested the quality of ideas. The teachers especially

tested quality for they undertook the ultimate examination in their classrooms with students.

Teachers also provided essential and valuable feedback to the research team. Reflective teaching practice emphasises the importance of metacognitive processes (Bell & Gilbert, 1994). Originating in Schön's work (1983), dispositions towards reflection enable continuous learning through experience. Teachers were expected to reflect and use this as an opportunity to expand their knowledge and competence (Sternberg & Hovarth, 1995). Though researchers provided ongoing support and guidance, teachers needed to see their technology teaching as problematic and to take responsibility for changing their practices. They were their own change agents and a willingness to change was required for successfully modifying teaching practice and shifting thinking (Bell & Gilbert, 1994). Therefore time for teachers to engage in intellectual and professional conversation was in-built. Time was required to create a mutually respectful inquiring community so the shared interest of enhancing technology teaching and learning could be fostered.

6.2.2 Providing support and guidance

Bell and Gilbert (1994) found successful teacher development programmes included support and feedback. 1999 centred on teachers trying out new ideas, so support and guidance was important for keeping morale positive and the continual testing of uncharted waters. Encouraging conversation between teachers and researchers and between teachers was crucial for supporting the developing technology education knowledge in new ways (Schwab, 1978, in Poulson, 2001). Conversation became an integral part of the programme. At times it was relatively formally organised. For example, interviews at the end of teaching sessions and units, workshop discussions about targeted topics, school teacher meetings, and principal meetings. These conversations had specific goals with a pre-determined framework. On these occasions researchers were facilitators, adhering to timeframes and targeting particular aspects. On other occasions conversation was less formally organised and more anecdotal. For example, talking with teachers during teaching perhaps to clarify aspects or responding to requests for on-the-

spot advice, conversing informally after individual lessons, chatting in session breaks during workshops and conversing over the telephone.

Workshop days were carefully planned with organised sessions, specific activities and identified goals. Effective leadership is an integral ingredient in the mix for promoting successful teacher change (Jones & Compton, 1996; Rennie, 2001; Treagust & Rennie, 1993). Therefore, researchers ensured there were opportunities for teachers to learn, so learning was not accidental, random or unpredictable (Poulson, 2001). A detailed programme was designed allowing for time and co-operative opportunities to achieve the shared aim of enhancing student technological learning.

Researchers guided much of the process, but teachers participated in managing their own learning (Dewey, 1916; Rogoff, 1994; Rogoff, Matusov, & White, 1996). Organisation was built on all working together. The discourse was conversational where people built on each other's ideas and were guided by researchers' leadership (Rogoff, et.al, 1996). Facilitation by researchers acted as a catalyst and support for teachers' learning (Bell & Gilbert, 1994; Treagust & Rennie, 1993).

Researchers undertook demonstrator roles to model different aspects. In workshops ideas were demonstrated to provide examples teachers could utilise as a guide for their own practice. Two examples illustrate this. First, researchers demonstrated how to compile a list of technological learning outcomes using conceptual, procedural, societal and technical categories, recording these on a whiteboard for discussion. Second, researchers worked alongside individual teachers while they were planning units for the forthcoming term assisting them to write appropriate learning outcomes, often advising them with best-fit wording and directing them to suitable resources.

In classrooms, unwitting demonstrations of effective ways to work with students occurred. When visiting classrooms researchers spoke to students about their work to gain a better understanding of thinking and progress including successes and difficulties. In so doing, reciprocal dialogue often developed where the researcher

was no longer the interrogator of students; rather problems were explored together. Without conscious awareness on the researchers' part, teachers began to observe, listening to the types of questions asked and the kinds of suggestions given. An unexpected consequence was the degree of teacher imitation and modelling of researcher practices. As Ernie commented:

> I like watching what you do with children. I like the way you question children, but quite often when I'm teaching I don't get the time to sit down and actually watch you work. It'd be nice to have some time to sit back and observe and reflect. (Ernie)

However, researchers did not always take the lead. In a cooperative learning community (Rogoff, 1994) people undertake different roles at different times. Sometimes researchers provided strong leadership and extensive explanations. At other times teachers had primary responsibility, for example when talking about their students' achievements or describing their students' work. Rather than a hierarchical relationship, teachers sometimes undertook a more active role with more responsibility (Gipps, 2001). In addition, some teachers undertook school leadership roles. Burt and Penny were technology syndicate leaders at School A. Ally was responsible for information technology, Joan led school development in technology education assessment at School B and Tina organised and led a school-wide technology education teacher development programme in School C.

6.2.3 Building a spirit of co-operative inquiry

Building a sense of community (Bell & Gilbert, 1994; Fullan & Hargreaves 1992; Jones, Mather & Carr, 1994) through co-operative inquiry was a central aspect of the programme. Underpinning ideas centred on learning as a situated-social knowledge construction process and an active process empowered via collaborative activity (Hennessy, 1993; Lave, 1991; Resnick, 1991). Teaching was viewed as social practice (Poulson, 2001) where products of conversations and writings became evidence of the continuing social process to which all contributed. A scholarship and inquiry network was built amongst teachers and between teachers and researchers. Teachers and researchers were working at the leading edge of their knowledge and skills. Therefore, building a co-operative, supportive, innovative community with both groups (Bell & Gilbert, 1994; Hargreaves, 1992) was a prime goal. The communicative relationship was one of

open discourse, with communication oriented towards understanding and respecting the perspectives of others (Rogoff, et al. 1996).

A safe environment was fostered where teachers could challenge their thinking. Collegial support and building a spirit of collegiality (Bell & Gilbert, 1994) proved crucial. Collaborative interactions between researchers and teachers and between teachers themselves were fostered. Researchers and teachers knew each other from 1998, so none were strangers and they felt comfortable in each other's company. As McGee (1997) highlights:

> Change is more likely in schools where teachers interact with one another and personnel from outside the school who are also involved in the change (McGee, 1997, 292-293).

Teachers also worked in collaborative teams in their schools so they could see each other working and talk with each other. Personal contacts assisted the change process. As Burt commented:

> Ernie came through and said 'oh, you've got some better questions here' and I said, 'well what are you doing?' He says, 'I'm doing this' and I look at those ideas and think, I might try those. ... Penny and I also shared ideas about modelling, even though she is at a different level. ... That was nice. I said, 'I did this with my children, I gave them some models', and Penny said 'oh, I can do that.' (Burt)

When implementing technology as a new curriculum area, teachers working in isolation, as in the Stein, McRobbie and Ginns (1999) study (in Rennie, 2001), are less successful than those working in a spirit of collaboration. Therefore, the aim was to build a spirit of collaboration between groups of teachers in schools, between teachers across the schools and between teachers and researchers.

In sum, allowing time for trialling ideas and reflecting, providing support and guidance, and building a spirit of collaborative, co-operative inquiry were the key principles in the professional development programme.

6.3 The professional development programme

This section describes the programme including its structure, workshop content and organisation, workshop strategies and teacher reactions to the programme.

6.3.1 Programme structure

The programme provided in-depth, multiple, full-day workshops followed by classroom practice opportunities. Placing workshops between classroom teaching provided teachers with opportunities to build stronger foundations for enhancing their teaching. Each workshop and interspersed classroom practice was used as a stepping-stone to the next phase. The programme avoided the shortcomings of one-shot in-service courses, with no follow-up opportunities, and superficial programmes (McGee, 1997). A long-term course with ongoing follow-up opportunities and an in-depth programme was organised (Fig. 6.2).

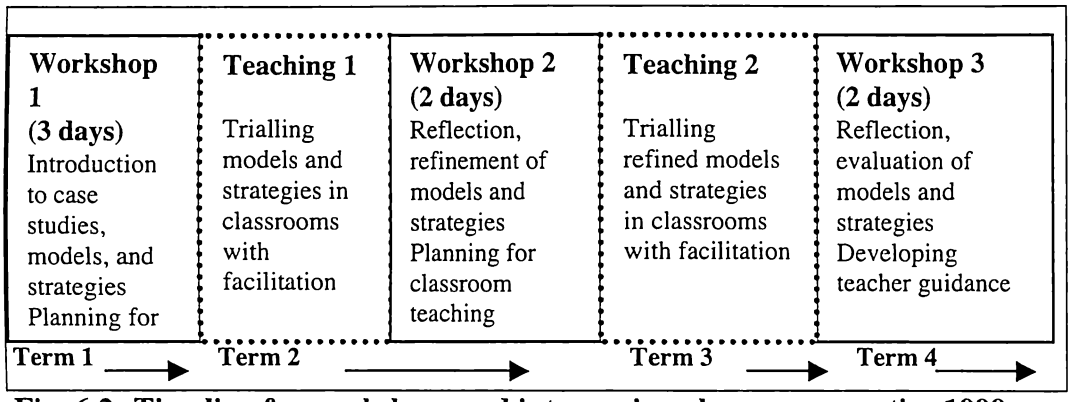


Fig. 6.2: Timeline for workshops and intervening classroom practice 1999

On-going facilitation provided vital support during workshops and once teachers returned to classrooms. There was a commitment to feeding back information quickly to teachers to access their interpretations. The research aims, data collection methods and research findings were honestly and openly communicated to teachers in workshops. Teachers needed to see evidence that change was working. If researchers wanted them to continue to trial and test out ideas, teachers needed to believe their time, commitment and effort were worthwhile (Fullan, 1991).

Support material, demonstrations and clear instructions about workshop and classroom outcomes were provided. Explanations were clear and well articulated so teachers could assess their importance and usefulness. The struggle teachers demonstrated meant support strategies were crucial. The collaborative atmosphere in workshops was also important. When teachers' foundations on which they had come to rely for teaching technology were shaken, when doubt became a

companion and when feelings of uncertainty surfaced, it was important researchers were understanding, supportive and appreciative of teacher efforts.

A planning framework was devised to assist teachers to plan and teach technology (refer Section 6.3.2 for a full description). Skills required to complete the framework were considerable. Extensive practice meant these skills would become more automatic for teachers, hence the three workshops alternating with classroom practice spread over the year. As Anderson (1992) emphasises, what can be initially effortful and resource consuming, with practice, becomes automatic and relatively resource independent (Anderson, 1992 in Sternberg & Horvath, 1995). By providing repeat opportunities to try out ideas in workshops and in classrooms, teachers' planning with the new planning framework could become more user-friendly and streamlined. It is of little consequence if teachers can alter thinking about technology teaching, learning and assessment if this cannot be transformed for use in classrooms. By interacting more than once with new ideas, teachers understood what was involved. To this end considerable support, guidance and external assistance were provided when teachers embarked on classroom technology teaching. There was no sense of the teachers 'going-it-alone'. Maintaining one-to-one, ongoing support in classrooms was essential in helping and guiding teachers and building a collaborative technology teaching community. Each time teachers taught technology a researcher was there to observe, question, listen, talk, guide and share other teachers' progress. Allowing teachers liberty to experiment and try out different approaches in combination with researcher support and assistance were important for success.

6.3.2 The workshops

Three workshops were undertaken throughout 1999 (Fig 6.2). The first workshop was a three-day workshop; the second and third were two-day workshops. Each is described. Teachers' workshop reactions and responses are integrated into descriptions of each workshop, as are researcher evaluations.

The first workshop

Introduction

The professional development programme commenced with a three-day workshop in Term One and was attended by all teachers. The programme was based on a series of scaffolded sessions (see Appendix 12). A review of technology education's current position was used to begin discussion. Case studies from 1998 provided an up-to-date teacher base for thinking and reflecting on their own practice. Small group and whole group discussion was undertaken throughout the three days, so teacher opinions and views could be aired and they could explain, argue, consider, test out and review their developing ideas. Teachers' accounts and explanations were valued and their individual perspectives, personal constructs, and explanations of situations were actively sought (Cohen & Manion, 1994). A significant proportion of the three days was spent focussing teacher attention on technological learning outcomes using the planning framework and planning their teaching for the following term. The use of 1998 case studies, details of the technological learning outcomes focus and the planning framework are described.

Using case studies

Case studies were a concrete, detailed, current and individualised description of each teacher's 1998 technology views and teaching practices. Therefore, teachers clarified similarities and differences and tested their experiences against the elements of other cases (Cohen & Manion, 1994). These were not cases about teachers and students from other geographical areas, schools, or times, but about themselves. The immediacy and depth of information was recent and detailed for reviewing their technology teaching.

Teachers discussed the implications of case studies ideas for their classroom practice. Used as a beginning point they engaged teachers, so they could consider implications for their own technology teaching (Rhine, 1998). Being current and personal meant discussion was very up-to-date and particularly fitting. Teacher comments included:

> It was good to see the findings presented in the case studies. I could see myself in there so clearly. (Burt)
> It's good to use these (the case studies) to reflect on the unit I taught. (Penny)

I can see I need a clear-cut vision of where to take technology. (Sarah)
I can see my knowledge base is not so good in technology. I'm getting confused between the pedagogy of technology and the knowledge base itself. (Tina)

Comments indicated the usefulness of the case studies for reflecting on teachers' own teaching of technology. The case studies provided:

- a description of each teacher's technology, technology education and assessment views and practices;
- a unit overview with a description of the task sequence and an analysis of that sequence;
- an analysis of individual lessons within the unit highlighting prominent issues;
- a summary of all case studies.

Most detailed was the individual lesson analysis. This analysis employed a three-perspective structure in relation to the key players' views: the teacher, the students and the researcher. A segment of this three-perspective structure is presented to show the format, a sample of the content, and to illustrate a portion of analysis (Table 6.1).

Table 6.1: Segment of three-perspective structure of individual lessons

Teacher actions & perspectives	Student actions & perspectives	Researcher commentary
Session 3.1, designing & producing the menu, followed a similar outline to the design & production of the invitation. Ally had placed on the whiteboard the information the students needed to include in their menu. She had divided the students into groups & instructed the students to think of descriptive words that could be used to describe the food to be served at the restaurant	The students brainstormed suitable vocabulary & recorded their ideas onto a large sheet of paper. In turns, the groups shared their results. The group recordings were taped to the whiteboard for others to see & use.	This section of the session was related to language, where students were expected to record a large variety of descriptive vocabulary. As a facet of a technology task, it had little relevance. However, as this aspect received the most attention, it was the focus for most students. Their menus bore a strong resemblance to their invitations except for the language used. This was not surprising, as the opportunities to reflect on the invitations they had already created, or the examination of other menus, were not provided.
Next Ally instructed the students to create their draft menus, followed by the production of the final copy. In interview, Ally mentioned the tight framework to which they were working. This resulted in her encouraging the students to use many of the ideas from the invitation sessions in the menu sessions	The students worked individually. All produced a menu that had a similar appearance to the invitation in that they tea-stained the paper, tore the edges & pasted this onto black paper. Greek lettering, symbols, borders, logos & graphics featured. The main difference was in the content.	Session 3.1 followed a design & make process, as had the invitation making sessions. This was consistent with Ally's views of technology in that technology required hands-on involvement by the students. The similarity of the menus & invitations was to be expected, as the students were not required to produce anything else. Different learning outcomes were not focussed on. There was no evidence of progress being made by the students. They appeared to just repeat the earlier exercise. It reflected the teacher's minimal knowledge about progression in technology.

(Moreland & Jones, 1999: 99-100)

Reflections on the case studies led teachers to see that as much importance was being placed on understanding student learning as of understanding teaching views and practices. Understanding case study findings facilitated a shift in focus from examining just teaching towards examining student learning. Research findings acted as a catalyst to enhance teacher understandings and practices in technology education and as an orientation towards inquiry into student thinking (Rhine, 1998).

A focus on technological learning outcomes

Models developed by the research team were used to assist teachers to move from task and activity descriptions to a conceptual and procedural focus. The change strategy was a negotiated intervention process (Jones & Simon, 1991) used to move teachers from existing practice to new negotiated positions. No change was possible without teacher support and commitment, and it would not occur unless teachers wanted it to happen. They needed to see the potential rewards of the change and to interact with it, experiment and try out new approaches (McGee, 1997).

The development of a planning framework was directly related to the 1998 research (Chapters 4 and 5) and teacher identification of the importance of developing a more complex and sophisticated applicable knowledge base in different technological areas. Enhancing planning practices was used to focus teachers on technological learning outcomes suitable for student activities. The quality of classroom practice improves by enhancing teacher thinking quality, which in turn spotlights the crucial importance of the planning or pre-active stage of teaching (Bennett, 1997). The target was to use teachers' knowledge of subject matter content and pedagogy in the context of planning.

> An expert in the domain of teaching must know subject matter content and pedagogy. An expert in the field of teaching must know how to apply teaching knowledge in a particular social and organisational context. (Sternberg & Horvath, 1995: 11)

The practical aspects of enhancing teachers' planning expertise were crucial for teachers to develop a mental framework for decision-making when teaching technology. This mental framework would assist to construct extensive, accessible knowledge organised for use in teaching. By undergoing a process of articulating

concise learning outcomes, teachers would deduce what they personally needed to know to teach technology and guide definition of clear student learning goals and outcomes. Being clear about intended learning in selected technology tasks would *help teachers learn what to listen for* (Rhine, 1998: 30) and what might be next steps when working with students.

The final planning framework (Fig. 6.3) evolved over the year and developed after a classroom trialling process, workshop discussion and discussion with other research colleagues. Technology education is concerned with complex and interrelated problems that involve multiple conceptual, procedural, societal and technical variables (Jones, 1997). So a planning framework was devised with the following features: specific task definition, overall dimensions of technology (knowledge, capability and societal) and specific learning outcomes in terms of technological concepts, procedures, societal aspects, and technical skills. It was a tool to assist teachers access, identify and organise technological knowledge for use in teaching.

Task definition:		**Tech Area/s:**	
Overall dimensions of student technological practice: • ..... • ..... •			
Conceptual Learning Outcomes • ..... • ..... • ..... • ..... •	**Procedural Learning Outcomes** • ..... • ..... • ..... • ..... •	**Societal Learning Outcomes** • ..... • ..... • ..... • ..... •	**Technical Learning Outcomes** • ..... • ..... • ..... • ..... • .....

Fig. 6.3: Planning for learning and assessment in technology (Moreland, Jones & Northover, 2001: 166)

The framework was based on five dimensions:

- conceptual (C) – knowledge and understanding of relevant technological concepts and procedures;
- procedural (P) – knowing how to do something, what to do and when to do it;
- societal (S) – aspects related to the interrelationship between technology and groups of people;
- technical (T) – skills related to manual/practical techniques; and

- the operationalisation of the conceptual, procedural, societal and technical aspects in student technological practice – integrating all four dimensions in undertaking and completing the technology task.

Students need to work across the five dimensions to develop technological literacy. Additionally, all five are critical in assisting teachers to provide a comprehensive and balanced approach to teaching technology (Moreland, et al. 2001). For teachers to successfully plan they also need to undertake an iterative process between task definition, overall dimensions of technology and specific CPST aspects in technology. Figure 6.3 was not the first planning framework teachers used. Figure 6.4 shows the planning framework used in Workshop 1.

Key aspects of Technological Practice (Strand/Achievement Objective Level) •..... •..... •.....		
Conceptual learning outcomes	Procedural learning outcomes	Technical/skill learning outcomes
•..... •..... •..... •.....	•..... •..... •..... •.....	•..... •..... •..... •.....

Fig. 6.4: First Planning Framework

Space for key aspects of technological practice and separate spaces for specific learning outcomes in conceptual, procedural and technical categories were required. Teachers needed help in defining key (holistic) aspects in the technological practice section, hence the reference to the technology strands and achievement objectives and the idea that students need to bring the conceptual, procedural and technical aspects together. Although technical learning outcomes could be encompassed in the procedural category, teachers found these difficult in 1998, so their specification as a separate entity was included. Specification was designed to draw teachers' attention to technical learning outcomes at the planning stage. Being aware was being prepared. Societal learning outcomes did not have a separate category as yet, for they were not viewed as problematic at this stage. Teachers were expected to account for them in the conceptual category. An iterative process of definition between overall aspects and more detailed aspects was required. When the overall outcomes were defined holistically, this would impact on the more detailed specific learning outcomes, and vice versa.

Compiling the list of intended learning outcomes meant teachers needed to consider their students, their conceptual development, interests, prior learning and backgrounds. Knowledge of the technology curriculum, technology pedagogy, learning and learners also needed consideration alongside the task goals and outcomes. Figure 6.5 shows the model used to demonstrate this process.

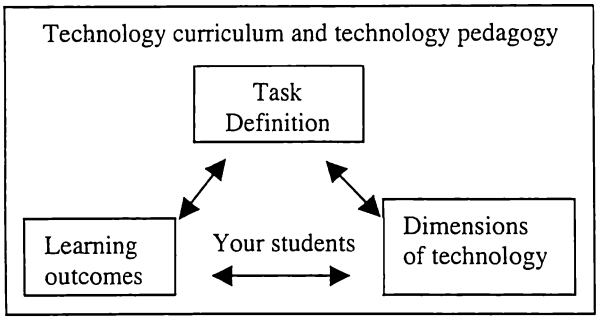


Fig. 6.5: Aspects to consider when planning

To begin the identification process, teachers decided on an appropriate technology activity from a specified technological area or areas. They brainstormed as many potential learning outcomes as they could. From here they began to itemise the learning outcomes they intended to target. The focus was on *intended* learning goals, those likely to occur during the unit. It was not to exactly predetermine the learning that must occur. Rather than being a rigid articulation of learning outcomes, planning was a guide. Teachers were expected to work with a planful and self-aware approach, not follow pathways blindly nor jump to premature conclusions (Sternberg & Horvath, 1995).

Teachers were also expected to be aware of negotiated and unexpected learning that might occur. By initially articulating the intended technological learning outcomes, teachers had a firm base from which to make decisions about student learning once they began teaching. An awareness of negotiated and unexpected learning outcomes at the planning stage was fostered, so teachers might adjust to different situations when teaching, be responsive to their students as learners and alter learning outcomes if necessary. Figure 6.6 illustrates the model developed for the identification process.

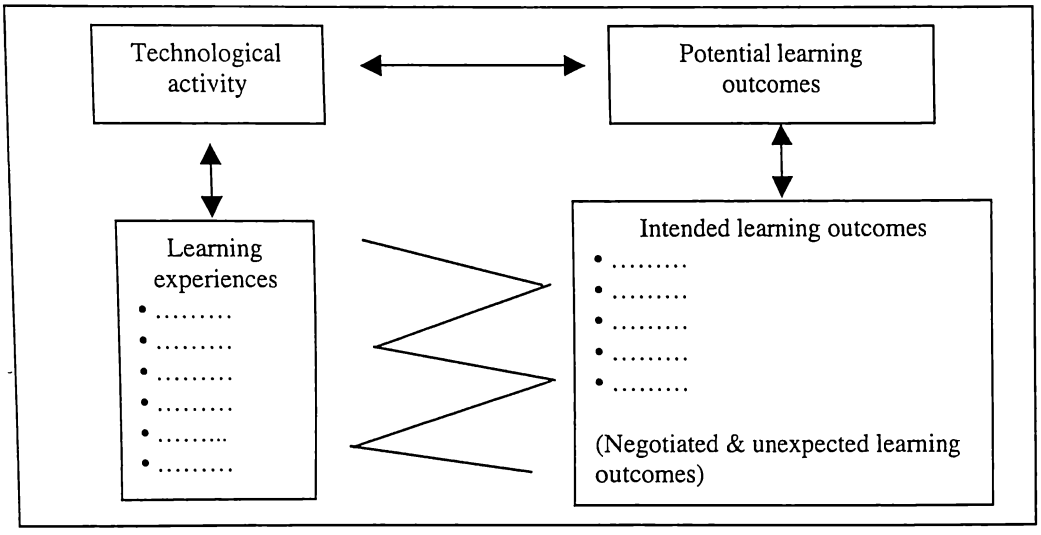


Fig. 6.6: Process of identifying learning outcomes

An iterative process of cataloguing was required to identify learning outcomes and learning experiences when planning. Learning outcomes derived from identified learning experiences. They were also derived before learning experiences so these then required interconnected learning activities. As more intended learning outcomes were specified, corresponding learning experiences needed identification, just as when more learning experiences were specified, learning outcomes needed adjusting accordingly. Moving back and forth between learning outcomes and learning experiences ensured planning was clear. As well, negotiated and unexpected learning needed to be kept in mind when planning.

First workshop outcomes

The workshop challenged teachers to examine and change their existing practices in technology. Not surprisingly most teachers felt unsure of what to do and required support and guidance. However though less confidant, they were focussed and *prepared to go back to the classroom and give it a go* (Tina). There was consensus that by taking on new ideas they would be doing a better job than previously. There was agreement that the framework gave teachers valuable assistance for planning, teaching and assessing technology. The teachers were unanimous in acknowledging Workshop One had resulted in substantial learning including:

- the development of technological knowledge, of concepts, procedures and technical skills and the ability to tease these out in specific learning situations;

- the ability to work at a level beneath the achievement objectives to identify potential learning and from this intended learning outcomes. Also there was acknowledgment that there will be negotiated learning outcomes and unexpected learning outcomes in any technological learning;
- a beginning understanding of holistic aspects of technology learning;
- understanding the notion of gap analysis and the central role of formative assessment in identifying and closing gaps;
- an understanding of and familiarity with technology education terminology and assessment language;
- a broadening understanding of summative assessment especially in examining how students bring all aspects together as well as examining conceptual, procedural and technical aspects.

By workshop's conclusion teachers had completed preliminary planning for the following term's technology unit. Sound guidance had been provided for teachers to better plan, teach and assess technology. Researchers were positive that teachers had the confidence to try ideas in their classrooms the following term. Teachers were excited about exploring the knowledge base of technology and were keen to reveal specific conceptual, procedural and technical aspects in their technology activities. Teachers were able to work with the models and moved from their previous emphasis on social and managerial aspects of tasks. Modelling by researchers proved to be very effective, a strategy continued throughout the year in all workshops.

> The idea of you modelling was great. It guided us through the process. (Ernie)
> Modelling the whole process with the KitKat example was useful. (Ally)

The three-day structure was also vital, as teachers had time to work through their concerns and uncertainties. Tina commented:

> The three days allowed for concentrated effort. We could go away overnight and reflect and come back with questions. (Tina)

When teachers left intervention had occurred, as teachers believed in the worth of the change, were prepared to change their practices and thought the models would enhance student learning and their teaching. Subsequent work in classrooms would show whether teachers could translate planning changes into practice.

Teacher and researcher evaluations inform planning for Workshop Two

Before planning the second workshop and after teachers had completed their classroom teaching they were interviewed to consider the impact of the first workshop. Ascertaining requirements for further assistance were discussed. The effects of the planning models were examined. Taking heed of teacher opinions was important as was taking into account their use of the models. Teacher and researcher reflections were both taken into account in planning the second workshop. By considering and reflecting on the use of the models, changes could be made to enhance the models if deemed necessary and outcomes would influence the way the second workshop was undertaken.

Teacher evaluations

There was no doubt that the first workshop had considerable impact on teachers' technology teaching, planning, ways of working with students and assessment practices. Teachers commented on the planning framework and the impact of defining conceptual, procedural and technical aspects:

> For me it was huge. ... I feel that to me it's brought over the whole philosophy of where the technology document is coming from. ... It helped unpack the philosophy of the New Zealand Technology document for me. By developing the learning outcomes in the conceptual, procedural, technological skills way, you end up finding that all the strands are actually covered. (Ernie)
>
> The whole idea of looking at the conceptual, procedural, technical thing. Isolating those and being more specific, and more focussed in planning and teaching. (Penny)

Other teachers made more general comments about the overall intervention programme and its impact on their ideas about technology education. For example:

> It was excellent working with other teachers. The first day, your intro, gave you a feel for what you were trying to do. The second day you were starting to get the meat out of it, but the third day gave you time to reflect, refocus, toss ideas around. (Joan)
>
> The intervention impacted on everything. Everything we talked about, the conceptual, procedural or the technical, the teaching for transfer, the formative and summative assessment, the gap analysis, I've tried it all. I've had a go at everything. ... I obviously took a lot away from it and I've also taken on board the fact that I want to change. (Sarah)

Teachers' uptake of the ideas presented in the workshop and their willingness to try out the ideas was obvious, as was the impact of the planning format in their ways of understanding, defining and examining technology. Also valued was the three-day timeframe, which gave opportunities to work with others and to reflect on ideas presented.

Teachers suggested a number of ideas for their further development. All requested opportunities to examine and reflect on each others' work, for example:

> I'd like to sort of see what everybody else has done because that'll give me a way of giving me further ideas of where to go for teaching. (Ernie)
> I guess interaction with people of like mind, although you often find that when you start talking to teachers that you don't think the same or you wouldn't have done it in quite the same way. That's all valuable, sharing ideas is valuable. (Tina)

All wanted further opportunities to examine, critique and try out the models. They especially wanted specific time to plan their next units using the models. For example:

> I'd like to develop my teaching, to move to a different technological area. ... I want to see if the ideas still apply in a totally new technological area. ... I want to know that the model works. So I'd like to sort of hone in and see if I plan more efficiently. The idea of conceptual, procedural and technical - I'm getting better you know, knowing where to put things. I'd like to refine that and I just want to make sure that I'm really getting the guts out of the technology that I'm doing, because the model makes sense. It's just making it practical so that I can fit it into my daily timetable. (Burt)

Others asked that the researchers provide further guidance, support and feedback. Teachers' opinions and the variety of requests were respected and appreciated, as they gave guidance on what to include in the workshop and negotiated intervention strategies and collaborative ways of working contribute to successful change. Teacher input was highly valued.

Teachers' use of the models had a very significant impact on their planning, teaching and assessment of technology. They believed the greatest impact was from the use of the planning framework (Fig. 6.4). Though the model for thinking about negotiated and unexpected learning and the model for identifying learning outcomes were used, the categorisation of conceptual, procedural and technical learning outcomes impacted the most.

> I suppose looking at those conceptual, technical and procedural, looking at breaking it up into that. Before I just concentrated on the procedural and not really the conceptual. I probably should have gone more into the technical but just breaking it up into those things is so useful. I suppose I'm just so keen on getting into the making that I forget about those other ones. I found the CPTs really, really, good and just having that going through and now when I write the plan up again, I will be more aware of those things. (Rachel)
> The CPT model was very useful. I felt it was particularly important. ... For me it's quite a good starting point. I'm actually able to use those to make a better and a more informed overall judgement of the technological practice. (Ernie)

The teachers found working with the planning framework somewhat difficult in the early stages but believed persevering with it was worth the effort. For instance:

> I liked the model with the technical, conceptual, procedural. It made most sense. It took me a while to get round the jargon, the terminology and I found it difficult to put some objectives or aims in particular categories because they overlapped so much. ... It helped define what I was going to teach because I'm so easily sidetracked. (Burt)
> For me was a very hard process, but it's still in the background of my mind and those words kept popping up, so I guess I'm slowly changing but I guess I just couldn't do it automatically. (Ally)
> It was really hard. Because of my lack of content knowledge, the conceptual part of it was very hard, very difficult. I don't know how well I did it but it's that lack of content knowledge that is the biggest stumbling block in this. (Sarah)

Indications were that all teachers would require more support and opportunities to use it. Repeated practice opportunities would be built into the second workshop where researcher support and guidance would also be provided.

Teachers' understanding of the different learning outcomes – intended, negotiated and unexpected was enhanced. They believed that thinking of learning outcomes in this way assisted them to realise that teaching and learning in technology could alter throughout the course of a unit.

> I was more honing in on those negotiated outcomes right from the beginning. (Burt)
> You're more aware that things are going to make your plans change just like the kids have to adjust their plans according to negotiated outcomes. That one made me have a really good think. (Rachel)

They were more prepared to adjust their teaching once the unit was under way and they were better prepared for unexpected events. For example:

> When I was initially planning this unit some of my potential learning outcomes included design and make but when I actually went down to plan, I decided to throw the making part out because it wouldn't actually benefit. I think the planned learning outcomes were the absolute because they prepared me better for the unexpected ones that came up. (Ernie)

All teachers were cognisant of the different types of learning outcomes. To consolidate teachers' understandings and practice with this model it needed to be included in Workshop 2.

The most difficult part of the planning framework model was in making overall, holistic statements and understanding the relationship between overall statements and specific learning outcomes. For instance:

> I found it hard to actually document something with an overall impression and that's why I still feel more comfortable with the bits. But by being focussed with the learning outcomes right from the start did make it easier to actually focus on what I was looking for at the end. (Penny)

Tina was the only teacher entirely confident with this seeing the relationship between making holistic statements and specific learning outcomes.

> This is good. This is fine for summative assessment. It has clear guidelines as far as I'm concerned because you do have your indicators, you have your objectives, which are specific, and you are going to mark off according to the criteria that you've set out for the objective. This is very good as it flows very well. (Tina)

With only one teacher expressing confidence in making overall statements and others finding it difficult, this model required more attention in Workshop 2.

Researcher evaluations

Taking into account the analysis of researcher classroom work and teacher interviews, teacher requests, and discussions between researchers, decisions were made relating to the areas requiring attention and further development in Workshop 2. These included the development of concepts of technology and in different technological areas, exploration and development of the process of articulating of learning outcomes, and enhancement of formative interactions and summative assessment practices.

Further development of concepts of technology and in different technological areas was critical for assisting teachers to move forward. Though, teachers had made advancements in developing their concepts, they indicated a lack of understanding of some technological areas and concepts common to different areas. Their planning sometimes showed knowledge gaps related to specify learning outcomes and categorisation. They were not always clear about the relationships between specific learning outcomes, achievement objectives and technological practice.

Further exploration to articulate learning outcomes was necessary, especially developing learning outcomes from the technology task. Though tasks were more technology focussed, lack of technology and society aspects were particularly noticeable. Societal learning outcomes had not been included, as a separate

category in the first planning framework. It was thought teachers would encompass them within the conceptual category. This did not happen, so the societal learning outcomes category was added (Fig. 6.3).

Teachers had continued to emphasise technology as hands-on and conceptual aspects received more attention than before. Formative feedback was better related to technological aspects with less emphasis on praise and social and managerial aspects. However, to ensure coverage of conceptual, procedural, societal and technical aspects these four categories were deemed important to enhance comprehensive learning.

Space for a task definition was also added to assist teachers to describe the task in technological terms rather than as an activity. For example Term Two tasks were described thus: 'A hanging birdfeeder', 'The ultimate school bag', 'Packaging biscuits', 'Tic Tac Toe for the visually impaired', 'Kites' and 'Sweet making'. Giving a fuller task description was aimed at providing a stronger technological direction. The task definition would give a lead to the main features of the task, provide an overall guide indicating primary direction, and assist in providing a planning focus.

Teachers had also demonstrated a lack of in-depth understanding of the relationship between specific learning outcomes, achievement objectives and technological practice. More understanding and experience in using all models to enhance their planning and formative interactions was required. Finally with summative assessment, teachers had targeted specific separate technological aspects better. However, making overall judgements was problematic. Enhancement of this aspect was therefore needed.

Indications were that teachers had relatively high general pedagogical knowledge and sound general classroom management practices but still lacked detailed technological knowledge and ways to alter this for developing appropriate student technological learning.

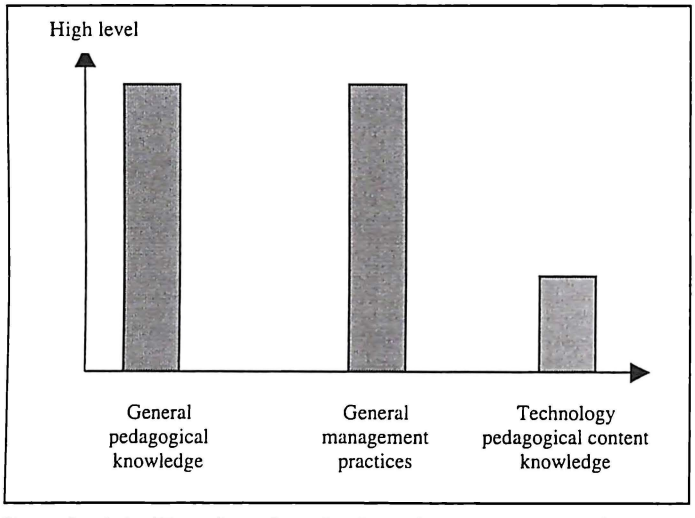
The second workshop

Introduction

The second workshop was held at the end of term two after all teachers had taught technology. The results of classroom practice are presented separately in Chapter Seven, as the interesting teaching practice stories require a chapter of their own. The focus of Workshop Two held over two days, was on refining strategies presented in Workshop One, with a specific focus on identifying overall, holistic dimensions of technological learning and specific societal learning outcomes.

Outline of the second workshop

With the issues derived from our findings and teachers' perceptions in mind, the second, two-day workshop was planned and undertaken (refer to Appendix 12 for outline). Initial sessions focused on reviewing and reflecting on the term's technology teaching and assessment in classrooms. Researchers discussed the findings related to the progress teachers had made to date and Graph 6.1 was presented demonstrating teachers' positions in becoming competent technology teachers. Though somewhat crude, it showed teacher gaps pictorially. Pedagogical content knowledge for technology was not at as high a level as in other curriculum areas, although general pedagogical knowledge and classroom management techniques were robust. As technology teachers they were novice-like with low levels of specific pedagogical content knowledge. Though improved since 1998, it was still relatively low in comparison to PCK in other subject areas.



Graph 6.1: Teacher level of understanding after Workshop 1 & 1st classroom practice

As relatively inexperienced teachers of technology they still required considerable support and guidance in defining suitable technology learning goals, enhancing student learning through formative interactions and reflecting on student technological progress. Concentrating on technology pedagogical content knowledge was still very important. The graph was a discussion catalyst for teachers to talk about changes already made. They commented on what they were hoping to gain from Workshop 2. This reciprocal sharing of ideas was a continuation of ways of working together established in Workshop 1 and enhanced collaborative relationships and co-operative inquiry.

The enhanced planning framework was presented along with explanations for the changes made. Other models were re-introduced. Teachers' discussed the successes and difficulties they had had. By giving concrete examples understandings were being enhanced. Researchers also gave examples they had seen. This sharing and discussion gave rich descriptions of what had happened. By comparing and contrasting, teachers could begin to ascertain their knowledge and practice gaps and could begin to close them.

Day 2 examined notions of student learning progression. Of particular impact was teacher examination of student work from all classes. The concrete illustrations of student achievement provided excellent opportunities for discussing student technological progress.

Teachers also planned their teaching units for Term 3 using the new version of the planning framework (Fig. 6.3). Several strategies were used to keep teachers to the task of defining learning outcomes rather than lesson activities. First, they had to write a task definition in technological terms. This directed them to the main technological features rather than deviating to activities. Second, questions focussed teachers' thinking on student learning that had occurred in Term Two and ways it could be advanced. Emphasis was on defining tasks technologically and identifying the dimensions of technological learning teachers would use to make overall learning judgements. Third, researchers worked alongside teachers while they planned. Side by side working provided strong direction and facilitated prompt feedback. Fourth, resources were provided, for example, the Science with

Technology (SwT) and Design and Technology Association (DATA) booklets (The Science and Technology Project, 1994), to help identify learning outcomes. Researchers also modelled the development of overall dimensions of technological learning using teachers' planning examples. Finally, teachers shared and critiqued each other's examples. Experiences talking about the work were invaluable for building on each other's understandings.

Outcomes of the second workshop

Like Workshop 1, Workshop 2 was extremely challenging. Considerable progress was made, but there was a sense of being asked to move even further. However, teachers felt their knowledge had increased. For example:

> We feel that our understanding of technological principles took 3 steps forward and 2-4 steps back. (Sarah)
> My comfort zone has been pierced and somewhat shattered, but I have learned heaps. (Penny)

Teachers reported that working with the models assisted their thinking about planning and assessing technology. They agreed with the planning framework changes, as they could see how the additional societal category provided a better balance for defining technology aspects.

> Learning outcomes and CPST models are helping my planning and assessment and the potential learning outcomes are good for focusing our thinking. (Tina)
> Excellent models, as they keep technology aims succinct. (Ally)
> Found the models very challenging but useful to move us on. The planning format is good for me because I can work out where my gaps are. (Ernie)

Recording the task definition in technological terms was also useful as it compelled teachers to think of the main task direction rather than just the activities in which students would be involved. Examples included: designing and making a prototype mask for the school production; modification of plain, cultured yoghurt to meet palatability requirements identified by the class; design a 3D storage container for classroom use to hold maths equipment that is attractive, durable and portable; and, modify existing pieces of handheld, home technology for arthritic sufferers.

> The task definition keeps us focussed and specific throughout the unit. (Penny)
> Thinking about the task definition first was a valuable way to focus on the children's learning that could come from the task before thinking about the activities. (Rachel)

There were still questions and uncertainties about applying the models, reflected in Penny's comment:

> I find the intended learning outcomes valuable and essential. However it's hard to determine the unexpected learning outcomes and negotiated learning outcomes. Is it ok to address these when they come up? (Penny)

Teachers perceived that their technology curriculum knowledge had improved, were even more aware of knowledge gaps and the necessity to seek guidance:

> We are more focused with the aspects of technology and have a better understanding of the three strands. (Burt)
>
> We still need conceptual technological knowledge to teach technology and more resources to help with planning. (Rachel)

Making links between the specificity of learning outcomes and the generality of curriculum achievement objectives, and writing overall holistic statements was problematic for all. With no existing examples on which to model their practice, other than researcher modelling, teachers struggled to bring the specific outcomes together. For example:

> I'm not sure what is expected in the overall statement. (Ernie)
>
> It's very difficult to write effective statements about key aspects of technological practice. (Ally)

Teachers considered the focus on thinking about teaching, learning and assessment strategies while planning was useful. They also expressed positive feelings about their ability to assess student learning summatively: For instance:

> The workshop has made me consider summative assessment and formative assessment before teaching the unit and I feel more comfortable about the relationship between holistic statements, achievement objectives and specific learning outcome and making holistic judgements. (Tina)
>
> The new planning format model will, I feel, move my summative assessment forward and I can focus on summative assessment through defining key aspects of technological practice. (Ernie)

When teachers left Workshop 2 intervention had occurred. Ways were provided for teachers to better plan, teach and assess technology. Though their confidence had been shaken at different stages and they struggled with overall aspects of technological practice, they left with the will and determination to try the enhanced models in classrooms with their students.

Teachers' thinking had changed. Their planning especially demonstrated the changes, with more detailed learning outcomes across the four categories being

written, task definitions more reflective of targeted technology aspects and attempts were made to record overall technological practice statements. An interrelationship between task definition, overall practice statement and specific learning outcomes was evident. Teachers knew their own technological knowledge gaps and used resources to help close them. They had persevered with the models and made every effort to keep student technological learning to the fore. Work with the models meant teachers had better ability to:

- audit technological activities for relevant technology
- ascertain their own knowledge gaps
- decide on valued learning goals
- transform their own knowledge into suitable knowledge and goals for their students
- focus on technological aspects during planning
- plan, as they could:
    - think about how students might bring the CPST aspects together and how they relate holistically;
    - tease out task learning outcomes in conceptual, procedural, societal and technical terms; and
    - undertake an analysis of the task to ascertain the task affordance.

Support and guidance were essential throughout the two workshop days. On-going support was also offered. Teachers could fax or email plans to researchers at any time for assistance. They could consult by telephone or researchers would visit when required. Support strategies would be an integral feature of the next phase of research and development.

Teacher and researcher evaluations to inform planning for Workshop Three

Before planning this final workshop and after teachers had completed their final classroom teaching, they were interviewed. The impact of the second workshop was considered, as were the effect of the models and the planning format on teachers' understandings and practices in classrooms.

Teacher evaluations

Like the first workshop, the second workshop had considerable impact on all teachers' perceptions and understandings of teaching of technology, their planning, their ways of interacting with students, and on their assessment practices. Of importance was the idea that they needed to focus on technological learning outcomes rather than just providing technological activities. Comments included the following:

> You can lose the technology concept that you're trying to teach really easily and I think I've tightened that up quite considerably, because I've been very conscious of it and that's been as a result of the workshops. (Sarah)
> The activities that I'm giving my children are more clearly targeted and identified. My children have a fair idea of where they're going to go and I think that's important. That's perhaps something I didn't focus enough on before, making sure my children knew exactly where they were going to go. I also think I'm better at clarifying the task for the children. (Burt)
> It was good. My overall objectives, my specific learning outcomes and my assessment are all linked and I've got specific learning outcome number one there so that I know exactly why I'm doing that activity. (Sarah)

Aligned with the idea of focussing on technological learning for students was the teachers' recognition of their need to be more technologically knowledgeable as this assisted them to define and focus on technology for their students. For example:

> I understood I needed to understand the technological content. In the past in my planning I would decide on the context and the topic. Now I justify doing a particular topic because of the technology in it. I am more focussed and I'm looking at real quality technological things. (Rachel)

The enhanced planning format had a considerable impact on the way teachers' planned their units. All were able to categorise learning outcomes into the four categories despite this not being easy to accomplish. However, all teachers believed they were becoming more proficient in planning with the workshops providing extra practice opportunities. For instance:

> I tried to link my strands to my specific learning outcomes, the conceptual, procedural and technical and societal. ... So I've tried to get really specific and I've been trying to really tighten everything up. It's had a big influence. (Sarah)
> I still found the planning model quite hard. But I think I'm better at actually writing up the unit than the last time. (Ally)

Teachers used the planning format as a checking devise to audit the balance of learning outcomes. For example:

> I will use the CPTS model from now on as it justifies what I am teaching and it is a checklist, a reminder of what to cover. For example I ask, is there enough conceptual? I used it lots. I kept flicking back to it. (Rachel)

> I've moved more into your planning model to have a better look at exactly what the technology is being taught and technology that is involved in the activities. I'm getting better I think at wording my plans and I still find that quite difficult, because I'm not a very good writer. But yes, I do like the headings. I'm playing with them and becoming more and more proficient using them. I'm fairly happy now. (Burt)

The addition of space for the task definition was viewed as worthwhile. Rachel illustrated this point:

> Having your task definition is good. It just sort of keeps you on track really and what you want the kids to get out of it, rather than just sort of pottering along doing things. It's sort of linking everything up to that one thing that you want them to achieve. (Rachel)

Making overall holistic judgements of student progress still proved difficult for teachers to understand and undertake. However, looking at other teachers' attempts in the workshop did assist, especially of how to assess the whole process students had undertaken as well as how they attempted to link the interactions of different specific aspects. Comments included:

> That overall judgement thing I found quite hard to do. I suppose once you get on to doing it, it will be all right. Just the initial one, like I kept going back to things we did in the workshop and try to link it in with that. (Rachel)
> I find it hard to think about accumulating information about children. I still tend to sum up at the end, but I feel a bit more confident making an overall holistic judgement. I would find it uncomfortable going back to the checklist thing I did before. It wasn't until I saw the other examples I realised my first attempts were too general. I could see that by going backwards and forwards, how it worked together. My planning was not linear or sequential, but far more iterative. (Penny)

Teachers' spoke of how the workshop programme and use of the models were impacting on planning and teaching in other learning areas. As illustrations:

> I think that now that I've taught a science unit that way, I think I'd be much clearer in my mind how to get the best out of that, using that model. I think also using the model is actually making me revert more to learning about things across the curriculum and I feel that in the areas that I have a weakness, then I'm more likely to go back now and think of the learning outcomes more. It's acknowledging carrying the practice over to other subjects and I hope that it will make my own teaching better in other areas of the curriculum. (Ernie)
> I've actually started trying to use the same model in different areas, science. (Burt)
> I found it absolutely brilliant and I have transferred that into social studies and I can see where I can transfer it in science easily and I could do it in all other areas as well. I've done it in writing. I was able to do unexpected learning outcomes in health and in social studies. So there was a crossover. Yeah. I was quite excited about it when I got it. (Sarah)

The overall impact of the workshops was considerable with all teachers commenting on how the workshops had affected their ways of working in classrooms. In particular they commented on their better ability to define their teaching goals and plan for their students' technological learning. For example:

> My planning is more focused, the whole process is refined. Everything's been sort of narrowed down. Again that comes through the activities in the initial planning stages. ...

> My assessment is very clear. ... I'm looking at technical skills, conceptual skills, and those sorts of things. (Burt)
> Yes, oh definitely. I mean I'm much more focused on knowledge now and that applies to science areas, applies to maths teaching. I think that the knowledge component is important. (Tina)

Although teachers acknowledged the difficulties they had in changing their practices in technology, they also acknowledged the worth of taking part in the professional development programme.

> The impact of the workshops has been quite tremendous. I expected to be challenged, and it is difficult, but it definitely isn't too hard. We've been kicked out of complacency from all we already knew into where we really have had to dig deep. But that's okay because I expected that by being on a research project that would happen. (Sarah)

Teachers had sound suggestions for the next workshop specifically mentioning an ongoing need to share and talk about each other's work. Building collegiality was valued.

> I want more opportunities for building collegiality. Teachers' willingness to share and support each other has been excellent. (Joan)

Teachers also thought sharing sessions would provide a forum for gleaning ideas from each other's work. Plus examining student work could begin to develop ideas related to progression in technological learning. For example:

> Sharing our work to see the range of activities and areas covered might help me understand where children might be in the Junior/Senior areas. It could give me an idea of where I'm working towards, what to think about next, how to enrich what the children are thinking. (Penny)

Specific requests were also made for researchers to provide ongoing opportunities to work with all the models especially the planning framework where teachers were encouraged to write overall statements, and with summative assessment where teachers were expected to make judgements related to overall aspects of student technological learning. Finally, concerns for other teachers outside the professional development programme were raised. In particular, methods needed to be discussed to assist other teachers to gain access to the models the research teachers had used.

Researcher evaluations

Researchers concluded that teachers still appreciated assistance with planning, they used the planning tools with more confidence and used the workshop

facilitation to confirm their ideas rather than to form entirely new ideas. Teachers' progress included:

- increased precision in thinking about progression;
- an improved ability to make stronger links between detailed learning outcomes and technological practice;
- an enhanced ability to make overall judgements which were more reflective of technological practice;
- an more iterative process of developing the task definition, technological practice and specific concepts and procedural aspects in technology; and
- a better balance across conceptual, procedural, societal and technical features of technology.

Further development of summative assessment strategies was needed. Though teachers had made advancements in summing up students' learning in technology, they indicated a lack of robustness in summative practices, especially when trying to make an overall holistic judgement across interrelated conceptual, procedural, societal and technical dimensions and when examining student progress across the school. More understanding and experiences in making holistic summative judgements and school-wide decisions were required in Workshop 3. Progression ideas were also just beginning to develop, so opportunities to examine a range of student work from Year 1 to Year 8 would be included to build on developing ideas about progression.

Noting the developments, teacher requests, the analysis of workshops, classroom work and interviews, and especially examining teachers' use of the models, planning for Workshop 3, the final workshop, was undertaken.

The third workshop

Introduction

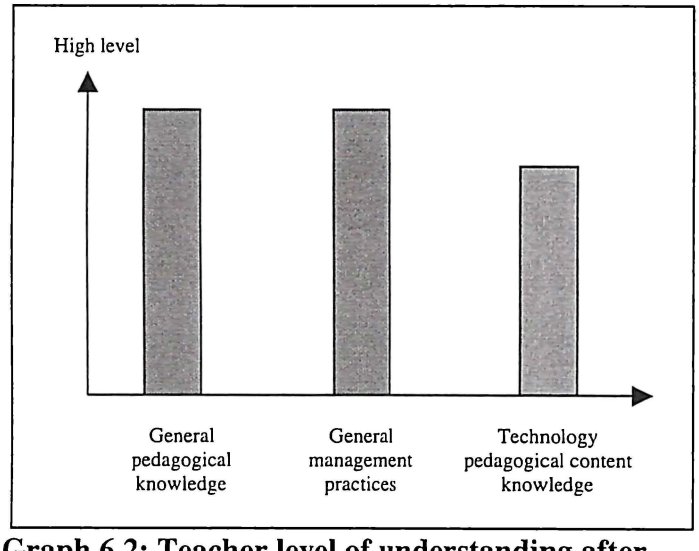
The third and final, two-day workshop was held in term Four after all teachers had taught another technology unit. The results of this classroom practice are presented separately in Chapter 7 as the stories gathered from classrooms present interesting, distinctive examples on their own. Workshop Three had a reflective,

evaluative focus looking back at teacher progress. It also had the focus of getting ideas suitable for other teachers.

Outline of Workshop Three

The development of teachers' progress throughout 1999 was not always straightforward. Therefore continuing support strategies were an integral and vital feature of Workshop Three. Researchers focussed on developing more refined technology summative assessment understandings. Teachers' 1999 progress required summing up. Effective strategies for informing other teachers about the research findings and possibilities for research in 2000 were included. Workshop Three therefore included summative assessment strategies, reflections about 1999 and developing guidance for teachers (refer to Appendix 12 for Workshop outline).

Day One focussed on reviewing the year's programme. Researchers discussed the progress teachers had made throughout the year. Graph 6.2 was presented to show altered teacher positions relative to Graph 6.1.



Graph 6.2: Teacher level of understanding after Workshop 2 & 2nd classroom practice

It indicated an increased level of technological pedagogical content knowledge, though not as high as general pedagogical knowledge and general management practices. Developing summative assessment practices, understandings of student

progression in technology and understandings of teaching in all technological areas were still needed. Teachers were no longer technology novices, but room for more growth was evident. The graph was a catalyst for discussing teacher progress made throughout the year.

The bulk of Day One concentrated on progress teachers had made from 1998 to the end of 1999. Effectiveness of the models for enhancing student learning, strategies for effectively implementing models, differences in student learning, methods and strategies for identifying differences and this programme's impact on other curriculum areas were the considered categories.

Day Two focussed on three aspects. First, summative assessment strategies were discussed. Second, teachers analysed their progress. Topics included enhancing student learning, improving teaching strategies and enhancing recording and reporting; and, the effectiveness of the models. Third, developing guidance for other teachers and suggestions for assisting teachers to understand and implement the models were discussed.

Outcomes of third workshop

The third workshop provided opportunities for teachers to strengthen understandings of summative assessment, reflect on the progress they had made throughout the year and develop guidance for other teachers.

Examining student work from different areas of the schools was worthwhile as it allowed comparative opportunities for considering differences in student understanding and progress. By looking at all student work teachers saw student technological thinking and skills from the Year One through to Year Eight. They reflected on and discussed these and began to formulate ideas related to progression. They thought about sequential ways to connect one technology unit to the next so that student learning would build on previous understandings and experiences. Summative assessment practices were prospective and reflective. Teachers anticipated where to take student learning next based on current position, progress already made and where they believed the next goals were. For example:

> Next time I teach technology, I will think about children's existing knowledge base, what has been covered and where the gaps are. (Ally)
> Thinking about how my learning activities link and helping students to transfer ideas and knowledge from one unit to the next has been important. (Penny)

Although they acknowledged the growth made in making overall judgements about student progress, they found recording summative statements about this difficult to undertake. It was easier to summatively judge discrete aspects in each of the four conceptual, procedural, societal and technical categories. Clearly, summative assessment required more attention in 2000.

Undertaken individually and in groups, reflective exercises focussed on researcher questions. Areas covered included the effectiveness and impact of the models, effective classroom strategies and student learning. The effectiveness and impact of the models is reported in this chapter. Classroom strategies and student learning are covered in Chapters 7 and 8.

Like Workshop Two teachers reported that working with the models was highly effective in changing their thinking and practices with planning, teaching and assessing technology. General comments included:

> The models have provided an effective intervention generally and the all-encompassing approach of the curriculum, facilitating therefore effective interpretation of the document. I have found the models effective in focussing teaching and assessment practice. (Tina)
> The models enabled me to focus on technology and not get sidetracked into other curriculum areas. (Ally)

Again, the greatest impact was from the planning framework. Its use assisted teachers to interpret what they were going to teach and how they might go about it.

> Thinking about the learning that I wanted to take place enabled very focussed activities to meet the learning outcomes. (Ernie)
> By looking at the learning outcomes first then the learning tasks, we were able to justify why we were doing the activities. Often, before I would plan a 'cool' idea then try to fit the technology for the sake of curriculum coverage. (Penny)

Teachers believed that the planning framework enabled a more accurate interpretation of the curriculum and that technological and curriculum knowledge had improved.

> My knowledge of technology has certainly taken another positive step forward. (Sarah)
> Increasing my own knowledge base and use of technological language has been important. (Burt)

> Focussing on conceptual, procedural, societal and technical aspects improved interpretation of the curriculum. (Tina)

Finally, the use the framework enabled clear identification of learning outcomes, which impacted on assessment and appreciation of the technology aspects most worthwhile for their students. Teachers no longer expected activities to define student learning; rather they knew they needed to define suitable technology learning outcomes before teaching began. For example:

> Planning was very focussed in terms of learning outcomes and focussed on actual technological concepts. Planning was specific so assessment was more effective. Thinking about the learning first, then the activities next, made the learning worthwhile for the children. The iterative planning process helped us to justify the learning needs versus the activities. (Rachel)
> My approach to planning became more iterative to really focus on the learning outcomes, the technological practice, the task definition and the activities, and to provide an effective match. (Ernie)
> Planning enabled me to justify selected learning activities, that is, truly explain their purpose and value. (Penny)
> Setting technological learning outcomes and using technological language refines where you're going and where you've been for teachers and children. (Ally)

Of importance was the friendly teacher-researcher work atmosphere. Teachers liked sharing emerging ideas with others. This helped to reflect back over their own learning, to more closely examine their own technology teaching and helped in building their understandings of the models. For example:

> Talking with others and working in small groups was worthwhile to assist with implementing the models. (Ally)
> Feedback from others, teamwork, discussion and the appropriate use of expertise have all contributed to effectively implementing the models. (Ernie)
> Discussion and debate and informal interactions with colleagues contributed. (Penny)
> We've had a great opportunity to consolidate our thinking. I think the overall points raised by the group showed a high level of reflection and connection to the curriculum document. (Tina)

Working with colleagues assisted to build a more in-depth understanding of teaching and learning in technology. For example:

> My interactions with colleagues helped me collate resources and focus ideas. Discussions between us helped to check and work through the planning. (Rachel)
> Interchange of ideas with other teachers in the project has been important in terms of conceptual development, knowledge of practice and the development of language. Consistently being re-focussed and supported by the research team has helped implement the models and to support risk-taking. (Tina)
> Great to reflect with other teachers and share their units to see what they did and what children are capable of. (Sarah)

Teachers had become positive about their technology teaching. It was no longer an area to be avoided, rather they were confident they could teach it well. They

believed they had made considerable gains, but acknowledged there was even more to learn. For example:

> The models have helped immensely and it has been particularly rewarding to see the quality of work that has been produced by the children as a result of the research. (Ernie)
> This workshop has been useful in clarifying for me how far we have jumped in our development and how far we still have to go. (Sarah)
> The overall project has been very informative to the practice of technology teaching. Intervention with the models has produced accelerated development. (Tina)

The models, the workshop organisation with everyone working together and the long-term nature of teacher development with on-going opportunities to trial ideas assisted teachers to become more effective technology teachers.

Providing guidance for others

After involvement for two years these teachers believed they had important ideas to assist others in becoming more competent and confident technology teachers. The most significant idea to share was the use of the planning framework and the conceptual, procedural, societal and technical categorisation of learning outcomes. Completing this was particularly important for it defined particular technology for teaching, learning and assessment focus. By focussing planning, student questioning and the language used became focussed, as did assessment practices. The importance lay in clear conceptual, procedural, societal and technical objectives so these could be conveyed to students. Then students would be clearer about their directions and teacher-student formative interactions would likewise be focussed on the same learning outcomes. A way to achieve this was to publish teacher and student work as this would provide examples of what teachers and students can do in technology. Examination of such work could provide teacher learning opportunities.

The core of the teachers' success had been deriving the outcomes of technology and introducing conceptual, procedural, societal and technical aspects. Again packaging their experiences was viewed as a valuable way to fast-forward other teachers' development, as others could work from the research teachers' examples, providing a more direct route into understanding teaching, learning and assessment in technology.

Summary of the third and final workshop

From the workshop discussions and written material it was evident teachers had gained considerable expertise in teaching technology. Their greatest improvement was in their confidence with working with the models. No longer were they tentative in approaching technology education, rather they were very confident, competent teachers. Their ability to identify and target technology learning outcomes was enhanced, evident in their summing up of progress made. Students' technological learning was better understood, especially when categorised in conceptual, procedural, societal and technical terms. All had attempted to understand how students brought these aspects together – holistic aspects were considered. This final workshop served as a suitable conduit for summing up progress and gains made throughout the year. Additionally, advice for other teachers was offered.

The success of the intervention was particularly demonstrated by the teachers' unanimous request for continued involvement with the research team in 2000, as the focus then was shifting to summative assessment, an area only just begun in 1999.

6.4 Summary of Chapter 6

This chapter provided an account of the 1999 professional development programme. Key features considered vital for success included the need to allow time for trialling ideas and reflecting, providing support and guidance, and building a spirit of co-operative inquiry. The main purpose of the professional development was to support teachers in becoming more competent, confident and effective teachers of technology. The key aims were to enhance teachers' planning, teaching and assessment strategies. It is evident from teacher comments the main purpose and aims were met.

The professional development programme had contributed to successful change. The initial use of case studies was a beneficial beginning point. The extended timeframe with ongoing opportunities to get together with other teachers and researchers helped to challenge, extend and consolidate ideas. Two and three-day workshops allowed for many opportunities to examine other teachers' work and

student work, to plan teaching units, to be introduced to new ideas and to develop new understandings about student technology learning, teaching and assessment strategies.

The use of the planning framework and focussing on conceptual, procedural, societal, technical and overall dimensions was important. Its continuing use led to teachers who could:

- audit technological activities for relevant technology
- ascertain their own technological knowledge gaps
- decide on valued technological learning goals for their students
- transform their own knowledge into suitable knowledge and goals for students
- focus on technological aspects during planning
- better plan, as they:
  - thought about how students might bring the different CPST aspects together and how they might put them into action in a holistic manner;
  - teased out the learning outcomes of tasks in conceptual, procedural, societal and technical terms; and
  - analysed the technology task to ascertain the task affordance.

Teachers' progress in the workshops included:

- increased precision in thinking about progression when planning;
- an improved ability to make stronger links between detailed learning outcomes and technological practice learning outcomes;
- an enhanced ability to make learning outcomes more reflective of technological practice and a better balance of conceptual, procedural, societal and technical learning outcomes;
- a more iterative process when completing the planning framework;
- advancements in summarising student learning using student work samples; and
- the development of some progression ideas through the examining Years 1 to 8 student work.

Overall, the intervention programme had been extremely successful as teachers were no longer tentative in approaching technology education, rather they were very confident, competent, knowledgeable practitioners.

Chapters 7 and 8 present data related to the final research questions: In what ways does teachers' enhanced pedagogical content knowledge in technology impact on planning, teaching and assessment practices and especially their formative assessment practices? What is the impact on student learning? Chapter 7 describes teacher' classroom practices changes made throughout 1999. The focus is especially on teacher-student formative interactions. Detailed are the pedagogical changes made by teachers. Student work and the conversations they had with their teachers, the researcher and other students are presented in Chapter 8 to illustrate the learning achieved as a result of enhanced teacher knowledge about planning, teaching and assessing technology.

7. ENHANCED CLASSROOM PRACTICES IN TECHNOLOGY: 1999 FINDINGS

7.1 Introduction

Chapter 6 described the 1999 yearlong teacher development programme. It focussed on the intervention strategies and workshops rather than teachers' classroom practice. Teachers' progress from the workshops included increased precision in thinking about progression and an improved ability to make stronger links between detailed learning outcomes and technological practice when planning. They enhanced their ability to make overall statements more reflective of technological practice, used a more iterative process and included a better balance across conceptual, procedural, societal and technical aspects of technology when using the planning framework. They also demonstrated heightened awareness of negotiated and unexpected learning opportunities when planning. They could better sum up student learning and make overall holistic judgements across interrelated conceptual, procedural, societal and technical dimensions. Finally, teachers had developed some technology progression ideas.

This chapter presents data gathered in Phase 3 (Fig. 7.1) and relates to teachers' 1999 classroom practices.

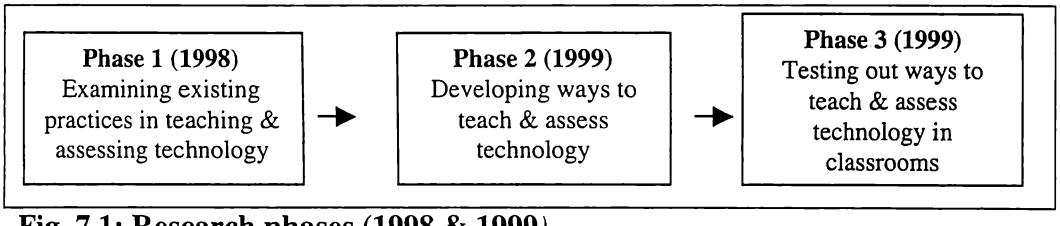


Fig. 7.1: Research phases (1998 & 1999)

Although classroom practice data informed workshop planning, they are separated in this chapter because teacher classroom practice development is one of the interesting stories. My classroom involvement was extensive, involving nearly 400 hundred hours of observation. From the cross-case analysis of data, three sections emerged to describe teachers' 1999 classroom practices. Section 7.2 details the effects of the models on teacher decision-making and planning; Section

7.3 presents changes to teachers' classroom approaches; Section 7.4 describes assessment aspects including enhanced formative interactions and summative assessment practices. A summary of Chapter 7 is provided in Section 7.5. The data related to enhanced student learning are presented in Chapter 8 and are kept separate from Chapter 7 as this chapter concentrates on teachers.

7.2 Effects of the models on teacher planning

This section outlines the effects the teachers' use of the models had on the planning decisions they made. Using the models for planning was useful for thinking about the important technology for focus. From the beginning they were encouraged to think of the technology they wanted their students to learn. They also thought about opportunities for negotiated learning and kept in mind that there could be unexpected learning. Defining the learning outcomes in the different categories drove teachers to an auditing situation. Not only did they need to make decisions about what they wanted their students to learn they also needed to make decisions about what they needed to know for teaching. Using the planning framework compelled them to confront their own knowledge gaps. Always their decision-making was based on learning targets for their students. Justifications for including learning outcomes were based on the technology they were focussing upon, their knowledge of the curriculum and students they were teaching. It was no use choosing learning outcomes that were technologically sound but unsuitable for their students.

Teachers' use of the models impacted on technology tasks chosen, use of the planning framework to outline intended learning goals for their students, the intended lesson sequence, and their planning for assessment. Each aspect is detailed to describe changes teachers made to their planning and decision making.

7.2.1 1999 technology tasks

Like 1998, all primary school class levels, except year 1, were taught and a variety of topics were chosen. Appendix 13 outlines the technology units taught in 1999 and includes the topics, technological areas, main technological learning foci, duration of units, and class year level.

The duration of units was similar to 1998; 6 of the 8 units in 1998 were 3 weeks or less, 12 of the 14 units in 1999 were 3 weeks or less. In 1998, teachers chose a topic because they wished to cover a specific technological area, the topic linked with other learning areas they had already taught, and the topic was engaging for students (Section 5.2.2). Reasons were different in 1999 where topics were related to the technology teachers wished to teach, not because of a technological area or a link to other learning areas. Teachers chose particular tasks for their potential to develop student technological learning. Technological areas covered in 1999 show the similar 1998 concentration on structures and mechanisms, and materials. Difference was demonstrated in the main foci where teachers specified the technological reasons for choosing a particular area. In 1999 the prime reason for topic choice was that the topic had the potential to develop particular technological learning in specific technological areas. This highlighted a move from curriculum coverage to learning. Technological learning opportunities also needed to engage students. For example, Rachel aimed to develop 3D drawing techniques as a means for students to express design ideas, introduce and develop the idea of using mock-ups for testing out variables, and introduce the technological principles of durability, portability and aesthetics. She also wanted to develop an engaging and meaningful task. As her students had already commented on classroom storage problems, she decided the technological aspects could be incorporated in a task where students attempted to solve the mathematical equipment storage difficulties. As she commented:

> I was very focussed in terms of planning and learning outcomes. I established where the children were, and where I wanted to take them, by focussing on actual technological concepts related to the topic. I was then able to work out the activities that would make it valuable for the children. (Rachel)

This shift to providing opportunities for students to develop particular technological learning outcomes was important. Teachers were able to investigate a wide range of learning outcome possibilities, and then select particular intended learning outcomes based on the goals they wished students to aim for. This was in contrast to 1998 where they provided technological tasks but were unsure of the learning embraced in those tasks. Teachers' developing ability to anticipate technological direction was new. It allowed teachers to forecast what they wanted students to achieve technologically. Teachers became focussed on the

technological learning of students in current situations as well as where they wanted to take them to. Progression in student technological learning was being addressed for the first time in planning.

7.2.2 Using the planning framework

Teachers' expanding ability to analyse tasks to identify appropriate technological learning was enhanced considerably by their use of the planning framework model. Table 7.1 is an example of one teacher's planning.

Table 7.1: Rachel's planning for Unit 2 1999

Task Definition: Design & construct a 3D-storage container to hold classroom maths equipment that is attractive, portable & durable.			
Key Aspects of Technological Practice • Knowledge: Develop an understanding of the importance of the design process in developing a solution to storage problems; • Capability: Develop & evaluate a suitable & practical storage solution for maths equipment taking into account attractiveness, portability & durability; and • Society: Identify the differing requirements for storing maths equipment for a variety of age groups of children.			
Conceptual LOs	**Procedural LOs**	**Societal LOs**	**Technical LOs**
Understand: • Design is an important factor in making storage containers • Planning includes criteria for making • Durability (takes lots of use over a long time) • Nature of material to be stored needs to fit inside container • Optimisation of materials (don't waste materials) • Container needs to be suitable shape for storage space (needs to fit) & suitable capacity for equipment (right size) • Portability (1 person can carry it and easily move it around room) • Joining of materials (staple, glue, tape, dovetails, tabs) • Purpose of a mock-ups - to test out some variables • Containers can be identified with labelling • Containers should be aesthetically pleasing (eye catching)	• Examine current storage in classroom to identify main variables for designing suitable containers Select an option that needs improving • Examine nets, 2D & 3D drawings Make annotated concept, net, & 3D drawings and take account of capacity, durability, portability & attractiveness. • Construct 3D mock-ups. Test and evaluate for shelf size, capacity & portability. Make modifications.	• Establish and understand classroom storage need/problem • Different people have different aesthetic responses – attractiveness of area & containers • Recycling material is important for minimising waste	• Draw from different views, magnify some areas • 3D drawing • Draw lines, right angles, nets • Measure • Cut • Join by: folding, interlocking, overlapping, glueing, stapling, taping

Table 7.1 shows how Rachel used the planning framework to identify the learning she was aiming for in her second technology unit taught in Term 3 1999. She defined the task, the overall dimensions of technology as key aspects of technological practice, and the intended learning outcomes in the four categories. Her task definition encapsulated the broad task boundaries and helped her to think about general technological learning direction. She identified the key procedural aspects of designing and constructing, the key technological principles of aesthetics, portability and durability and a description of the artefact to be constructed (a 3D storage container to hold classroom mathematics equipment).

The 1999 task definition provided a clear, summation of general direction and was in stark contrast to 1998 where she did not define the task; instead she just entitled the unit 'Mazes'.

Rachel defined three key aspects of technological practice; each matched to one of the three curriculum strands. Aspects of technological practice were more detailed than the task definition but were not as detailed as the more specific learning outcomes articulated in the conceptual, procedural, societal and technical categories. A close connection was made between task definition and aspects of technological practice where phrases from the task definition are evident. Noted is conceptual identification (knowing about the design process, aesthetics, portability, durability, practical solutions, and storage equipment for different groups of people) and procedural identification (being able to design, develop, evaluate and account for technological principles). Also noteworthy is her attempt to synthesise conceptual and procedural aspects. For example, an understanding of the design process is to be incorporated in developing a solution; and an understanding of attractiveness, portability and durability is to be incorporated in developing and evaluating solutions. This 1999 work contrasted with 1998 where Rachel did not define key aspects of technological practice, she only defined one achievement objective and both technological knowledge and technology and society did not receive any attention.

Finally Table 7.1 shows the intended learning outcomes in the four categories. There is a strong relationship between key aspects and learning outcomes with all aspects of technological practice referred to in the learning outcomes. The learning outcomes are specific, detailed and itemised across the four categories. Conceptual learning outcomes relate to technological principles (durability, optimisation, portability, purpose of mock-ups, aesthetics); techniques (joining of materials); and materials and structures (nature of materials and size, shape and capacity of container). Procedural learning outcomes relate to the procedures and processes to be undertaken. Societal learning outcomes relate to people and environmental considerations. Technical learning outcomes specify the technical skills required. The detail and breadth of learning outcomes are in complete

contrast to 1998. No detail at all was shown then, no categorisation undertaken and no specifics of technological learning itemised.

The close connection between the task definition, key aspects of technological practice and the detailed learning outcomes shows Rachel employed a process of iteration to complete the planning format. Additionally, she had her students in mind when defining learning outcomes as she defined meanings of many aspects in terms her students would understand. For example, durability was defined as 'takes lots of use over a long time'; portability as 'one person can carry the container and it can be easily moved around the room'; aesthetics as 'eye catching'; suitable shape as 'needs to fit'; and optimisation as 'don't waste materials'. Rachel had translated different technological aspects in terms suited to her students. These translations could be used as links to student thinking. She was clarifying in planning how she and her students could use particular terms in classroom situations. As a means for communication these translations could guide her formative interactions, as she had specified the terminology she would use when talking with students. As she commented after teaching the unit:

> Formative assessment was more specific as the interactions were constantly using the vocabulary that I wanted the students to understand. (Rachel)

Her students could also use this terminology in their descriptions for assessment criteria. For example, students could judge whether their container was portable by testing if they could carry it on their own and they could move easily around the room with it. No attention was paid to this translation act in 1998. For another detailed example of planning see Appendix 14.

All teachers used the planning framework in similar ways as they defined the task, aspects of technological practice and learning intentions in the four categories. A relationship was formed between task definition, technological practice aspects and specific learning intentions and a translation of technological principles, concepts, procedures and processes was undertaken to articulate meanings for particular students being taught. Appendix 15 includes other planning examples.

An improvement was shown in teachers' ability to match tasks and teaching activities to the learning outcomes they were aiming for. In 1998 all teachers chose a technological activity before they tried to identify the learning outcomes with learning outcomes closely aligned to the curriculum achievement objectives (Section 5.2.2). In 1999 teachers identified the learning outcomes alongside tasks. They always kept in mind their students to ensure their pitch was at an appropriate level. Gains in planning were reflected in teacher comments, for example:

> Very focussed in terms of planning and technological learning outcomes. (Ally)
> Actually looking at the conceptual, procedural, societal and technical aspects, that was the biggest thing. The idea about being specific and more focussed in planning and in teaching. (Rachel)

Planning showed some understanding of progression in task selection and development, as 1999 tasks were identified in order to develop particular technological conceptual and procedural aspects rather than to provide a balance of different technological areas as in 1998. Most noticeable was the shift from broad achievement objectives to using very specific concepts within different technological areas. Teachers' developing conceptual and procedural knowledge enabled them to write specific learning goals, and they moved with more confidence between the key aspects of technological practice and specific technological learning outcomes.

7.2.3 Intended lesson sequence planning

Completing the planning framework helped teachers plan the intended learning outcomes. They then considered approaches that they would use to assist students to reach intended goals, including suitable lesson sequencing. Like 1998, all teachers included an outline of their intended lesson sequence in planning for this was a group of organised, mindful teachers who did not take their teaching for granted (Section 5.2.2). Teachers' ability to match learning outcomes with appropriate activities was noticeable. Comments reflect improved confidence in undertaking this matching task:

> By looking at the learning outcomes then the learning tasks, we were able to justify why we were doing the activities. Often before I would plan a 'cool' idea, then try to fit the technology for the sake of curriculum coverage. (Penny)
> When unit planning I was clear about the type of learning outcomes related to the learning experiences, which also related to formative and summative assessment. This enabled me to narrow my focus and be sure I was teaching technology. (Sarah)
> To focus on specific learning outcomes first then planning activities to match allow me to better cater for the needs of students. (Tina)

As in 1998, all teachers followed a similar lesson sequence structure with introductory and exploratory activities followed by designing and manufacturing activities. Student self-evaluation tasks were concluding activities. A departure from 1998 was the deliberate planning of opportunities for students to review, shift and modify. Teachers realised the importance of building testing opportunities into lesson sequencing and so they planned for testing and modifying opportunities. As an example, a segment of Rachel's planned learning experiences shows this forethought:

- Children make package according to plan
- Test out the package
- Evaluate their design
- Make any necessary adaptations to their package
- Test it out again
- Change again if necessary

In 1999 teachers detailed in their planning an iterative cycle of review, whereas in 1998 this was not considered. In addition, when teachers planned their second 1999 unit, they thought more about each individual session and how they would link each session to other sessions. All planned to begin and end each session with a class time together. At the planning stage teachers made allowance for students to have opportunities to assist in solving others' problems, share in successes, learn from others, link to previous learning and think forward to next learning steps.

7.2.4 Assessment considered when planning

When planning in 1999, all teachers attended to aspects of assessment including formative assessment, summative assessment and student self-assessment. Teachers employed a considered approach where their planning incorporated thinking about these three aspects. This contrasted with 1998 where only student self-assessment and summative assessment were considered when planning (Section 5.2.2).

A major change was thinking about formative interactions when planning. The translation of technological terms into vocabulary suitable for students was a strong indication of this forethought (Section 7.2.2). Possible interactions were planned for. As teachers commented:

> The planned and probable learning outcomes made me more aware of the questioning that would be required. (Rachel)
> Clear planning guided my questioning. (Sarah)

Teachers also considered management of sessions when planning so they would have time to talk with students. In 1998 teachers often omitted to consider management issues particularly when students were constructing, and as a consequence more time was spent managing technical processes such as gluing, and less time was given to formative interactions. As Sarah commented:

> In my lesson planning I was careful to plan the sessions so I could be free to question children effectively to enhance their learning. In the previous units I had been caught up being the technician and was unable to be effective as a questioner. (Sarah)

Thinking about formative interactions when planning received strong attention in 1999 compared to 1998 where formative interactions were not explicitly considered.

Summative assessment also received stronger attention when planning in 1999 than in 1998 (Section 5.2.2). As 1999 planning concentrated on technological aspects, early summative assessment thoughts also heeded this focus. Only one teacher, Sarah, specified a social aspect (working in teams) for summative focus in 1999. This contrasted with 1998 where social and managerial aspects received attention by all teachers. A variety of summative assessment planning was undertaken. Three teachers (Tina, Ernie and Burt) recorded a list of technological aspects for assessment, recording them separately after the lesson outline. For example, Tina's summative assessment list covered the following: Feasibility report – will show whether children have thought through specification for mask and quality standards; Modify designs – if so, where, how; Final specifications; Production plan – able to see stages from beginning to end; Self-evaluate as go through mask-making.

Three (Sarah, Penny and Rachel) matched assessment with particular learning activities when planning. Assessment was recorded beside particular learning experiences centring on technological aspects. A portion of Rachel's planning demonstrates this practice (Table 7.2).

Table 7.2: Rachel's planning and summative assessment

Learning experience	Assessment
In groups and then as a class examine and record what makes a good package	Chooses a container and names important things about it
In groups children test out a variety of materials by putting a biscuit in and carrying it around the schools. Record suitability according to criteria.	Can relate back to criteria

A noticeable change in teachers' assessment planning was the consideration of assessment throughout the unit. In 1999 teachers became more aware of collecting and using information in an ongoing manner. In contrast, information in 1998 was collected at the end of the unit, was not used throughout the unit and was the final act used to close the technology unit (Section 5.3.3). One teacher, Penny, showed extensive assessment planning (Table 7.3).

Table 7.3: Penny's learning experiences and assessment

Learning experiences	Assessment
• Identifying needs Introduction of why bird feeders and the task of developing a hanging bird feeder. Beginning decisions made on considerations of task.	Has class identified a need?
• Identifying needs Visit by Mrs Brown to talk about feeding garden birds, bird feeders, types of feed mixtures and to show and describe milk carton feeder.	Have children considered main criteria for hanging bird feeder? Can they identify how to hang feeder?
• Examining everyday technologies Examination of other hanging artefacts.	Have main features been identified?
• Generating and selecting options Examination and testing of materials that could be used for hanging. Class summary of suitable materials.	Have main materials been identified? Can children identify where materials have been used before?
• Developing an option Reconsideration of task criteria. Designing hanging structure and deciding on most practicable one.	Does design reflect thought and justification for use of materials? Does it show reference to criteria?
• Developing an option Further develop plan of bird feeder for construction purposes.	Can children identify and justify modifications to plan?
• Making and testing solutions Making, testing and modifying construction.	Can children identify and justify modifications from plan?
• Evaluating solutions Self evaluate with regards to task criteria Share final solutions with others.	Can they evaluate success of bird feeder? What would children do differently?

Penny's use of a questioning assessment technique enabled her to forward plan. She could forecast how to remain focussed on technological learning when making overall judgements about children's progress each day. She thought about gaining head-note information for summarising the overall stage children would reach. She considered beforehand what to concentrate on for gathering knowledge about teaching direction for following lessons, and the questions helped her consider her teaching impact.

It was evident teachers' summative assessment planning focussed on technological learning, was carefully thought out and intentional. Like summative assessment, student self-assessment was attended to in the planning process where teachers thought about focus possibilities. However, in contrast to 1998, there were no teachers who designed self-assessment sheets for students in this pre-teaching stage (Section 5.3.3). Instead teachers and students designed worksheets within the unit closer to when formal self-assessment was needed. Worksheets were planned with students and incorporated elements related to overall technological practice as well as conceptual, procedural, societal and technical aspects. In addition, teachers were more cognisant of informal student self-assessment to be undertaken throughout the unit.

Planning for assessment at the pre-teaching stage was considered worthwhile with all teachers undertaking the task. Teachers believed linking assessment to planning helped maintain a technological focus. Additionally, being clearly technological in planning afforded the opportunity for effective assessment. For example:

> More specific planning focussed assessment practices early on. (Ernie)
> Planning is specific, so assessment becomes more effective. (Rachel)

7.2.5 Burt: changes from 1998 to 1999

Burt is used to detail teachers' progress from 1998 to 1999. His planning of three units is presented. He demonstrates the gains made, including the influence of the models, changes he made in defining learning outcomes and the planning effects on his teaching and student learning. As with the other teachers, I was involved with one of Burt's 1998 units and two 1999 units. The first of 1999 in Term Two, followed Workshop 1 and the second in Term Three, followed Workshop 2.

The Term Two unit, 'Tic Tac Toe for Visually Impaired People (VIPs)', was the first time Burt planned a unit based on specifically identified technological learning outcomes. In the Term Three unit, 'Modifying existing pieces of handheld home technology for arthritis sufferers', he also used the planning framework to identify the intended technological learning outcomes. He attempted to develop a sense of continuity and progression for his students. He did this by

identifying specific learning outcomes from the first unit that could be developed further in the second. This was the first time he had attempted to form explicit learning links between different technology units.

Differences in planning from 1998 to 1999 are evident with comparative analysis. In 1998, he chose a technology topic because he wished to cover a particular technological area. Learning outcomes were defined in terms of the broad curriculum level objectives. He did not attempt to define specific technological, conceptual and procedural knowledge, nor did he try to develop any sense of progression. His prime concern was to provide students with opportunities to experience different technological areas rather than develop any degree of sophistication or complexity of learning. Planning differences are best demonstrated with the learning outcomes Burt recorded for the different units (Table 7.4).

Table 7.4: Comparing 1998 and 1999 learning outcomes

1998: Time measuring devices	1999: Tic-Tac-Toe for Visually Impaired people (VIP)	1999: Hand-held home tools for Arthritis sufferers
		Key aspects of technological practice: In undertaking the design of handheld tools for arthritis sufferers students will: • Investigate and describe the use and operation of home technologies by sufferers of arthritis focussing on ergonomics; • Explore and modify existing technical aids for arthritic sufferers through drawing; and • Identify the positive and negative effects of existing, modified and adapted technologies for arthritic sufferers
Technological knowledge • Investigate and describe the use and operation of time measuring devices	*Conceptual:* • Explore and understand properties of different materials i.e. malleability, durability, strength. • Understand the purpose of various materials and select appropriately • Understand the role and purpose of target group surveys	*Conceptual:* • Explore and understand what is technology • Understand that interview schedules, surveys and open questioning are methods of collecting information • Understand ergonomics-the need for the product to fit the user • Understand the use of and drawing of exploded diagrams • Understand that modified, adapted and fail-safe are technical terms
Technological capability • Prepare a plan of action for creating specific time measuring devices • Collect resources and produce the selected design to meet the specified criteria • Test, adapt and reflect on time devices produced	*Procedural:* • Complete a focus group survey. Collect data on board games for VIP • Complete a needs analysis of resources needed. • Rank resources based on positive and negative values to the project. • Analyse and interpret data to design a brief with criteria accounting for visual disabilities. • Improve and reflect on design • Construct and test game	*Procedural:* • Conduct an interview to find out about problems people face with arthritis • Complete a needs analysis • Define the target group needs • Negotiate the criteria for designs • Explore existing modifications to technologies employed • Complete a materials analysis • Draw 2D, 3D and exploded drawings of existing and modified technologies for sufferers
Technology and society • Identify and discuss the importance and impacts of time in our lives	*Societal:* • Understand that a blind person would face different barriers when playing a board game.	*Societal:* • Cost, the user and materials will affect technical developments • The traits of a group will affect ergonomics of a product
	Technical: • Understand how to do a 3D scaled drawing.	*Technical:* • Orthographic drawing • 3D drawings • Interviews - develop open-ended questions

In 1998, Burt defined learning outcomes in terms of broad curriculum level objectives. These objectives have a feel for the general substance of technology but are too broad for undertaking any worthwhile assessments that might inform future learning. No attempts to define specific technological conceptual and procedural knowledge were made. Nor did he develop any sense of progression.

1998 objectives' generality inhibits their usefulness as guidelines for teacher-student formative interactions. Burt's prime concern had been to provide students with opportunities to experience different technological areas.

A major difference between 1998 and 1999 objectives is the specificity. First, technology was described in technological learning terms, rather than as an activity. He moved from describing technology by the achievement objectives to thinking about technology in detailed, conceptual, procedural, societal and technical terms. Additionally, he brought this detail together to form an overall statement. Together, the overall statement and the conceptual, procedural, societal and technical aspects provided a base for his teaching, enhancing both student interactions and assessment practices. Notable is the technological detail, particularly the itemisation of technological principles. Burt had articulated technological subject content suitable for his students.

Also notable was defining technical learning outcomes in 1999. In 1998 teachers failed to take enough account of difficulties many students had dealing with technical skills (Section 5.3.3). Student inability to use particular skills resulted in teachers spending an inappropriate amount of time being technicians for them. Articulating some of the required technical skills meant teachers were likely to better deal with them within the unit as they had already considered them beforehand. They would be readied.

The expansion in the detail of the technological knowledge base and the defining of the societal learning outcomes was also important. Defining societal learning outcomes resulted from researchers working alongside teachers in their Term 2 1999 teaching where societal issues had taken a diminished place. In Term 3 with teachers especially recognising societal learning outcomes they were likely to be more prominent in teaching.

Burt also defined the key aspects of technological practice, a further area of development for him. He described these so that a comprehensive whole for his teaching and student learning was outlined. This was to counter the detrimental

effect of only defining specific learning outcomes as isolated items, where the sum of the parts may not add up to overall learning.

Another planning difference was identifying specific learning outcomes that linked the two 1999 units together. These learning outcomes were based on student progress in the first unit and where students would benefit from similar experiences. He tried to provide continuity from one unit to the next and develop a sense of learning progression. Linked learning opportunities included opportunities to extend knowledge with different materials, especially concepts of flexibility and malleability. He provided opportunities for broadening drawing skills to include 3D annotated drawings and exploded drawings. He commented on the results:

> I was impressed that I could take them further. They were superb and I could see the progression. The annotated comments were more relevant and more focussed. They weren't as wishy-washy. They were more 'we'll attach this here and we'll use this and we'll do it like this'. I could see my children including the criteria from the beginning. I could see them using 2D, 3D and annotated drawings appropriately. Even my younger ones like Janet and Jean and Annie could say 'no my product can't do that, yes it can do this' and so on. That was good. It was quality learning. (Burt)

One of Burt's concerns in using the planning framework that so clearly defined the technological learning was that this itemised identification could close down the technology task as a teacher might only concentrate on these learning outcomes. Therefore of particular importance was the planning model dealing with potential, planned, negotiated and unexpected learning outcomes (Section 6.3.2, Fig: 6.6). By initially brainstorming potential learning outcomes he thought of many possibilities and from these he could select the particular learning outcomes he believed pertinent to the task and worthwhile for students. As he said:

> The models focussed my thinking in the planning process. They allowed me to hone in on the technological concepts and skills. ... I had a clearer understanding of outcomes and this actually enhanced my teaching and made the process easier for me. My formative interactions with students were more purposeful and productive. (Burt)

Burt relied heavily on using the models to change his teaching practice. They assisted him to tease out technological learning outcomes. He no longer described technology in terms of an activity, but in terms of technological learning. He moved from thinking of technology as broadly described by the achievement

objectives to thinking about technology in detailed, conceptual, procedural, societal and technical terms. In addition, he began to bring this detail together to form an overall statement. He began to develop notions related to continuity in student learning between different technology units. Together these provided a base for enhancing his teaching and assessment practices.

The systematic approach to defining learning outcomes helped Burt and the others to reduce ambiguity in conceptual, procedural, societal and technical aspects of technology. The risk was in using the planning framework as the sole approach for defining learning outcomes because it could lead to an absence of opportunity to pursue multiple and/or divergent goals. However, the importance of acknowledging and accounting for negotiated and unexpected learning outcomes alleviated this danger. Burt's recognition of this model's importance resulted in student pursuit of a variety of ideas.

Like the other teachers, changes Burt made to his technology teaching were difficult to achieve. Final comments from Burt serve to illustrate this struggle and the worth of his perseverance:

> I initially found that the models were difficult especially the wording and I still find that difficult. But I'm becoming more proficient in using them. ... The whole process has become more refined. I knew that when I was planning, I knew exactly what I was going to assess and how I was going to assess it, so I was very specific. ... The planning models helped me to have a better look at exactly what technology is being taught and what the technology is in different activities. The activities that I am giving my children are more clearly targeted and identified. My children have a fair idea of where they are going to go. ... But they have still gone in a thousand different directions and they've really enjoyed it. You can start to see the divergence coming out in children and that's neat too. (Burt)

Evident was Burt's increased confidence and competence in technology planning. The improved identification of technological learning outcomes was noteworthy as was his satisfaction in the learning gains students made.

7.2.6 Summary of the effects of the models on teacher planning

All teachers made significant gains in their ability to plan technology based on detailing technology goals. From the start they specified technological reasons for teaching particular topics in particular technological areas. Topics were chosen because of the potential to develop particular technological learning, a contrast from 1998 where teachers were unsure of the technological learning afforded by

chosen tasks. Teachers' developing ability to anticipate technological direction was new allowing them to forecast what they wanted their students to achieve.

Using the planning framework assisted in facilitating the greatest planning changes. Instead of defining goals through the broad curriculum achievement objectives, technology was defined in specific conceptual, procedural, societal and technical categories. Key technological practice aspects and task definitions were also defined. The relationship between all three was evident. Teachers' better-matched activities to appropriate learning outcomes and were mindful of negotiated and unexpected learning opportunities when planning.

Teachers employed a translation process in 1999. Translating different aspects into reworked terms suited to particular students helped to clarify at the planning stage how teachers and students could use particular technological terms.

Planned lesson sequences shifted to deliberately planning opportunities for reviewing and modifying. Testing, review and self-evaluation were not planned as end-point activities as they were in 1998. In 1999 teachers planned so students could operate in an iterative cycle of review and analysis.

Finally, assessment was carefully considered. A major change was in teachers' thinking about formative interactions when planning. They believed clear articulation of learning outcomes assisted with thinking about questioning, language-use and student interactions. Sessions were also organised to maximise student dialogue opportunities, a contrast to 1998 where often teachers became embroiled in technician-type roles leaving diminished time for talking with students about learning.

Summative assessment had a stronger technological attention. The 1998 attention to social and managerial aspects was sidelined. Teachers also thought about summative assessment throughout the unit, not just a concluding task as in 1998. Information collected from previous technology units was incorporated in planning subsequent units. As with summative and formative assessment student

self-assessment, both formal and informal, was also attended to at the planning stage.

The use of the models heavily impacted on teachers' 1999 planning. The planning framework assisted in teasing out technological learning outcomes; a close relationship was forged between task definition, key aspects of technological practice, and learning outcomes. Learning experiences were linked closely to learning outcomes. An iterative planning process included thinking about tasks, technological learning outcomes, curriculum knowledge and knowledge of students. Negotiated and unexpected learning was thought about as was formative, summative and student self-assessment. The planning changes teachers made were not easily achieved, but all acknowledged the importance of the changes they had made. They became focussed on students' technology learning and employed a considered approach to planning.

7.3 Changes to pedagogical approaches

The extensive data gathering and ensuing analysis of classroom practices in 1999 form the basis of these findings. As in 1998, the aim of examining classroom practice was to gain an understanding of both teachers' changing classroom practices in teaching technology and student learning. This section details teachers' enhanced pedagogical approaches. Section 7.3.1 highlights how the nature of the task was more readily understood. Section 7.3.2 details teachers' expanded awareness of a hands-mind balance. Section 7.3.3 examines enhanced practices in dealing with transfer. Section 7.3.4 shows how teachers' approaches improved student iteration. Section 7.3.5 presents a summary.

7.3.1 Nature of the task

In contrast to 1998, the influence of the nature of the task on learning was more likely to be taken into account (Section 5.3.2). Tasks were no longer so openly defined that any solution was possible and acceptable. There was less emphasis on the acceptance of any solutions and more encouragement and opportunities for students to develop and include particular technological concepts and procedures. Pedagogical approaches became very purposeful, as teachers wanted students to

learn about specific technological aspects. Though the production of a variety of solutions was still expected and encouraged, acceptance of any student solution was no longer the expectation, rather solutions needed to be inclusive of planned goals. In 1998 solution variety for its own sake was the goal, as teachers believed that technology was about students creating multiple solutions to problems. In 1999, pedagogical approaches were less inclined to aim for unspecified, unrestricted, wide-ranging ends. Teacher encouragement of creativity and seeking divergent solutions was still important, but not at the total expense of technological aspects. As teachers commented after teaching their second units:

> I valued not having the task too wide and being focussed more clearly on what's going on. It meant I could cope with the unexpected and negotiated learning. More focus hasn't led to less divergency and hasn't stopped creativity. The learning was just more technology focussed. (Tina)
> My classroom practice was more focussed with learning clearly targeted. Students had a clearer idea of where they were going and I was better at clarifying the task for the students. Though the scope was narrower, they have still gone in a thousand different directions. (Burt)
> Helping students to define the technology in their tasks gave them a framework to be creative. They developed greater technological knowledge and so seemed to be more creative. (Ally)

Teachers believed technology had its own knowledge base worthy of developing and so planned opportunities to assist in the development of this were undertaken. As Penny stated:

> I changed about not being afraid to intervene. I knew what I was aiming for and had more understanding of what I wanted students to achieve in technological learning. As I had visualised where I wanted students to go and how to get there, I was more comfortable in predicting where to go and was more focussed and specific in my interventions. (Penny)

Non-intervening pedagogical approaches were no longer an option in 1999.

In 1998 teachers sometimes changed the nature of the task part way through and were unaware of the consequences to student learning. As task definitions were clear, this did not happen in 1999. Teachers had anticipated possible achievements so pedagogical approaches were more surefooted and considered in consequence. Sarah commented:

> I was aware of not letting my teaching and the task run away, or we could lose the technology ideas. (Sarah)

The influence of closed tasks on student learning was also better understood. Tasks affording few opportunities for developing a wide range of technological aspects were avoided. As Burt stated:

> Defining the task and learning opportunities technologically seems vital for success because this gave an overall guide while teaching to where we might go and what we might expect. (Burt)

Considered, carefully thought about tasks meant task affordance and probable learning goals were to the fore when teachers taught technology in 1999.

7.3.2 A hands-mind balance

In 1998 technology was viewed as a pre-dominantly practical activity (Section 5.3.1). Pedagogical approaches allowed students to undertake hands-on, designing, making and testing activities and little attention was given to technology as an intellectual pursuit. Often teachers were unsure of the detailed technological conceptual aspects that could be fostered alongside practical goals. In 1999 attention to technological concepts and principles was prominent. Technology was no longer viewed as just practical. As Tina commented:

> I was able to intervene positively and my interventions were more focussed on the knowledge components than in 1998. (Tina)

Detailed planning related to the key aspects of technological practice and conceptual, procedural, societal and technical aspects had ensured teachers were mindful of these aspects when teaching. Teachers were particularly thoughtful in focussing on appropriate technological concepts and principles for they believed this was a way to help students develop technological understanding alongside procedural aspects, to build understandings alongside skills. For example:

> I had not included conceptual so well before, as I was keen to get into the making. Now I am surer of all aspects. (Rachel)
> The knowledge aspects were far more specific and linked to the task. It was valuable not having the task too wide because we could focus more clearly on what's going on. (Sarah)
> I had a better focus on the technology being taught and the technological ideas involved. The conceptual aspects went all the way through. There was a more holistic approach. (Burt)

7.3.3 Practices in dealing with transfer

In 1998 teachers were unaware of difficulties students had in transferring ideas and skills from other subject areas to technological activities (Section 5.3.2). Teachers assumed that conceptual and procedural knowledge students acquired in

other learning areas and situations would be freely transferred during technology tasks without their intervention. Leaving the problem of transfer up to the learner became problematic. In fact, in most instances it failed to occur. In 1999 transfer was no longer left to the individual learner or chance. Teachers' awareness was raised and they deliberately assisted the process and taught for transfer. They cued students to aspects that could be utilised in the technology situation by reminding them of their previous learning and experiences. This meant ideas and skills were more readily brought to mind and therefore accessible. For example, Rachel showed and talked about a maths activity related to drawing and constructing nets students had previously covered when she wanted students to undertake a similar task in technology. Burt and his students examined art drawings students had previously created to remind them of how they could use the same skills in technology.

Teachers also modelled how knowledge from other sources could be used in technological situations. For example, Ally drew joining mechanisms from photographs to show how student could use ideas in their own planning. After student examination of commercially drawn cross-section examples, Penny drew a cross-section diagram to show how to glean and transfer ideas from the commercially drawn examples.

Questioning by teachers provided another vital aid for facilitating transfer. For example, Burt realised some students could not draw accurately in detail ideas they had in their 'mind's eye', of particular mechanisms and ways devices worked. So he organised a research session in the Library where students could readily access books of drawings. He assisted their search by directing them to appropriate texts. He continually drew alongside them, supporting their efforts and conversing consultatively. He helped them use book information by questioning them about how the illustrated ideas could be used. For example:

- How will you show the cylinder? Go and get the 'Springs' book. It will help.
- Do you think you can draw it 3D? Would you like me to show you a small bit? Then you can look at the 'Wheels and Cranks' book. There are more ideas in there.
- How are you going to attach the cutter to the base? Come and look at this book. See what they've done.

Transfer was not left to chance. It was assisted by cognisant teachers appreciative of how hard it was for students to bring ideas from other learning areas and experiences to the technological task. As Sarah commented:

> I made the learning up-front by making the learning visible to the children. I was encouraging and I had clear directions and I made the learning aims explicit. I had first intentionally planned a maths unit in volume because I knew they would need it in the yoghurt unit. Because of this the children were able to conduct required measurements in the making of yoghurt with a gentle reminder that it was what we had been doing in maths. It did not become a stumbling block. (Sarah)

7.3.4 Approaches to enhance iteration

In 1998, many students had difficulties working in an iterative manner when undertaking technology activities (Section 5.3.2). Though teachers understood the need to work iteratively, students were often unaware of it and teachers did not realise it would be difficult for them. Teachers did not always make links between stages explicit to students. However, in 1999 all teachers were mindful of this and planned to overcome a linear, discrete process. Using different strategies to encourage the development of iteration meant students were more likely to links between stages and work in a connected manner.

Strategies included using written, diagrammatic and verbal means. Teachers also used appropriate management techniques to foster and encourage iteration.

Written and diagrammatic means

A number of written and diagrammatic means were employed to illustrate connections and to help students work iteratively. Some teachers used flow charts to help students see and work through an iterative process. Flow charts showed a cyclical process linking different stages and were a diagrammatic illustration of non-linear sequencing. For example, Penny created Figures 7.2 'Where are we at with Bird feeders?' and 7.3 'Making your hanging structure', with her students while they were making hanging bird feeders.

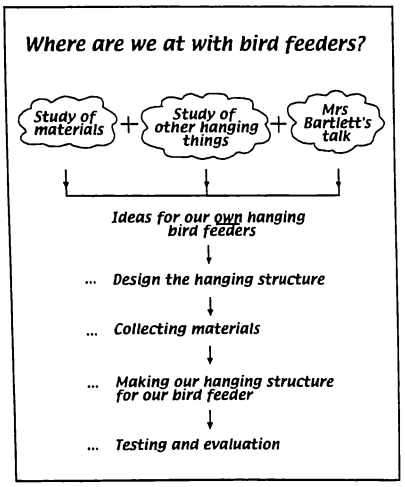


Fig 7.2: Where are we at with Bird feeders?

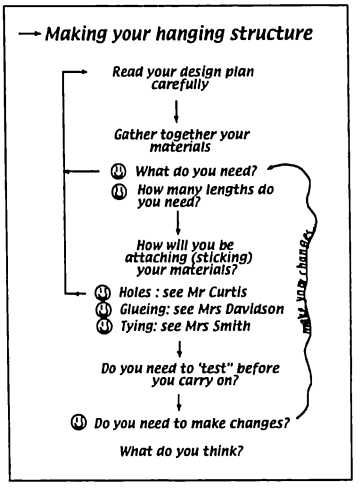


Fig 7.3: Making your hanging structure

Penny used the flow diagram 7.2 *Where are we at with Bird feeders?* after students had gathered ideas about bird feeders and before generating their own ideas. The flow diagram 7.3 *Making your hanging structure,* was used to introduce the construction sessions. Penny's students were familiar with flow diagrams, so they were skilled in using and interpreting them. She did not develop these diagrams in isolation from the students. Instead, as students were talking about what they had accomplished and where they thought they would be going, Penny drew the diagrams. They were particularly useful for Penny's students to reflect on the process they had already undertaken, think about their next steps, see the whole technological process, guide their technological process and evaluate their work. Once created, Penny used them more than once, especially flow diagram 7.3. They were used in class discussions as an aid to work out different stages students had reached; for example where are you up to? What will you do next? Student responses then helped her plan the next day's activities. She also used them as a reference point in discussions; for example, how did you get on when you were designing? How did you solve any problems when you were testing? Students also used them independently as guides to what they could do next. As she said:

> These flow diagrams were very good for helping children to bring their ideas together. It made it easier for them. They helped them look through everything and highlighted things along the way. They acted as a constant prompt to help children work through the process of design and it helped explain the iterative process. (Penny)

Another written and diagrammatic aid was teacher use of planning templates and worksheets. These helped to focus students on more than one technological aspect at a time, think about what they might do next, how they might do it and what they had already accomplished. They directed student attention to the essential technological aspects to be taken into account. The two examples Fig 7.4 'Planning for maths containers' and Figure 7.5 'Student evaluation worksheet' are from Rachel and Burt's' teaching respectively.

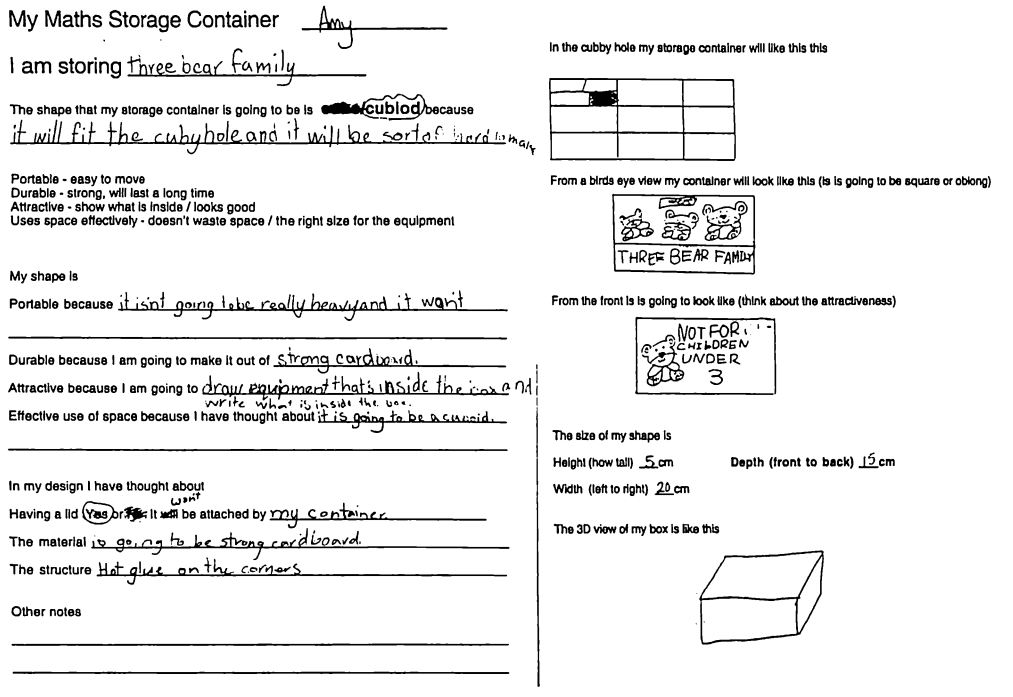


Fig.7.4: Planning for maths containers (Rachel)

Tic Tac Toe –The Evaluation	**Names:**			**Date:**
1. Did your final construction function properly? **Yes** **Sort of** **No**				
2. Our design was successful because?				
3. Our design was not so successful in these areas?				
4. Did your final construction change from the ideas you had planned? **Yes** **No**				
5. If so, how?				
Circle				
6. My plans were:	1 Poor	2 OK	3 Good	4 Great
7. My design was:	1 Poor	2 OK	3 Good	4 Great

8. Tick or cross which criteria your game met or did not.	9. After reflection my design would look like this.
* The game and its materials were affordable. * The game was durable and reusable. * The game was fair to both players. * Age appropriate * Was fun and safe to play. * Had clear instructions for both players. * No way for either player to make a mistake. * Was three dimensional or "feelable". * Was practical and safe to build.	

Fig. 7.5: Student evaluation worksheet (Burt)

Rachel's planning worksheet was used to link the previous task (developing initial design ideas) to this task (exploring and critiquing designs) and onto the next task (constructing containers). It guided students to explore, critique and justify decisions, explore the size and shape relationship between the containers and cubby space, draw containers from different perspectives and include aspects of aesthetics, appropriate size and shape. It also guided them to think about the materials to construct containers, suitable measurements to use and other construction aspects. By completing this worksheet students were being compelled to think ahead to construction while planning.

In contrast, Burt's evaluation worksheet was more focussed on reflection as it linked back to what had already happened and what students had learnt. Like Rachel's worksheet it was heavily focussed on technological aspects and the technological process students had undertaken. Critique and justification were required which meant students needed to look back over their whole process as well as look forward to any more changes they might make.

Teachers usually designed worksheets like these alongside students so they had direct input. Templates and worksheets helped students link previous ideas and work to the current task and to link to what might happen in the future. Always, technological aspects were foregrounded.

Teachers also compiled charts and lists when working alongside students to foster iteration. These were then left on show and could be easily accessed and used as reminders and guides to provide summaries, direction and focus. As Ally stated:

> Giving children the language and meanings of words they needed and listing them on the board helped because they could remain focussed. (Ally)

Lists and charts provided an effective means for teachers to highlight the key task, which helped students to keep those aspects in mind. This meant students could work in their own ways to solve problems as they were constantly reminded of the whole task and what was required. For example, while Penny was undertaking a class analysis of different skipping rope handles she recorded focus points on the whiteboard: be strong, have grip, be safe, easier to use, be comfortable, help us

store them easily. Students then had a visual reminder of the main points. Penny subsequently recorded these points on a chart where they became guiding criteria for creating solutions to the skipping rope problem. Students were being encouraged to see how artefact analysis could link to solving their own problems. Like Penny, Burt used many charts and lists. He commented:

> Having the data always present meant students could go backwards and forwards. And they always had something to go back to which helped them to know where they were. (Burt)

Conversational means

Besides written and diagrammatic means, conversation and discussions were invaluable for providing students with linking opportunities. Teachers used class discussions at the beginning and conclusion of each session to help students sum up their progress, think about next steps and work iteratively. Beginning sharing sessions assisted students to be clear about overall task goals, to link each day's work with what had happened previously and to link it with what was likely to happen in that day's session. Sharing times at the end of each session provided opportunities for students to look back over what they had accomplished to date and provided other opportunities for them to think about what they would do next. As Tina commented:

> Using sharing sessions to link student ideas was very successful. This helped to link them back to the whole process. (Tina)

Teachers also directly cued students through ongoing conversations to think about processes that they were undertaking and what needed to be included. As Rachel commented:

> Now I'm getting to children to question them so they change things on the way if they need to, to improve things while they are going. (Rachel)

Management techniques

In contrast to 1998 (Section 5.3.2), teachers managed sessions so planning, constructing and testing were explicitly linked. Planning was linked to construction as students were asked to consider and include construction aspects in their planning. Testing and evaluation was in-built as part of the process and not additional to it. This was unlike 1998 where testing and evaluation were the last stages of student technological problem solving. Students were rarely given the chance to put the results of their testing into practice and usually had to accept

that review and testing were add-on, concluding activities rather than recurring pursuits undertaken throughout the process. Burt commented:

> I used a more holistic approach. Student questions, issues and problems raised all the way through were dealt with directly. That meant they could assess and test throughout. (Burt)

In 1999, teachers provided adequate time for students to alter plans and constructions in light of their evaluation and testing and students were encouraged to test and evaluate frequently throughout their technological activities. Iterative processes resulted.

Other techniques were where teachers provided early access to materials and appropriate construction techniques. These were helpful for generating feasible ideas, and they meant that students were aware of more aspects while planning. For example, with the early availability of many materials, students could examine them and consider suitability early on. In 1998 they often planned without knowing the range of suitable materials or how they could use them and this resulted in many changing their minds and discarding plans when it came to construction. In 1999 with research undertaken alongside planning, students were aware of suitable materials and how they might use them before constructing. The following comments reflect the importance of giving early and ongoing access to materials to assist with generating ideas.

> There were lots of examples for children to manipulate and they were available for a two-week period for children to keep going back to. This helped them develop their own ideas. (Burt)
>
> I was really pleased with the materials examination. It helped give children focus. I wanted them to stretch, grab, yank, to play with the materials rather than just look. I liked the way it linked, not just to the birdfeeder context, but the idea of hanging stuff, because all their planning, their designing, even their reflection became all linked. (Penny)

In 1999 teachers directly taught appropriate technical skills, demonstrated different techniques and directed student attention to different ways of constructing especially when planning. This meant teachers were helping students to build a repertoire of skills and techniques they could call upon while planning. Ideas about construction were under consideration early on and thus firm links were made to planning. As Ernie commented:

> Children used an iterative process. They used previously learned skills and were more reflective. (Ernie)

In other instances, teachers directly taught particular technical skills when they realised the students were unable to do something. This was in contrast to 1998, where skills were rarely taught and students were expected to pick up the skills through casual, unplanned means (Section 5.3.2). Penny commented:

> I was a little disappointed with some of their skills, like tying knots. But we had a session on knots and that helped. (Penny)

7.3.5 Summary of changes to pedagogical approaches

In 1999 teachers' improved technology teaching was evident in their changed and enhanced practices. First, they demonstrated a heightened awareness of the importance of a hands-mind balance. Teachers focussed on appropriate technological concepts and principles to help students develop technological understanding alongside procedural aspects

Second, they developed enhanced practices in dealing with transfer issues. In contrast to 1998, transfer was no longer left to the individual learner or to chance. Teachers cued students for transfer by reminding them of previous learning and experiences they had had. Teachers modelled how knowledge from other sources could be used in technology situations. Teacher questioning provided another vital link. Teachers' awareness was raised. They deliberately assisted the transfer process and taught for it.

Third, pedagogical approaches improved student iteration. In 1999 all teachers were mindful of it and planned to overcome the linear, discrete process many students adopted in 1998. They used written, diagrammatic and verbal means, and appropriate management techniques. The combination of strategies meant iteration was fostered, as students were guided to see how stages linked.

7.4 Enhanced assessment practices

The success of the teacher development programme was seen in teachers' enhanced assessment practices. They were knowledgeable and confident in formative classroom interactions and in summative assessment. Section 7.4.1 describes teachers' enhanced formative interactions, section 7.4.2 details their enhanced summative practices and section 7.4.3 provides a summary.

7.4.1 Enhanced formative interactions

Importance of planning

Teachers acknowledged the importance of planning and its influence on their formative interactions. Planning in an organised way to identify the technology aspects assisted to form a picture of the essential technology elements for teaching, student learning and assessment. Having the conceptual, procedural, societal and technical and overall aspects in mind meant they became a foci for formative interactions. They considered that a thorough audit and compilation of appropriate technological learning outcomes exerted a considerable influence on their formative interactions. The planning acted as a guide to their teaching, student learning and assessment (Section 7.2.4). As Ernie commented:

> I used the learning outcomes to feed formative assessment, questioning and language. (Ernie)

With more secure ideas about the technology to aim for, teachers demonstrated a much greater confidence with formative assessment in 1999 than in 1998 (Section 5.3.3). As Penny stated:

> Because I was confident with technological concepts and knew where I wanted the children to go, I was not afraid to intervene and redirect them on a task. (Penny)

Teachers had formed strong links between planning and formative assessment and used their planning to guide conversations with students.

Enhanced emphasis on technological aspects

Formative interactions focussed on technological aspects with far more assurance and competence. Teachers improved their ability to provide appropriate technology feedback to the learners. Considered direction was given where deemed appropriate, which led to more considered interactions. Not only was there more emphasis on providing feedback and assistance to students to develop particular technical skills, there was also more emphasis on conceptual and procedural aspects. Descriptive feedback became the norm. The heavy attention on praise, task completion and social and managerial aspects that occurred in 1998 (Section 5.3.3) was no longer prominent in 1999. The focus was definitely technological. Even when students were off-task teachers concentrated on technological aspects to draw their attention back. For example, Ernie noticed his

students were off-task. To help refocus the students he deliberately highlighted technological aspects. He commented:

> It was interesting this time that when I needed to intervene because of off-task behaviour of some students I regained their focus by reminding all students about a technological aspect. This sparked the off-task students to get back on task. I thought this was a very positive way to deal with negative behaviours. It was a very useful strategy. (Ernie)

Teachers' technological focus in formative interactions was enhanced from 1998 (Section 5.3.3). In 1998 teachers identified some broad conceptual and procedural aspects. However, these were not detailed or specific and did not address underlying technological principles. This changed in 1999. Teachers clearly targeted specific, detailed technological principles in their formative interactions with students. For example:

> I found it a lot easier to bring the class discussion to the conceptual, procedural, societal and technical aspects because I was more comfortable in my mind about where we were heading. It was easier to focus discussions. (Penny)
> My formative interactions have definitely changed. Before I'd go over and see how they're getting on and let them go. But now I'm getting them thinking all the time. I used to accept things whereas now I look to see if the conceptual, procedural, technical and societal stuff is there. My questions got them to think about things, so they could change them on the way. They could improve it while they're going. (Rachel)

A comparative table, Table 7.5, details two conversations Burt held with students demonstrating the enhanced technological focus.

Table 7.5: Burt and student conversations in 1998 and 1999

1998 conversation when constructing a clock	Burt: *How are you going to decide on the size of the hole?* **Student A:** *We're going to use a nail*? **Burt:** *What if it is too big?* **Student B:** *Oh, we will use different sizes.* **Burt**: *That sounds wise to me.*
1999 conversation when drawing a toothpaste tube depressor	**Burt:** *I'm not sure how this works? Does it go in to the toothpaste tube and push against it?* **Student (S):** *That clips into it so you can clip it on.* **Burt:** *OK. But what does this do?* **S:** *There's a button that you press there and then you pull up the handle and the toothpaste comes out.* **Burt:** (Begins to draw on page) *This is a tube of toothpaste, the lids here, that's my tube of toothpaste, yes?* **S**: *Yes.* **Burt:** *There's a little piece at the bottom. It's my Colgate Fluoriguard.* **S:** *It's not that kind of squeezey toothpaste tube. It's the hard one.* **Burt:** *Oh, those pump ones. So you are making a device that will depress the pump easier.* S: *Yes.* **Burt:** (Points to S drawing) *So this is your device and it is going to go on here and basically you are going to have a bigger device to press down the existing depressor. Is that where you're going?* S: *Yes.* Burt: *I'm sorry, I was thinking you'd have something like this and you'd put your toothpaste between the blades and press* (Is drawing to demonstrate his meaning). *What an interesting idea. So that bottom one is going to be fixed* (points to S. drawing). **S:** *No, the top one doesn't move.* **Burt:** *But wont you have to press down with the button?* **S:** *No, you pull the bottom one up.* **Burt:** *I see. You're saying that as you pull this one up its going to push down like that. So you might need a hinge in here.* **S:** *Yes, I suppose I will.* **Burt:** *And this one is going to be locked on. I want you to think about how you are going to lock that on and think about how you attach it to there. You will need to draw them as exploded drawings. My one concern is, that I've got this device and it is attached to the toothpaste pump here, I'm wondering about how to make sure the pump doesn't fall over, I'm wondering about its stability. That's what I want you to also think about. What an interesting idea. It's different. Cool.*

In 1998 Burt was an encourager and a manager of student learning with an emphasis on praise. In 1999 Burt focussed on guiding the student towards technological learning goals. The descriptive feedback included technological language and principles, for example, hinge, depress, device, pump, stability, and exploded drawings. He modelled aspects by drawing beside her. The conversation was based on consultation, rather than praise. The formative interactions were increased and were more interactive. A shared, interchange of ideas was evident. The descriptive feedback also acknowledged strengths and weaknesses (eg. You're saying that as you pull this one up its going to push down like that. So you might need a hinge in here. Student: Yes, I suppose I will). There was deliberate specific guidance given. As Burt commented:

> Focussing on formative assessment during teaching enabled me to look at particular strengths and weaknesses of children. (Burt)

Students and teachers were clear of desired goals and how well student work matched those goals. Students were no longer confused about the purpose of tasks as they were in 1998 (Section 5.3.2). Penny commented:

> I've become a lot more focussed and specific, moving on to actually telling kids why we are doing things. The idea that you do share where you're going and why you're doing this and feeding them information, instead of actually waiting for them to discover. It's impacted on my other teaching in that I am a lot more up-front with what I want the kids to do. ... and a lot more specific about what they should be looking for, instead of making them discover on their own. (Penny)

The improved identification and articulation of student technological learning gaps demonstrated enhanced formative assessment understandings. Teachers were better able to make judgements about the technological strengths and weaknesses of student learning. They were then able to assist students to build on their strengths and close gaps to reach the desired technological goals. With descriptive feedback concentrated on strengths and weaknesses students were more likely to take technological principles into account. Teacher knowledge of student conceptual and procedural understanding was more detailed so feedback also concentrated on these aspects.

The following examples demonstrate how formative interactions assisted students to become aware of and attempt to close technology gaps. They also show how teachers were better able to see technological strengths and weaknesses and use these to foster student learning. The first is between Penny (the teacher) and Heather (a 6-year-old) that occurred when Heather was planning how to build a hanging birdfeeder. Penny was not sure whether Heather had thought about stability (a targeted principle). The brief conversation shows how Penny helped Heather to think about stability while still planning. It also indicated to Penny whether Heather could include it.

> Penny: You've got three cords for hanging your birdfeeder. Can you tell me how you will keep your birdfeeder even and balanced?
> Heather: I'm going to make it level by putting all the string together. And if one is longer than the others, I will cut one of them.
> Penny: That should work.

The second conversation between Ernie (the teacher) and Henry (a 9-year-old) happened when Henry was creating a plan for making a cereal box. Their conversation directed Henry to think about what he needed to include by

undertaking an examination of existing cereal boxes, as Ernie believed an analysis of existing products was a way to gain technological ideas.

> Ernie: I see you have space here for information. How do you know if it's enough space?
> Henry: I don't.
> Ernie: How could you find out?
> Henry: I could check on an existing box. (He gets one and checks). It's fine.
> Ernie: What else do you need on the cereal package?
> Henry: The ingredients I think. Maybe the bar code, and a guarantee. No, I don't think you have to have a guarantee.
> Ernie: You could get more boxes to check and compare.

The third example lists some of the questions Tina asked her 7- and 8-year-old students when they were drawing bird mask patterns. The questions indicated how Tina guided her students to think about aspects they had not included.

> Have you thought about having lots of space for glueing on bits?
> Where will it be fastened?
> How is it fastened?
> How will you add the beak?
> What is your mask for? So will it be strong enough to last through the production?
> Do you think this material you have chosen will be flexible? What could you choose? How will you make it flexible? (Tina)

In 1998 conversations between teachers and students often targeted technical aspects, especially when students were constructing (Section 5.3.3). In 1999 formative interactions shifted from this focus to a more in-depth discussion of students' current understandings, progress and intended directions. Teachers were no longer the technicians solving the technical difficulties students were experiencing. Sarah commented:

> I was careful to plan the sessions so I could be free to question children effectively to enhance their learning. In the previous units I became caught up in being the technician and was unable to be effective as a questioner. I set things up in the classroom so things were not too difficult for the children to do on their own. I set up so I could go and talk to students individually and knew what I wanted to ask. (Sarah)

A far more balanced approach to developing conceptual, procedural, societal and technical understandings was evident in 1999 formative interactions. Careful planning informed formative interactions and assisted teachers to be more confident and competent with their formative interactions. They were able to give descriptive feedback.

Included aspects of technological progression

Formative interactions showed a growing understanding of student progression. This was a development from 1998 (Section 5.3.3) when technological progression was little understood and rarely fostered. Teachers began to see how they could move students on in technology and how they could build on previous experiences and existing learning to progress student understanding. For the first time they began to consider where they might go next with their students based on what they knew about them.

Teachers began to think about developing student ability to process increasingly more complex ideas and increasing conceptual understandings. They developed progression in conceptual and procedural aspects by increasing the number of independent variables in a task and altering the complexity of the variables. They also looked at progression as transferred to different contexts and how different aspects of task variables interacted with each other. Additionally, they began to think of progression as complex and not in a linear fashion that could be applied to all learners. For example, Rachel and Penny provided extra variables to progress those students who more easily included the main variables. Burt examined students' planning abilities in the first unit and developed these in the second unit where students were expected to include far more construction ideas. Ally assisted students to progress their technical drawing skills in the second unit where they attempted to draw exploded views with more accurate measurements not expected in the first.

Student self assessment

Student self-assessment continued to be a focus for 1999. Unlike 1998, student self-assessment was not treated just as a concluding activity (Section 5.3.3). There was more emphasis on assisting students to reflect and to assess their own progress throughout the technological process, not just at the end. Student self-review became embedded in the technological process. This meant students could respond more easily to their self-evaluation and utilise the outcomes of their reflective thinking.

In 1999 self-assessment worksheets were less likely to be devised solely by the teachers and more likely to be co-written by the teacher and students. They focussed on the technology aspects teachers and students identified as important. Judgements about accomplishments and future considerations were incorporated. Clear matches between task goals and evaluation were evident. Two examples follow. Figure 7.6 is the 'Storage Containers Evaluation' undertaken in Rachel's class and Figure 7.7 the 'Sensational Cereal Boxes Self Evaluation' undertaken in Ernie's class.

Technology - Storage Containers _____

I have made mock-up and now I feel ◯

Something about my storage container that I feel good about is

_____

_____

After doing my plan, my net and my mock-up I am going to change

_____

_____

My actual measurements are
Depth (Front to back) _____ cm
Width (Side to side) _____ cm
Height (Top to bottom) _____ cm

I am going to write a statement about what I have learnt from doing this technology unit. I am going to tell
* What is technology
* How this problem is technology
* What I have learnt

_____

_____

_____

Fig. 7.6: Storage Containers Evaluation

Sensational Cereal Boxes Self Evaluation

Name_____ Date_____

I can.....

- Design a cereal package with a bold a clear title ☹ ☺
- Design a cereal package with graphics that appeal ☹ ☺
- Design a cereal package that attracts customers ☹ ☺
- Design a cereal package of a suitable size ☹ ☺
- Develop a specification plan for a cereal box ☹ ☺
- Develop lots of ideas when making concept drawings ☹ ☺
- Use information from my focus group ☹ ☺
- Change my ideas when I need to ☹ ☺
- Keep using my focus group to help my design ☹ ☺
- Use colour to make the cereal box stand out ☹ ☺

A good cereal box must include.....

My focus group thought that my cereal box design was successful because.....

Ways I would change my design are.....

Please circle:
I was pleased/not pleased with my design
Self evaluation overall score:
1 2 3 4 5 6 7 8 9 10

Fig. 7.7: Sensational Cereal Boxes Self-Evaluation

Both show a strong focus on the technological essentials in the tasks the students had undertaken. Students were expected to give technological justifications for their self-assessments. There was no mismatch between the worksheet and the tasks, as occurred in 1998. Absent were the main 1998 foci on student attitudes and broad procedural aspects. The 1999 focus was on a balance of technological aspects including the expectation that students would make an overall judgement about their whole process. All teachers used worksheets similar to these as a way for students to evaluate their overall progress.

Teacher self acknowledgement of improvement

Finally, teachers' improved confidence, as more informed formative assessors, was evident. All teachers believed their formative interactions with students were enhanced. For example:

> I'm far more confident with formative assessment as I catered for learning 'on the hoof'. I was more confident this time. I see the importance of my interventions. I think I've always known about one-to-one intervention but when you are actually designing something, a lot of skills become focussed all at once, so it's critical there. I think I'm always reflective, but I use formative assessment in a more integrated way now so that when we link backwards and forwards to sessions, we are using that; so the teaching is iterative. (Tina)
> I value interactions with children more now. I see its importance with formative assessment and it's use to help children clarify ideas and change ideas. (Penny)
> My formative interactions with students were more purposeful and productive which resulted in children being more focussed and tuned into the technology involved in the learning activities. (Sarah)

7.4.2 Enhanced summative assessment practices

More knowledgeable and confident

In 1998 teachers experienced many difficulties in undertaking summative assessment in technology (Section 5.3.3). In 1999 they were more confident and knowledgeable in summative assessment. School assessment practices had a lesser influence on teachers' summative assessment practices than in 1998. Teachers acknowledged the influence planning had had on summative assessment. Their planning had assisted them to articulate the probable learning outcomes for focus right from the beginning. For example:

> Had I not had my learning outcomes the whole thing would have been assessed completely differently. I think it was because I would have placed a different value on the learning that had taken place. It would have probably been more on presentation and that isn't the technology that's being assessed. So I think that's how that's changed my teaching. (Ernie)
> By being focussed with the learning outcomes right from the start it has made it easier to actually focus on what I was looking for at the end. (Rachel)

Enhanced summative assessment understandings were evident in two areas. First, they believed summative assessment needed to include decisions about next learning possibilities. In 1998 there was no obvious attempt by teachers to think about what the next steps would be for students. Rather summative assessment was seen as summing up the learning students had achieved and was a reflective backward looking practice. In 1999 teachers began to develop an understanding of progression where they endeavoured to link and enhance technological learning from one unit to the next. Summative assessment included making calculated decisions about next directions for learning. At the same time as looking back they looked forward. This meant they could link current student learning accomplishments to their next technology units where they could build on that learning. Technology teaching was no longer viewed as a series of isolated tasks. Instead next tasks were identified to develop particular technological conceptual and procedural aspects rather than just providing a variety of experiences in different technological areas. Teachers considered next learning steps for the class as a whole and for individual students. Class statements included:

> We might do some things with quantitative research rather than qualitative like this time. We could start extending out to look at different types of packaging, looking at aesthetics involved in designs. Also start going into different opening mechanisms as well. We've just done 3D conceptual drawings and 2D specification drawings so we could go into specifications of drawings especially 3D specification drawings. (Ernie)
> Next time I'm going to get them to go through the whole process of putting things together, but using something other than packaging or containers. I think their drawing can still be enhanced. And I'd bring in more technological words like we used portable, durable, attractive and mock-up this time. (Rachel)
> I'd probably do something else to enhance drawing as a way to plan and show their ideas. I want them to have more practice here. Maybe more things to do with mechanisms, maybe into gears, something moving. (Penny)

Though class statements were general in nature, all were based on the learning students had undertaken and aimed to move students on when they next encountered technology.

Examples of statements related to progressing learning for individual students follow. The first example from Penny was for Heather (6 years old). She recorded:

> I'll give her experiences in a different technological area. I need to see if her holistic view of this task was specific just to this context. She needs opportunities to develop other conceptual and procedural understandings, and I want her to continue to think about societal aspects of technology. She was good at that and I'd like to build on that. (Penny)

The second example from Burt was for Damien and Hoi, two ten-year-old boys who had worked together on their task.

> I'd like to further develop their drawing skills and develop more understandings about materials. I'll build on their skills of looking at possible solutions and problems that arise and how you get around those. I'd also like to pull in some designers and architects to offer critical advice and guidance and perhaps get them (designers and architects) to do some work with all the children. Going to another technological area like food to try something totally new is also important. (Burt)

The individual student statements were specific to the particular students and based on their accomplishments. Like the class statements, individual statements were aimed to build on the learning students had already undertaken.

Summative assessment that included decisions about next learning possibilities was a significant change from 1998. Then, no teachers had specifically considered how they would link student learning from one unit to the next.

Second, changed summative practices showed teachers assessing throughout the units and not just at the end. This was a shift in their timing of summative assessment. Attempts were made to assess summatively at different points in the learning process for making decisions about the progress students had made to that point. The teachers could immediately redress gaps and also think about next learning steps. For example:

> Undertaking summative assessment through the unit on mask making brought considered reflection on the design process, concepts, and the purpose of mask making. ... Keeping in constant touch with progress was effective in catering for learning gaps and moving kids on. (Tina)
>
> By looking at the work and seeing where I might want to go next with individual children, I did a lot of that. I didn't write anything down but again it was the learning outcomes that focussed me in on that to actually have a clear focus on what I was trying to get. (Ernie)
>
> Gathering stuff along the way was important for making comparisons and to help support an overall impression of student learning and achievement. It highlighted things along the way that needed addressing at the time and helped me look through everything. When I looked at the student work at the end it was very easy to recall what we'd talked about and what had happened. (Penny)

Teachers thought it valuable to sum up learning along the way, as this practice assisted them to be aware of ongoing student progress. It also helped them make more insightful overall summative statements at the end as they had accumulated significant student progress information throughout their learning. Finally, the importance of being clear about task goals for a summative assessment focus was evident in the match between task goals and summative statements.

Focus on technological aspects

Focus was no longer on social and managerial aspects. Instead when teachers assessed summatively, they placed emphasis on technological learning outcomes. These learning outcomes were detailed and covered conceptual, procedural, societal and technical aspects. In effect this meant that the achievement objectives were no longer being used to represent one item of assessment as they had in 1998 and task completion was no longer chosen as an appropriate learning outcome for assessment (Section 5.3.3). All teachers had a dominant focus on technological aspects. This is shown in aspects for summative assessment (see Appendix 16).

Another change was in some teachers' attempts to assess holistically. Ally, Ernie, Penny, Rachel, Burt and Tina made overall judgements about their students' effectiveness in bringing all aspects together. The focus on only some parts of student learning evident in 1998 was less noticeable. For example:

> My summative assessment has been based around the overall key aspects. I focussed on brainstorming activities, each plan, constructing, evaluating, the aspects of technological practice and it's making direct reference to all those that I made by the final judgements on. (Ernie)
> I'm getting more specific and focussed with summative assessment. I was able to get an overall impression and I could comment on the knowledge, their actual procedures and designs, their technical skills and the society aspects. (Rachel)

One workshop exercise was to record summative statements for a selected number of students as written statements. Burt's example shows the differences in the descriptive summative statements he made from 1998 to 1999 (Table 7.6).

Table 7.6: Summative statements made by Burt in 1998 and 1999

1998	1999
Student A: Excellent planning model, excellent reasoning **Student B**: Plans checked, Able to explain process **Student C:** A detailed plan, yet unable to follow it, unclear about scaling or measuring units	**Student A:** An excellent detailed solution using the information gained from interviewing the arthritis sufferer and the data collected on the ergonomics of the hand. Carefully selected criteria for planning and was able to draw 2D annotated device as well as present 3D views showing the internal workings and appropriate dimensions of his chip cutter. Exploded drawings were included. **Student B:** A solution showing the inclusion of information from the interviewing and understanding of ergonomics. Able to set suitable criteria and draw annotated solution in 2D. Some difficulties with 3D views but exploded views included. Described the uses of her multi-peeler with some knowledge of its workings.

In 1998 Burt's summative statements lacked technological detail and were mostly related to student planning, for example, 'excellent planning model'. Little technological detail was given to assist him for teaching technology next time.

These comments were similar to other 1998 teacher comments. In 1999 his summative statements included an overall judgement related to how the student brought some aspects of the task together. For example, 'an excellent detailed solution using the information gained from interviewing the arthritis sufferer and the data collected on the ergonomics of the hand'. Some technological learning was included related to specific technological knowledge, for example 'understanding of ergonomics' and 'able to present 3D views showing the internal workings and appropriate dimensions of his chip cutter'. Procedural aspects, for example 'carefully selected criteria for planning', and technical aspects, for example 'some difficulties with 3D views but exploded views included', also received attention. Societal aspects related to people's interactions with technology were included, for example, 'an excellent detailed solution using the information gained from interviewing the arthritis sufferer'. Far more technological detail is evident. These comments would be useful for teaching technology next time, as they include specific technological information about each student and cover a broad range of technological features. The next-years teacher would also have more appropriate technological detail from which to work. The level of detail and the focus on many technology aspects was typical of summative assessment changes teachers made in 1999 evident in the two written summative assessment examples in Appendix 17.

7.4.3 Summary of enhanced assessment practices

Teachers became more knowledgeable and confident in formative classroom interactions and in summative assessment. The auditing and compilation of appropriate technological learning outcomes exerted a considerable influence on assessment practices for the detailed planning became an assessment guide.

Formative interactions focussed on technological aspects with more assurance and competency. Teachers improved their ability to provide appropriate technology feedback to the learners. Not only was there more emphasis on providing descriptive feedback and assistance to students to develop technological conceptual and procedural aspects, the heavy attention on praise, task completion and social and managerial aspects of 1998 was no longer prominent. An enhanced understanding of formative assessment was demonstrated with improved

identification and articulation of student technological learning gaps. Descriptive feedback concentrated on the detailed technological conceptual and procedural strengths and weaknesses of students' work and the teachers were more likely to take technological principles into account.

A growing understanding of student progression in technology was also shown. Teachers began to see how they could move students on and how they could build on their previous experiences and existing learning to progress student understanding. For the first time while interacting with students they considered where they might go next based on current understandings and skills.

Unlike 1998, student self-assessment was not treated just as a concluding activity and it became embedded in the technological process. This meant students could respond more easily to their self-evaluation and utilise the outcomes of their reflective thinking.

School assessment practices had less influence on teachers' summative assessment practices than in 1998. Summative practices included decisions about next learning possibilities. Technology teaching was no longer viewed as a series of isolated tasks. Instead succeeding tasks were identified to further develop particular technological conceptual and procedural aspects. Changed practices showed teachers summatively assessing throughout the units and not just at the end. This meant that they could make decisions about progress students had made to that point and they could immediately redress gaps and think about next learning steps.

Focus was no longer on social and managerial aspects but on technological learning outcomes. These learning outcomes were detailed and covered conceptual, procedural, societal and technical aspects. This meant that the achievement objectives were no longer being used to represent one item of assessment and task completion was no longer chosen as an appropriate for assessment. Instead the main focus was technological.

The final change was in attempts to assess holistically. Teachers' made overall judgements about how effective students were in bringing all aspects together.

Teachers' growth in understanding technology in detailed conceptual, procedural, societal and technical terms influenced all their assessment practices throughout 1999. The teacher development programme and focus on careful planning had assisted the change process. In all, teachers became more confident, competent, informed assessors of student learning and achievement in technology.

7.5 Summary of Chapter 7

This chapter presented findings related to teachers' use of the models in classrooms, their changed pedagogical approaches and their enhanced formative and summative assessment practices.

- ***Use of models***

Teachers made important gains in their ability to plan technology. Using the planning framework assisted in facilitating the most change with planning. A shift was made to defining technology in specific conceptual, procedural, societal and technical categories, along with a description of key aspects of technological practice and the identification of task definition to indicate general technological direction. The relationship between all three was evident with their robust interconnections. Teachers' better matched tasks and activities with learning outcomes. Also translating different aspects of tasks into reworked terms suited to particular students, clarified at the planning stage how teachers and students could use particular technological terms in their classroom. No longer were testing, review and self-evaluation planned as end-point activities. In 1999 teachers planned lesson sequences so students could operate in an iterative cycle of review and analysis. Finally, assessment was carefully considered when planning. Teachers forward planned for formative, summative and student self-assessment. All teachers focussed on technology learning and employed a considered approach to planning.

- *Enhanced pedagogical approaches*

Teachers improved the way they taught technology. They were more aware of fostering a hands-mind balance and particularly focussed on technological concepts and principles to help students develop technological understandings alongside procedural aspects. They developed enhanced practices in dealing with transfer issues.

All teachers were more mindful of iteration and planned to overcome the linear, discrete process many students adopted 1998. To overcome disconnected technological processes and activities they used written, diagrammatic and verbal means and appropriate management techniques. The combination of strategies encouraged iterative ways of working.

- *Enhanced assessment practices*

Teachers became more knowledgeable and confident with formative classroom interactions and in summative assessment. Most noticeable was the strong emphasis on technological aspects. Teachers acknowledged how planning influenced formative interactions and summative assessment practices. The auditing and compilation of appropriate technological learning outcomes guided assessment practices.

Formative interactions focussed on technological aspects with more assurance and competency. There was more emphasis on descriptive feedback to develop technological conceptual and procedural aspects. Praise, task completion and social and managerial aspects were no longer as prominent. An enhanced understanding of formative assessment was demonstrated with improved identification and articulation of student technological learning gaps. Descriptive feedback concentrated on detailed technological conceptual and procedural strengths and weaknesses of the students and technological principles were taken into account.

A growing understanding of student progression in technology was shown. Teachers began to see how they could move students on and how they could build on their previous experiences and existing learning to progress student

understanding. For the first time while interacting with students they considered where they might go next based on current understandings and skills. Student self-assessment was not just a concluding activity as student self-review became embedded in the technological process.

Teachers' summative assessment practices changed to include decisions about next learning possibilities. Succeeding tasks were identified to develop particular technological conceptual and procedural aspects rather than to just provide a variety of experiences. Also teachers were assessing summatively throughout their technology units and not just at the end. They made decisions about progress students had made to that point, in order to address gaps and think about next learning steps. Focus was no longer on social and managerial aspects but on detailed conceptual, procedural, societal and technical learning outcomes. The main focus was technological. The final major change was in attempts to assess holistically where teachers made overall judgements about how students brought all aspects together. In all, teachers became more confident, competent, informed teachers and assessors of student learning and achievement in technology.

Chapter 7 described enhanced classroom practices in technology. Chapter 8 describes the 1999 student learning that resulted from teachers' enhanced practices and answers the final research question: What was the impact on student learning?

8. STUDENT LEARNING IN 1999

8.1 Introduction

Chapter 7 presented data related to teachers' 1999 technology perceptions and practices. Teachers' enhanced understandings about technology education and student technological learning, and improved pedagogical approaches and assessment practices, resulted in effective student learning throughout 1999. Student learning is the focus for this chapter.

Although this chapter is related to student learning, it should be noted that in all classrooms increased enthusiasm and interest in technology were evident. As the researcher I noted a lively, bustling tone and air of excitement for technology. This increased interest and eagerness was demonstrated by students bringing technology artefacts and books from home to share with others, voluntarily working on solutions at home, and working readily before school and during school when work in other learning areas was completed. For example, Burt's students were willing to continue with technology whenever they could, so he encouraged them to place work on desk-tops so it was readily accessible for any free time. Teachers noticed the increased enthusiasm and interest and commented:

> The students were really hooked in and keen to be involved. (Ally)
> Children showed high interest, were keen to use technological language, were more willing to persevere and showed increased confidence and self-esteem. (Ernie)
> The children were challenged but supported and were therefore successful. They were very happy, involved all the time, interested even out of technology times, and they had fun. (Penny)

Increased enthusiasm and interest in technology contributed to the general buzz in classrooms. An air of excitement was evident and this would presumably have contributed to student success in learning technology.

Teachers also recognised and confirmed effective student learning in technology. They noted differences in their students' accomplishments when comparing their learning in 1998 and their learning in 1999. They believed students showed a better ability to deal with more variables and use of technological vocabulary and skills. They commented:

> The intervention strategies based on the frameworks produced accelerated learning. (Penny)

> Children's differences in learning were better identified with specific learning outcomes and the more effective children coped with more variables. (Tina)
> The students have had quality opportunities and have shown what they can do. They had improved vocabulary, language and skills. (Burt)
> The children were engaged all of the time, they had the vocabulary and could use it appropriately. This was evidenced in mock-ups and drawings. (Rachel)

As in 1998, I observed student learning in classrooms, gathered student work, took photographs of finished products and I listened to and tape-recorded student conversations between students and between students and teachers. I also talked with students while they were undertaking tasks. At the completion of each unit I undertook more structured interviews with students. These interviews were taped and transcribed (Chapter 3). Like 1998 I worked in-depth with a small number of students in each class. This equated to 22% of the 1999 students. For example, in Rachel's 1999 Year 2/3 class I followed four girls and three boys, four were Year 2 and three Year 3, two were five years old, three were six and two were seven. All students were volunteers recruited during classroom observations. Selection considerations included gender, age and class level balance, and willingness to communicate. A high technology performance level was not a criterion. The extensive gathering of student data and ensuing analysis form the basis of findings presented in this chapter.

Section 8.2 describes students' understandings about the nature of technology and section 8.3 their conceptual and procedural understandings. Section 8.4 describes students' effective ways of working while undertaking technology activities. Section 8.5 provides an overall summary.

8.2 Students' understandings about the nature of technology

In 1998, few students had a broad comprehensive understanding of the nature of technology; rather they tended to define technology in terms of the current activity being undertaken. For example, when making a timer, students thought technology was making timers; and when making games, technology was making games. The current activity defined concepts of technology. Narrow, construction views of technology pre-dominated (Section 5.3.1). Technology as situated in a specific activity also meant that students had some difficulties generalising about technology. Teachers did not address enhancing student views about the nature of

technology in 1998. Throughout 1999, teachers included opportunities to develop student understandings related to the nature of technology views. Some teachers even explicitly included this in their planning; for example, Burt, Penny, Ally, Sarah and Rachel. As a result there was a broadening of concepts fostered through 'nature of technology' conversations between students and teachers. Teachers undertook conversations; used charts to sum up and describe the main features of technology and had students record their views of technology more than once over a period of time.

The broadening of student ideas related to the nature of technology is best illustrated by some student quotes. Younger students made this first set of quotes:

> It's sorting a problem out and designing a solution. (Lydia, 7 years)
> It's about making things so that they are better. (Edward, 6 years)
> You have to draw and plan it and get everything ready. You have to make things. (Anna, 6 years)
> It's human made. It's learning about trying to improve things. (Jerome, 7 years)
> It's when you have a problem and you have to solve it by trying to make something better. (Horiana, 7 years)

Younger students focussed mostly on ideas of problem solving, designing, making and improving existing artefacts, but not just the artefacts they were making. There was a practical focus as in 1998. However, the narrow definition of technology as the activity being undertaken was less evident. Instead more students viewed technology as the design and construction of many artefacts. Also included were critical ideas related to improvement and betterment, ideas not focussed on in 1998.

Older students made the second set of quotes:

> It's like building things and having tools to do things. It's more than designing. You need to think about possible steps for making and you need to think about who could use it. (John, 9 years)
> It is something made and used to make life easier. It's something made to do something. You can even design for someone else to make. You can be dealing with food, computers, electronics, building. (Marcia, 9 years)
> It's about thinking and making and designing for other people. (Josh, 10 years)
> It's about designing and making ideas and better things for our world. (Rachel, 10 years)

Older student views were more comprehensive. Similar to younger students they included the ideas that technology is a practical activity involving problem solving, designing, making and improving existing artefacts and that it is about

improving and bettering technologies and lives. In contrast they also included the idea that technology was specific, purposeful designing and making. The realisation that technologies were for particular groups of people was included.

Student views about nature of technology were broader and more comprehensive in 1999. Technology was not just the current activity being undertaken by students.

8.3 Conceptual and procedural understandings

Throughout 1999 more complex and sophisticated technological conceptual and procedural understanding by students were evident than in 1998 (Section 5.3.3). This was shown in student conversations and work. Teacher focus on student use of appropriate technological language fostered the development of technological concepts. Student conversations showed a more prolific and accurate use of technological vocabulary. The examined student work showed a much greater emphasis on technological aspects. Students were able to incorporate more complex and sophisticated technological principles and concepts. Effective understanding was evident in all phases of student work such as planning, manufacturing, testing, self-reflection and self-assessment.

8.3.1 Effective understanding evident in conversations

In 1999, with the teacher focusing on specific conceptual and procedural aspects in their formative interactions, more opportunities were afforded for students to develop and use appropriate technological vocabulary. This was in contrast to 1998 when specific conceptual and procedural aspects were not as prominent in teacher-student conversations (Section 5.3.3). Teachers explicitly targeted specific technological vocabulary and assisted students to incorporate the vocabulary in their conversations and work. Students were reminded of targeted vocabulary frequently and were constantly encouraged to use it. The following quotes show appropriate student use of a variety of technological terms:

> My handle design is better . . . school ropes are uncomfortable and my handle has a padding for the thumb and has grip for the fingers. I thought about how to design it and I thought to make it of plastic and glue it down. The grip had got cross-hatching where it is cut both ways for extra grip (Jerome, 7 years)
> This is a cross-section view. It helps us see inside and how it works. (Anna, 6 years)

My school bag is good but it hasn't got much durability because it is single stitched rather than double. The material is waterproof though. (Kane, 10 years)
This tap handle is ergonomically designed because it's a piece of equipment that fits a person's hand shape. (Julia, 10 years)

Teachers encouraged questioning and talking about specific technological principles and concepts. In consequence, students learnt from shared discussions with teachers and from one another. For example, Rachel discussed introduced three technological concepts to her 6- and 7-year-old students during their task of designing maths storage containers (Fig. 8.1).

Rachel: *Today we're going to look in other classrooms and see how their maths equipment is stored. We might get some answers from them. What does our container need to be?*
Peggy: *Have enough room so we can put things in.*
Johnny: *Be strong.*
Becky: *The right width.*
Linda: *To make more space on the shelves.*
Rachel: *We want it to be portable. What does that mean?*
Taylor: *So you can carry it.*
Simon: *And we want it to be strong.*
Rachel: *We call that durable. It will last a long time, like years, not just a week. And we want it to look attractive.*
Kate: *Yea, it's all messy. We want it to look nice.*

Fig. 8.1: Class discussion

The conversation showed that these seven students were developing an understanding of the problem to be solved. They understood concepts of portability (you can carry it), durability (strong, not broken) and aesthetics (looks nice). For reinforcement Rachel recorded the concepts on the whiteboard and students talked in pairs about their meanings. The explicit use of technological vocabulary helped build and extend student thinking. Whole class involvement assisted students to glean ideas from their peers. After students returned from other classrooms where they examined storage containers, Rachel talked to them about their findings, for example in Figure 8.2.

Rachel: *How were some things portable?*
Johnny: *They had less things in them so you could carry them.*
Rachel: *Did they look good?*
Emma: *Some looked crumbled, jumbled, rumbled. But some looked good.*
Johnny: *And some things were broken in our room.*
Horiana: *None of ours were broken cos they were made of strong plastic.*
Rachel: *Portable?*
Horiana: *Yep.*
Rachel: *Attractive?*
Horiana: *Yep. Most were blue and other bright colours.*
Rachel: *Did you have to look inside to see what was in them?*
Nikki: *No, they were labelled.*
Rachel: *Sounds good, go and get one so we can see.* Students do so.
Rachel: *Would it fit on our shelves?*
Nikki: *No way, too big.*
Horiana: *It won't fit on our shelf.*
Rachel: *So not quite right. Not the right size.*

Fig. 8.2: Ongoing conversation

Rachel assisted her students to analyse storage containers based on features she wanted her students to include in their own solutions. They compared positive and negative features of containers by examining and talking about them. This helped build understandings of portability, durability and attractiveness. Students were also introduced to the concept of size suitability (shelf-fit) through conversation. Teacher-student talk and student-student talk were cornerstones for exploring, challenging, building, reinforcing and checking meanings of student concepts.

In another example Tina discussed with her 7- and 8-year-old students what to include in masks they were to make for the school production (Fig. 8.3). Students became involved in setting some learning goals as Tina used student contributions for task guidelines. As students made contributions, Tina recorded their ideas on a chart.

Tina: *Let's talk about our mask specifications. Our characters have to be able to dance, to sing and to talk.*
Student (S): *We have to make that – one for dancing, singing and talking.*
Tina: *Think about the considerations for dancing.*
S: *It has to be stay – not fall apart.*
S: *It has to stay together.*
Tina: *Yes, it has to be strong material and stay together. What's a way to do this?*
S: *We could use strong cardboard.*
S: *It has to be flexible and it has to fit. We'll have to measure heads.*
S: *And make eye holes.*
Tina: *What about a mask for singing?*
S: *You need room for the sound to come out.*
Tina: *Yes, what will you do?*
S: *Make a hole for the sound to come out.*
S: *You could make a quarter mask.*
Tina: *We have to stick stuff on it for different characters, so what do we need to think about?*
S: *It's got to be big around the edge.*
Tina: *What about talking?*
S: *You need a big space.*
S: *The quarter mask would do.*
Tina: *What about fastening?*
S: *Well, tight but not too tight.*
S: *Elastic to hold it on would be good.*
S: *It would be comfortable.*

Specifications (Recorded on a chart for future reference):

- We have to make a mask for dancing, singing, talking
- Must stay together
- Need strong material
- Must be right size - measure size
- Sound needs to come out – hole for mouth, 1/4 mask
- Need comfortable fastening – maybe elastic, just tight enough to hold mask on

Fig. 8.3:Mask making conversation

Tina and her students talked about suitable materials and appropriate procedures for designing, testing and constructing masks. Students were very involved and able to learn from shared discussions with Tina and from one another. Like Rachel and Tina, other teachers recorded main points from conversations. This assisted students to see a summary of their conversations. They could also use the recordings as guidelines for what needed to be included, as a means to keep track of progress and to see that their contributions were important as they were directly involved with setting task specifications.

Students' effective understandings were also evident in conversations with the researcher. An increased use of technological terminology and understanding of technological ideas was noted. For example, Heather talked about her work, justifying changes made and showing personal satisfaction:

> I went quite good because after having a few tests with my other one I decided I didn't like it. So I could actually just still change it but have a few different things. I changed the way that I hung it. See I already had three strings tied on the top with hooks and I decided that I would just have one. I had one hook instead of three because I though it was much stronger

cause the other things hanging in the classroom only had one. It is easy to use. You just hold on to the branch and you hook it to the branch and you can adjust it a bit. I wouldn't make any changes to this one (pointed to finished product) now though. I like it. (Heather, 6 years)

She showed procedural understanding of drawing as a means to communicate, to clarify thinking and plan next steps.

> I did lots of drawing actually so that I could get this (pointed to her plan) to stick in my mind. So I could actually just think about how I would actually make the bird feeder. (Heather, 6 years)

She also showed detailed understanding of different materials and their uses and concluded that sometimes compromise is the best way forward.

> I learnt that... to make a good bird feeder you have to work very hard. I learnt that washing line is good in a way and bad in a way. Good cos it's quite strong and bad cos it's a bit slippery, cos like chain is quite strong, that's good, but the bad thing is it might rust. String is quite strong as well but it's actually quite thin and it's quite light so your bird feeder will actually just turn round and round and round. You have to choose the one that is actually much more best. (Heather, 6 years)

In a second example, Dan commented about the mask he made for the school production:

> It was fun drawing and thinking of a mask. We had to think about what we were going to do, how to attach stuff and if it would work. I used elastic not string because string might break. We trialled it and I had to change the place where the beak was cause it squashed my nose. My material was good because it didn't rip and it was flexible. And the hot glue for adding the beak was stronger than staples. They pull out. (Dan, 8 years)

Dan showed he understood material qualities required for masks including the need for flexibility and strength. He understood suitable processes for making masks including planning, testing and constructing.

In the third example, Stephanie talked about the school bag she designed:

> It's a very good bag. It's got a place for books, swimming togs and drink bottle. And it hangs vertical not horizontal. It's got lots of pockets and divisions. My focus group thought I had put everything in they wanted. My 3D drawings help to show the shape more clearly and the zips were hard to draw. I need to draw different views because I'm the only one that knows what's on the other sides. When I was looking at materials some were not as strong as others. Some were waterproof and some weren't. Some were more durable and long lasting. I used polyamide because it is easy to clean and is waterproof. I've got nylon on the outside to make it more durable. I've got a waterproof bottom. (Stephanie, 9 years)

Stephanie's conversation showed she understood many material qualities including durability, waterproofing and cleaning ability. She knew that a school bag was multi-purposeful so needed many storage spaces. She also understood the

purpose of 3D drawings and the importance of taking into account the wants of the user group. She understood her weakness in not drawing other views of her design and decided she would do that next time. Her use of technological terminology and understanding of technological ideas is apparent.

Technological concepts and procedures were embedded through constant articulation and exploration. Teachers actively involved students in learning situations through dialogue. This meant students began to understand their strengths and weaknesses and how to deal with them. The engagement of students in conferring, consultative conversations related to technological aspects with the provision of continual support and reinforcement and overt cueing by teachers, led to effective student understandings.

8.3.2 Effective understandings evident in student work

With teachers targeting specific conceptual and procedural technological aspects, students were more able to target them too. Not only did teachers plan with these in mind, formative interactions and descriptive feedback, and summative assessments focussed here as well. In consequence students also concentrated on technological aspects. Students became very clear of task goals. The confusion evident in 1998, where students often believed the targets were social and managerial, disappeared. (Section 5.3.3) Instead, a technological emphasis was seen in all phases of student work.

Evident in planning stages

Teachers deliberately focussed on technological aspects during students' planning stages to assist them to develop and target specific technological aspects. Techniques teachers used included highlighting specific conceptual and procedural technological aspects on student planning sheets, on whiteboards and charts. This meant technological aspects were highly visible. It directed students to those aspects and emphasised what that they were expected to incorporate in their work. The following planning example from Heather (a six-year-old) shows she successfully used the specific aspects targeted by Penny (her teacher) (Fig. 8.4).

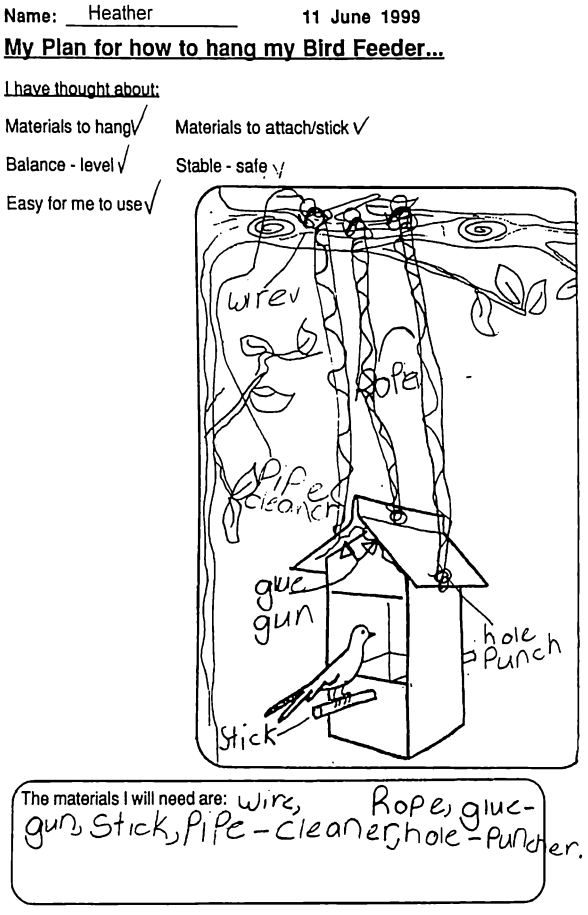


Fig. 8.4: Heather's second idea

Heather's planning showed the understanding and incorporation of a large number of technological ideas including;

- stability (using three supports with one through roof ridge; extra glue to better secure roof to sides, perch for bird),
- balance (make level by using three supports with one through roof ridge),
- suitable hanging materials (wire wrapped around string/rope),
- suitable methods of attaching (wire bends to create a hook, rope can be knotted),
- ease of use (easy hanging method, safety aspects),
- planning for construction including materials needed (wire, pipe cleaner, rope, glue, stick), tools needed (glue gun, hole puncher,) and methods ((punching holes to attach supports to roof, glueing beneath roof to join roof to sides more securely), and
- using 2D annotated drawings to communicate main features of her design.

Penny had assisted Heather to focus on the main aspects. First, she listed the main aspects on the planning sheet for Heather to check list. Second, she partially drew the planning diagram so Heather only concentrated on her task of hanging the birdfeeder. Third, Penny provided space to list construction materials, and finally all planning conversations related to these aspects. Teacher-student and student-student conversations focussed on them and how well they were being included.

Amy, a 7-year-old, produced the next example of student work. This is the same figure as in Figure 7.4 where it was used to illustrate how teachers used planning worksheets to help students focus on the essential technology components of the tasks. In this case the figure is used to show how Amy attended to these essential technological aspects. Amy's work was very effective compared with other students in her class and is some of her planning for making a maths container. It shows how she explored the size and shape relationship of the container to the cubby storage, how she explored different drawing perspectives, her inclusion of aesthetics, appropriateness of shape and size, appropriate measurements, and her thinking about appropriate materials and construction aspects (Fig. 8.5).

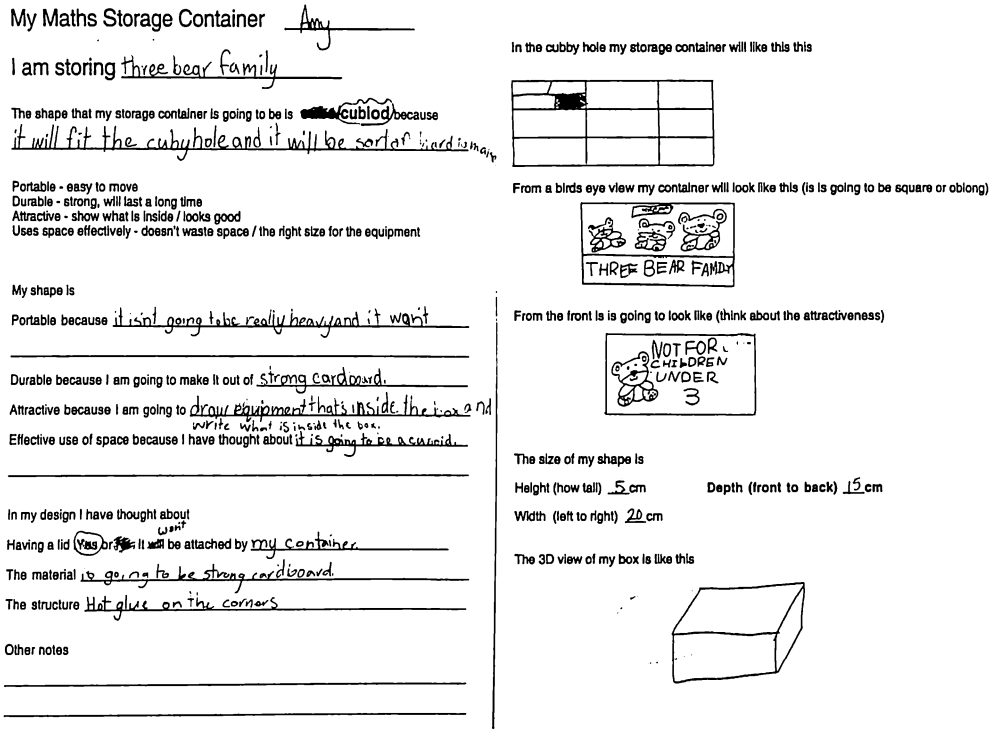


Fig. 8.5: My maths storage container

Amy's planning showed an understanding of a large number of conceptual and procedural aspects including containers need to be particular sizes and shapes to fit the contents and the storage area, durability is related to strength of material, portability is related to weight, and box-like structures require particular materials for construction and use. She used 2D views to show size & shape relationships between container & cubby space, used suitable centimetre measurements, choose suitable materials, and critiqued and justified her decisions. Her understandings were related to both conceptual and procedural aspects and showed her ability to consider many task variables simultaneously, a skill not all students effectively undertook in 1998 (Section 5.3.1).

Rachel, Amy's teacher, had assisted her to focus on the main aspects by first listing the main aspects and their meanings on the planning sheet as a visual reminder. Second, she provided space for Amy to justify how she had thought about the main aspects. Third, Rachel provided a 2D diagram so Amy could show how her container would fit into the cubby. Fourth, she provided space for Amy to draw her container from different views and she was directed to consider size aspects. Finally, planning conversations focussed on understanding these aspects and whether they were being accounted for.

The two examples are typical of the many analysed and demonstrate student planning attention to technological detail in 1999 was far more pronounced than in 1998. 1999 planning showed students' enhanced ability to account for many specific conceptual and procedural aspects.

Evident in constructions

As with planning, student 1999 work in construction showed similar attention to technological procedural and conceptual detail. Students were no longer expected to undertake construction without considered input from teachers, a contrast to 1998 (Section 5.3.2). Students' enhanced understanding of procedural aspects was also evident while they were constructing as they built in on-going testing procedures. They realised that testing products as they were constructing them to ensure the products met all requirements was important. Testing results were heeded and changes were made accordingly. This was in contrast to 1998 where

testing procedures were often undertaken at the end of product development and testing results were less likely to be taken into account. Teachers had deliberately targeted testing as a procedure tied to construction. They encouraged students to continually test ideas and allowed students time for this.

Teachers also deliberately planned and targeted knowledge and skills students would need for building and testing. For example, students were no longer expected to already possess all required engineering skills, or to already know what and how to test. Teachers' formative interactions ensured students gained appropriate engineering skills, manufactured well and built appropriate testing into their manufacturing processes. This resulted in students enhancing their manufacturing and testing abilities. Finished products were totally student-produced with less teacher technician input than in 1998 (Section 5.3.3). Five examples of finished products are shown in Appendix 18. They show the high degree of finish students produced as a result of their enhanced manufacturing and testing skills.

Ability to make links between conceptual and procedural aspects

Teachers assisted students to make stronger links between the conceptual and procedural considerations of tasks when they were engaged with planning, constructing and testing. Students planned, constructed and tested with conceptual aspects in mind. Students were able to incorporate the main conceptual aspects in all solutions, an improvement on 1998 where often a practical dominance overshadowed conceptual focus (Section 5.3.1). In 1998 incorporating conceptual aspects were often discarded in favour of students completing a construction and the act of constructing was more important. This did not occur in 1999 as students were very mindful of key conceptual variables and they were encouraged to include them in product development. The following two examples illustrate student perception of conceptual requirements.

Caitlin (6 years) made a biscuit container that needed to keep biscuits fresh and intact. She therefore needed to think about suitable materials and structures (rigidity, shape) appropriate packaging fill (protectiveness) and ways to seal the

container. While constructing and testing her solution she talked to Rachel her teacher.

> Caitlin: I've got this round plastic container that's the right size, not too big, and I've put polystyrene pieces in the bottom. That's so they won't break. I've wrapped two biscuits in gladwrap to keep them fresh. And put them in. Now I've got more polystyrene and over that a lid that just fits in the container. See. (She then layered in more polystyrene, wrapped two more biscuits, placed them on top and covered these with even more polystyrene. She added the final lid.)
> Rachel: How about testing it?
> Caitlin: I'm going to test it now.
> Rachel: How will you do it?
> Caitlin: The shake test. (She shook the container and checked her biscuits). Yep, Okay.
> Rachel: Will that be enough? What about the drop test?
> (Caitlin dropped the container on the floor and checked the biscuits again.) They're fine. I think this will work.
> Rachel: Have you thought about the lid?
> Caitlin: Maybe some cellotape to keep the lid on and some air out. (Rachel and Caitlin)

Caitlin made clear connections between conceptual and procedural requirements of the task. She incorporated all the important conceptual aspects and was not diverted by the availability of a wide selection of materials, nor sidetracked into making an unrelated construction. She had clear goals in mind, knew what needed to be taken into account and endeavoured to meet task requirements. Teacher-student dialogue helped her focus on her work and how it could be improved. She was directly involved in assessing its quality and was encouraged to see what she needed to do next.

Rachel and Brooke (both 10 years) made a Tic-Tac-Toe game for people with visual impairments. They had to think of many things while constructing and testing including tactility, fairness, safety, ease of use, and stable, durable, strong construction. They had problems in using their counters because stones glued on top to differentiate the noughts from the crosses were very heavy. The counters kept falling over and spoiling the game and therefore players could not keep track of counter placement. While tactility, safety and construction strength and durability were not problems, fairness, ease of use and stability were compromised. With repeated testing and trialling of ideas they altered their counters so they could fit easily into the depressions in the playing board base to provide better stability. This meant counters did not fall over and it was therefore easier for players to use them and keep track of their placement. The game was fair for both players. They talked about their task.

Rachel: Planning and drawing our ideas was important. It gave us a starting point.
Brooke: We could think about what might go wrong.
Rachel: It helped us know all our resources. And was a reminder in the backs of our heads. But you can't see all the problems in planning. It wasn't until we were making it and testing it that some more problems came.
Brooke: We thought our game was quite good too. It was strong, durable and safe. We knew how we were going to make it. We thought it was fair because we had thought of different counters for noughts and crosses – a small flat cup for noughts and a tall skinny cup for crosses. You could easily tell the difference. But we had to try it out to see that the counters needed changing.
Rachel: Yes, the game wasn't fair with them falling over all the time.
Brooke: So, by turning them up the other way they could easily fit inside the trays on the base and it worked. (Rachel and Brooke, 10 years)

Rachel and Brooke were aware of all conceptual aspects at the planning stage. However, it wasn't until constructing and testing they saw their counter stability problem. Then they needed to alter their counters to meet all task requirements. As they understood what needed to be taken into account, they changed their construction. Talking with their teacher, talking to each other, and testing, focussed them on how they could improve their work. They were directly involved in assessing quality and were focussed on making a successful product for a particular group of people. Their clear focus on producing a product for a specific purpose enhanced their conceptual and procedural abilities, and the relationship between them both.

No longer were students constructing any artefact. In 1999 teachers assisted students to make stronger links between the conceptual and procedural considerations of tasks when engaged with planning, constructing and testing. Students therefore planned, constructed and tested with conceptual aspects in mind and were able to incorporate the main conceptual aspects in all solutions, an improvement on 1998 where often a practical dominance overshadowed conceptual focus.

The purpose and use of models

In 1998 there was confusion by students about the purpose and use of models. Students thought models were an end product in themselves and did not have to be representative of artefacts they were exemplifying (Section 5.3.1). Measurements did not need to be taken, scale was not important nor was replication. In 1999 students had a better understanding of the purpose and use of

models. They understood that models could be used for testing some aspects and could be used to demonstrate ideas in a 3-dimensional form.

Rachel's class of 6- and 7-year-olds made mock-ups of storage containers. They all understood very clearly that mock-ups only incorporate some variables and are useful for testing some ideas – a sophisticated concept for students of this age. The following student quotes illustrate their understandings.

> The mock-up was real good to test if it is big enough for the equipment but this one is a little too small to fit in the cubbyhole. It wastes space a bit. I need to make it a bit higher and a bit wider to fit more in and take up better space. (Amy, 7 years)
> The mock-up just tested two things – the shape and the portability. (Illya, 7 years)
> The mock-up is just to test out. Otherwise ours would have been a waste to make cos it was too big. (Cath, 7 years)
> If it was the real thing, I wouldn't use thick paper. I would use wood cos it's real strong. And I would join it with nails not tabs, because you can't fold wood. (Edward, 6 years)

Sarah's class of 8- and 9-year-olds made small models of kites. Students understood that this model was to help them understand the main elements of a kite and to test one variable – the length of tail on kite performance. The findings from trialling these models would be later used to make large kite. For example:

> We're doing a small kite to learn about kites and to know about them. With the tails we can see which one works. (Ann, 8 years)
> We're trying different tails to see if it might help it steer. If you had a bigger kite you'd need a much bigger tail. (Dean, 8 years)
> We're making small kites for the practice of making a big one. And to see if you have to make perfect measurements or not to fly very good. If the tail is too short it mightn't balance, and if it is too long it mightn't go up. (Gary, 9 years)
> We're making kites cos we want to know more about them. We're trying the tails to see what happens – the long one will put more weight on, so it might pull it down and it mightn't fly as well. (Mary, 9 years)

In comparison to 1998, both examples show effective conceptual understanding about the purpose and use of models. This was achieved through teachers being very clear and making explicit the goals for using models. Teachers used models/mock-up vocabulary and encouraged students to also use this terminology. They discussed how models relate to real things. They showed students models. They also discussed what their specific models were for and cued students to use them for the stated purposes. All of these approaches enhanced student understandings in relation to models and reduced the confusion that was evident in 1998.

Student reflection

Student reflection showed evidence of effective conceptual and procedural understanding. Not only did students undertake formal self-review at the end of their units; teachers also encouraged them to undertake continual self-review throughout their tasks. This meant students were able to repeatedly reflect on what they had done and were able to respond to that thinking throughout the process. A conversation between myself and Emma and Cherie (both 9 years) undertaken at the end of a unit demonstrated a technological focus and an awareness of the importance of ongoing self-review.

> Researcher: How did you get on?
> Emily: Quite good because we were looking for these cups but these ones were the only ones that were quite durable. The other ones were quite brittle plastic.
> Cherie: Yeah, so if people were going to grab them, they wouldn't get hurt.
> Emily: So ours are quite firm. The plastic ones would crack if someone pressed them too hard. And we've added a base that was not on our plan.
> Researcher: Oh, how come?
> Cherie: We didn't know when we were drawing that we would need one. But when we came to make it, we did.
> Emma: Yeah, it's so the base won't bend too much. It's stronger.
> Cherie: We've had to do heaps of changes because it's hard to test it on your plan.
> Emma: We couldn't even think how we would separate the board from the counters. We just thought that we would store the counters inside the board but when you start to play the game, you can't start with them in there and then where do you put them?
> Cherie: So we had to make some storage space to the side. (Emma and Cherie, 9 years)

The conversation shows understanding of material properties and uses (durable rather than brittle cups for counters, strong base required support) and the importance of user safety (choice of safer cups for counters). Links between planning and constructing are evident in their realisation that drawings only partially solve problems. They described changes they undertook from planning when constructing (adding a base, adding storage for counters) indicating the importance of the process of review they employed.

A second conversation between Mere (7 years) and myself provides a further demonstration of enhanced student understanding of the review process for assessing technological aspects.

> Mere: My 3D drawing showed how the container would fit in the cubby and I was going to have handles. But I changed my mind about the handles cause when I made it I could just take it down to the mat easily. I was also going to put wheels on it so it would pull out. But when I tested it out it didn't need them. It's portable already cause it's easy to carry. I tested it out. It worked. And it's the right size. I tested that too. It takes up half a cubby.
> Researcher: How did you get the right size?
> Mere: I worked that out by getting different containers and by looking to see which ones would fit 1/2 a cubby and then I measured for my planning.

Researcher: What else?
Mere: It's quite good. I like it. It's portable and it's attractive. It's not exactly durable because I didn't do that. I would have to use not paper, use a different material, maybe plastic or wood. Wood is good for joining together and plastic is good for stacking. Actually, where to put the tabs was hard. You think that you'd put the tabs on every side in the net. But no. You only need to join up the ends, so that's where you need them. The tabs helped to do the mock-up. You draw all the measurements out, cut it out, join it together and then you can test if it is the right size. Then you can use the mock-up to do the real thing. (Mere, 7 years)

The conversation shows Mere's understandings of material properties and uses (portability, durability and strength), the purpose of mock-ups and a product development process. Links between product analysis and planning are evident where she used exiting containers to figure out the size she wanted for her container. Links between planning and constructing are also evident in her realisation that her planning drawings only partially solved problems. She described the changes she undertook when constructing (eliminating wheels and handles) and her changed thinking about the use of tabs for joining nets indicates the importance of the process of review she employed.

The ongoing self-review process also enhanced the formal self-assessment tasks students undertook at the end of units, as they were able to use the ideas they had accumulated. They had been encouraged to focus on conceptual and procedural aspects throughout, so the self-assessment tasks held no surprises as had occurred in 1998 (Section 5.3.3). Examples of formal self-assessment demonstrate students' clear technological understandings they developed. The first example is 6-year-old Heather's (Fig. 8.6).

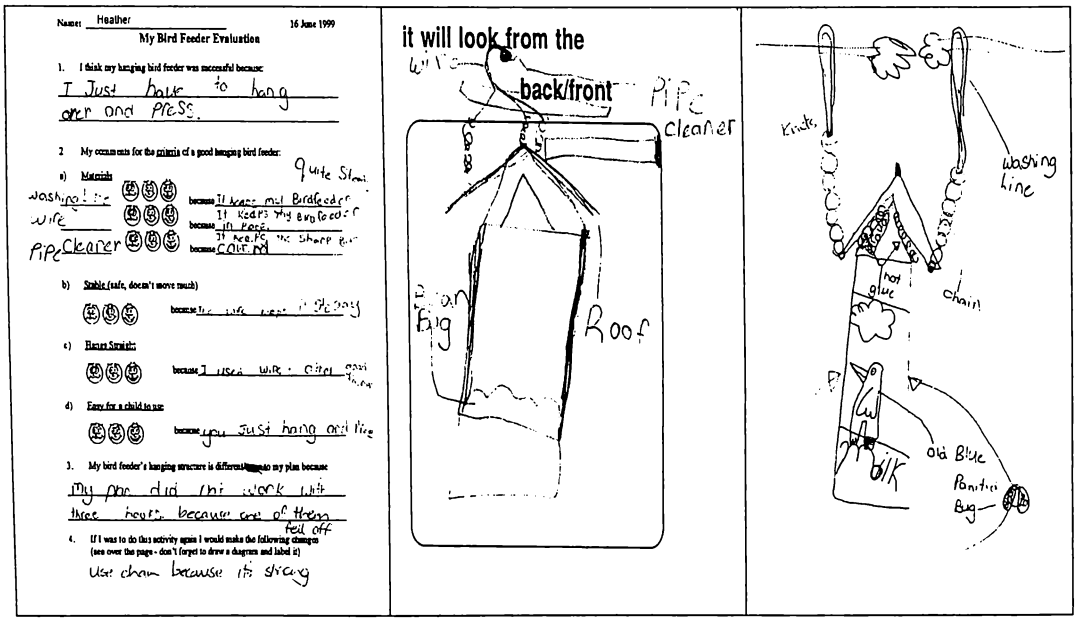


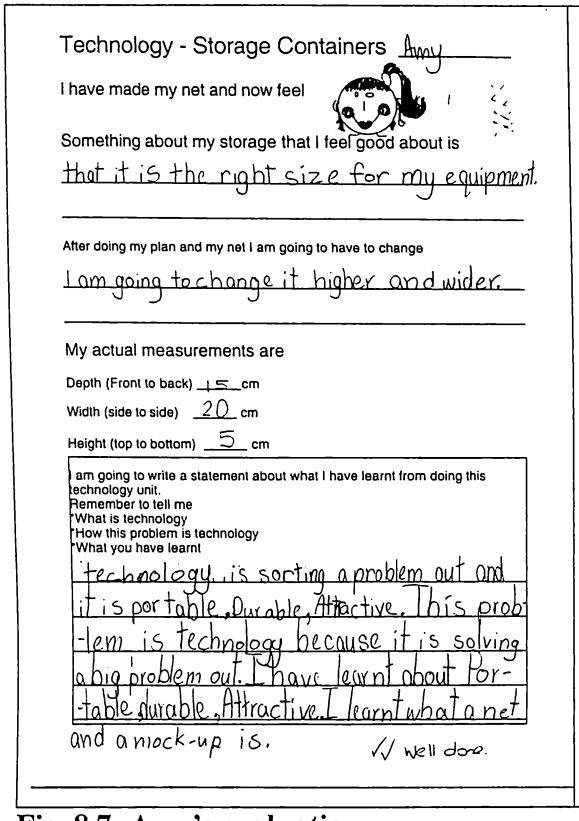
Fig. 8.6: My Bird feeder evaluation

Heather's self-evaluation showed she:

- made an overall judgement about the success of her technological undertaking
- accurately appraised the finished hanging bird feeder in terms of appropriate materials, stability, balance, ease of use
- justified technologically the decisions she made, eg washing line because it keeps the bird feeder quite steady
- related properties of materials to their technological use, eg pipe cleaner keeps the sharp bits covered
- recreated her finished artefact as a concept sketch
- justified her altered choice of materials
- considered what she might do next time
- did not think in terms of making mistakes, right or wrong, but in terms of ongoing development for her solution.

Her self-evaluation was strongly focussed on technological aspects, both conceptual and procedural. Additionally she saw review as forward looking as well as reflective.

The second example (Fig. 8.7) is from Amy (7 years).



Technology - Storage Containers Amy

I have made my net and now feel

Something about my storage that I feel good about is

that it is the right size for my equipment.

After doing my plan and my net I am going to have to change

I am going to change it higher and wider.

My actual measurements are

Depth (Front to back) 15 cm

Width (side to side) 20 cm

Height (top to bottom) 5 cm

I am going to write a statement about what I have learnt from doing this technology unit.
Remember to tell me
*What is technology
*How this problem is technology
*What you have learnt

technology is sorting a problem out and it is portable, Durable, Attractive. This problem is technology because it is solving a big problem out. I have learnt about Portable durable, Attractive. I learnt what a net and a mock-up is.

√√ well done.

Amy's work showed she:

- Gave an overall opinion about her work
- Justified that opinion in technological terms
- Considered other changes she might make
- Gave specific measurements
- Differentiated between mock-ups and real containers
- Understood material properties and uses (durability, portability, material strength)
- Understood different structures and their purposes (right size)
- Understood aesthetics (attractiveness)

Fig. 8.7: Amy's evaluation

Like Heather, Amy's self-review was strongly focussed on technological aspects, both conceptual and procedural. She also saw review as forward looking as well as reflective.

The final example (Fig. 8.8) is Damien's, a 10-year-old.

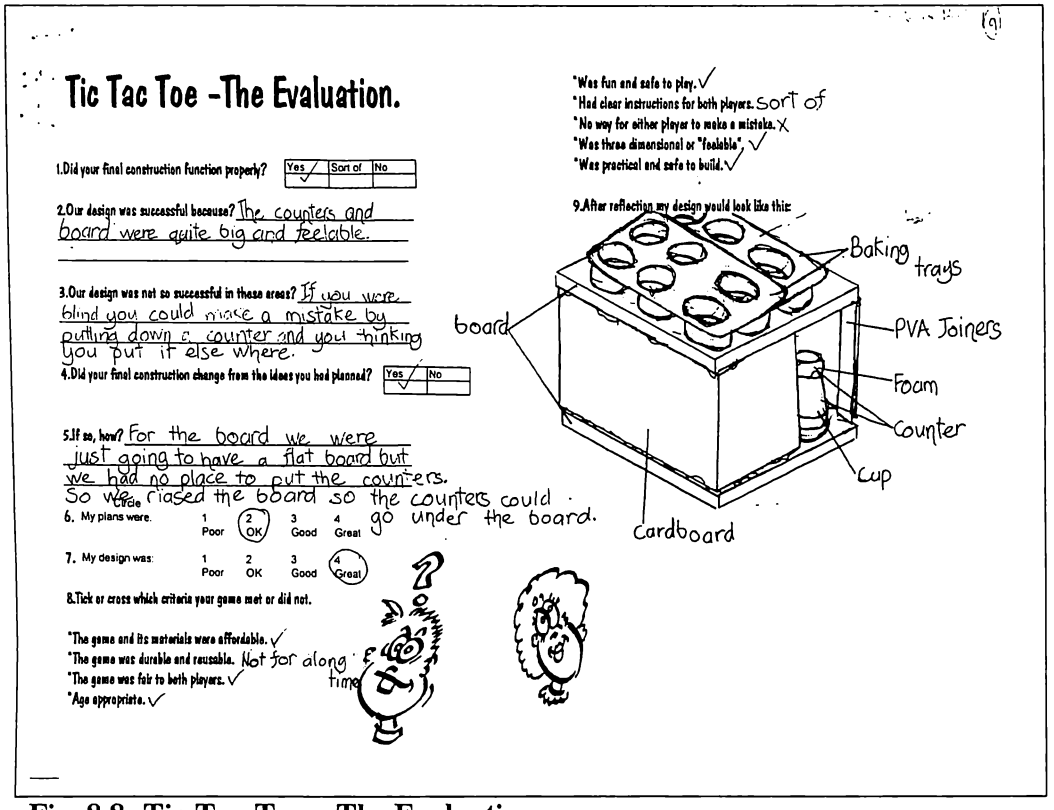


Fig. 8.8: Tic Tac Toe – The Evaluation

His evaluation shows:

- Ability to make an overall judgement about his work
- An understanding of user considerations (fairness - sound and tactility, fun and safety – soft foam on counters)
- An understanding of manufacturing considerations (durable and easy construction methods)
- An understanding of material considerations including materials for playing pieces need to be malleable (flexible and soft), tactile, safe, durable, and practical (able to be used); materials for board bases need to be strong (stiff and firmly joined), portable (can be carried) practical and durable
- An understanding of structural aspects including durability, tactility (3D shapes to differentiate counters, 3D board base), stability (level and strongly joined) and portability (not too heavy to be carried)
- An understanding of game's practicability (it functions as a game),
- Relatively sophisticated 3D drawing skills
- Satisfaction with his work

Like the other examples, Damien's self-review was strongly focussed on technological aspects, both conceptual and procedural. He reviewed a large number of technological aspects due to the worksheet focus on these aspects and the on-going self-review process he had undertaken while developing his game. He saw review as forward looking and reflective.

Student self-assessment worksheets showed evidence of increasing ability to identify technological weaknesses in their solutions and appropriate ways to rectify those weaknesses. For example Penny's students recognised the shortcomings of their skipping rope handle design work and wrote how they would improve it.

> Next time I would use better materials and show more of the inside and I will make it powerful. (Sarah, 6 years)
> Next time I will use wood, rubber, plastic, staple and sponge Wood is stronger, rubber is comfortable, plastic is waterproof, staples will keep the rubber and stopper together and strong for grip. So the difference is wood with plastic covering on the outside to keep the wood waterproof. (Heather, 6 years)

Students were better at evaluating their progress in 1999 than in 1998. Most noticeable was the strong emphasis on technological aspects. This directed students to profile their technological learning.

Ability to incorporate more variables

With teachers enhanced ability to teach many aspects of technology and provide descriptive feedback related to these aspects, students were more able to take them into account. They successfully undertook extended technology tasks and incorporated many variables. For example, an analysis of Amy's planning showed:

- conceptual understandings that drawing is a way to express initial design ideas, containers need to be appropriate shapes and sizes relative to their contents, nets can be used for patterns;
- societal understanding that labelling containers contributes to their aesthetics;
- procedural ability to develop initial conceptual ideas as 3-dimensional sketches and develop initial plans for construction as nets;
- technical ability to draw 3-dimensionally and to draw nets.

In another example, an analysis of Heather's work demonstrated ability to think critically about different technological aspects including societal aspects (safety issues for the product user), conceptual aspects (properties of materials), technical skills (tying, knotting, wrapping), and procedural aspects (drawing, construction processes).

Finally, an analysis of Damien's planning demonstrated his:

- conceptual understanding of the need for tactileness (3D board base and counters), the need for safety (use of soft foam on counters), the use of sound to assist player ease;
- procedural ability to select and use appropriate materials, methods of construction, list material requirements, methods of joining (overlapping trays held together with craft glue), detailed construction steps and the clear identification of appropriate materials and structures;
- societal understanding of user considerations; and
- technical ability to use different drawing views and to show an interrelationship between text and illustrations.

Students were able to include many variables successfully. Unlike 1998, students did not get lost in the task nor did they disengage (Section 5.3.2). Instead they incorporated many task variables as teachers helped them be clear about what should be included.

8.3.3 Summary of effective conceptual and procedural understanding

In summary, it was seen that students were effective in understanding conceptual and procedural technology aspects throughout 1999. These were shown in student conversations and their work. The complexity and sophistication of concepts students understood was noticeable, for example 6-year-olds understanding concepts of portability and durability, 7-year-olds understanding the role and purposes of models, 9- and 10-year-olds able to construct highly functional games for people with visual disabilities. Students' effective understandings were evident in all phases of their learning such as planning, constructing, testing, reflection and evaluation.

8.4 Effective ways of working

Students showed effective ways of working when they were undertaking technological tasks in 1999. Section 8.4.1 describes students' ability to work iteratively. Section 8.4.2 outlines their understanding of the purpose of the activities and section 8.4.3 details their ability to identify and close their own technology gaps. Section 8.4.4 summarizes the findings related to students' effective ways of working.

8.4.1 Ability to work iteratively

With teachers more mindful about encouraging students to work iteratively, students developed an ability to make connections between different stages when developing artefacts and processes. In 1998 students often struggled to realise stages were related to each other and that they built upon each other (Section 5.3.2). In 1999 students did not discard drawings when they undertook construction as they had in 1999. Teachers had assisted students to use drawings to show what they were going to construct and how. Drawings became useful construction plans, not to be rigidly followed as a perfect match, but to act as guides. The following quotes illustrate student understandings about links between planning and constructing.

> I would have forgotten what I was doing. The sketches helped me remember what I thought I should do. I knew exactly what I was going to do. I wrote all my measurements down so I wouldn't forget when it came to making my mask. (Hannah, 8 years)
> Drawing helped me to think about my ideas. I could think about what materials to use and how I might make it. (Nick, 7 years)
> Drawing helped you get ideas and if you were just making you wouldn't know what bits to put in and what to expect. (Simon, 6 years)
> Drawing helped with the making. I knew what I was doing, what materials to use. It helped with thinking and you can make it the same, but you mightn't do it just the same. I didn't put a cover on it. (Kate, 6 years)
> I just wanted to start building but I realised that plans help you to now where to go. (John, 9 years)
> Drawing helped me work out what I was aiming for. (Liam, 9 years).

A conversation held in 1998 shows typical student views of planning and its uses. The conversation was undertaken with Colin and Peter, while they were working at constructing a sand clock.

> Researcher: Why aren't you using your plans any more?
> Colin: We don't need them any more because we have changed our ideas and they can't help much.
> Researcher: So why did you need them at all?
> Colin: They were so we could get our ideas together.

Peter: They were a starting point to get ideas. Now we are trying our ideas out. Colin: Yeah, they are a starting point to get ideas. We didn't know each other's ideas.
Peter: My plan stuffed up because it won't work no matter what I do. I'm just trying ideas out in my head until I get one that works. I could have done this without drawing and it would have been faster. (Colin and Peter, 10 years)

Colin and Peter had viewed drawing as a valuable tool to begin the design process but saw no further use for it. Drawing was not linked to making and testing. It was the beginning point to idea generation rather than integral to the whole process. Peter also viewed drawing as a way to tell others about his ideas but saw no connection to the possibilities of using drawing as a means to develop his own thinking. In fact, he saw drawing as a hindrance.

The contrast in 1999 is evident in the next conversation. It is with John and Benjamin and undertaken while they were constructing their tic-tac-toe game. They have five stages of planning related to this.

Researcher: Why do you have so many plans?
John: Well, each one is different.
Benjamin: The first one is a brainstorm and it doesn't work. You couldn't make it.
John: No. Then we went to plan two and you can see we are thinking about making it. We are using PVC joiners to hold up the different levels.
Benjamin: And a large base.
John: But we didn't explain it well.
Researcher: What do you mean you didn't explain it?
John: Well, we didn't say we are going to use a glue-gun, or cardboard. It's just sort of the outline of our ideas.
Benjamin: The picture doesn't show it. So we started on another one.
John: So this is number three. This is about the counters.
Benjamin: This is more detailed. But the others [Plans 1 and 2] are just our ideas.
John: Then there is plan four. It is all about how we are going to construct our game.
Benjamin: We started to think more carefully about the board, how are we going to put the trays together, and stack them up and drill the holes.
John: We were thinking about how we are going to make it.
Benjamin: Then we did kind of a good copy. That's number five. We wrote down our materials and the things that we will need and the measurements.
John: This last one is what we did really.
Researcher: So I could follow it and make the same game as you.
John: Yeah, hopefully.
Researcher: Did you have any problems coming up with all of these plans?
John: No, not really. It was harder to make it [than draw it]. But we needed the drawings because you could have had different ideas from your partner.
John: We could see each other's ideas when we were working together.
Benjamin: We sort of agreed.
John: And they help to see the things you will use and how to prepare. It helps you to make it good. You can see some problems. (John & Benjamin, 10 years)

John and Benjamin saw drawing as useful way to communicate their thinking to each other, and to help them decide upon a common way forward. They used their plans to explore and their ideas becoming more refined and specific, as the

planning became more in-depth. They also realised that drawings could be used to think through potential problems and as blueprints for construction. They saw the value in using a series of drawings as evaluative tools as they could show the journey they had undertaken. Finally, they realised that not all problems would be solved in the planning stage, that more would emerge during construction. Strong connections between planning and construction were evident, as was their iterative way of working. The large number of plans they produced was more typical of students in 1999 than in 1998. Teachers and students realised the need to explore and refine thinking and ideas over a period of time. This resulted in students creating more than one plan to develop their ideas. Students could also make connections between different versions of their planning. They were able to work iteratively between planning stages and between planning and constructing.

As with planning and constructing, students showed effective ways of working iteratively between constructing and testing. Testing was not just confined to the end of the technological process (Section 5.3.2). With an on-going cycle of testing and review being encouraged, students viewed testing as part of an on-going process. In-built testing was evident in all classes and was regarded as a practical, recurrent pursuit important for realising feasible solutions. The following student quotes illustrate students' enhanced understanding of testing as integral to the construction process.

> Testing was really important. We tested all the way through when we were making our kites. It helped us to change things and to see if it worked. (Kirsty, 9 years)
> You think a little bit and then you make it. When you are making you have to try it out and think in your mind if it is working. You can change if it doesn't work good. (Helen, 7 years)
> We had to test to see if our mask would work. After one trial I had to change where the beak was cause it squashed my nose. I had to make the beak poke out, then it wouldn't squash so easy. We had to try it out lots to make it right. (Dan, 8 years)
> I put the cards inside my mock-up. It was too high for all my stuff. I had to make my sides shorter. I didn't know by how much, so I got my ruler and measured. I marked the sides the right size. If I didn't test I wouldn't know where to make the sides shorter. (Caitlin, 7 years)

The way students worked in classrooms showed that they knew on-going testing was part of constructing. The following two examples illustrate this. The first example is Annie and Mary, 9-year-old students in Burt's class. Their task was to construct a Tic-Tac-Toe game for visually impaired people. Annie and Mary initially built their game base with division markers glued on top of a hollow box. They subsequently found that counters moved around underneath rather than

staying in their placed positions, so they shifted the dividers to the base of the box instead. Making braille markings created many problems – blobs of glue ran together, cork tops only had a small area to use and it was hard to distinguish between braille noughts and braille crosses. To solve these problems, they glued the corks to cardboard bases to make bigger counters and then used pebbles in two different places (on the tops of the corks and on the counter bases) to distinguish the playing pieces. To store the counters, they added paint trays to the sides of the base. This made the game board unstable, so a large cardboard base was added beneath the playing board and paint trays. They talked about their work

> Annie: It looks pretty good. We've tested it and it works pretty good. We changed quite a few things when we started making and testing to make it work better.
> Mary: But we didn't just add anything, it was stuff to make the game work better. Like this cardboard base made it much easier to hold.
> Annie: And it made the game stronger. And then you could carry it by one person. (Annie & Mary, 9 years)

With ongoing guidance and appropriate feedback from Burt and by taking heed of their constant trialling and testing, Annie and Mary made ongoing alterations to account for all criteria. As a result, an effective solution was reached.

The next example is from Heather, a 6-year-old in Penny's class. Her task was to construct a hanging device for an outdoor birdfeeder. She originally fixed three hanging threads to the roof and hooked each thread separately onto a branch in the tree. However, she found it difficult to hang the feeder evenly, so her birdfeeder was not stable, a specification requirement. Her solution was to join the three threads together at the top with one hook for hanging. Her birdfeeder became stable. User-friendliness, another specification, was then also addressed, as the bird feeder became easier for her to hang. She commented:

> I went quite good because after having a few tests with my other one I decided I didn't like it. So I could actually just change it and have a few different things. I changed the way that I hung it. I already had three strings tied on the top with hooks and I decided to have just one. Because it was much stronger and it is easy to use. You just hold onto the branch and you hook it to the branch and you can adjust it a bit. (Heather, 6 years)

With ongoing testing and persistence, and encouragement from her teacher, Heather reconstructed her birdfeeder to meet required specifications to her satisfaction. She finally produced a very successful hanging bird feeder.

Teacher formative interactions ensured students worked iteratively throughout their technological problem solving process. They were able to link stages together and they realised the value of working in an iterative manner.

8.4.2 The purpose of the activities

In 1999 teachers worked to ensure students understood the purpose of activities. They wanted students to know the reasons for undertaking particular tasks. To enhance the chances of this, teachers clearly outlined task goals and often task goals enhance the chances of this, teachers clearly outlined the task goals and often task goals were also created jointly between teachers and students. This meant students had input into them increasing their chances of task ownership and they had opportunities to develop shared understandings of task purposes. Task goals were restated often, especially at the beginning of each session. Throughout sessions, teachers interacted with students helping them to understand and meet task purposes. At the end of sessions, teachers checked to see how well students had met the goals. This concentration on task purpose meant students were very clear about their goals. This was in contrast to 1998 when students often received mixed messages about task purposes and were confused about the learning focus, believing social and managerial aspects were more important than technological aspects (Section 5.3.3). Teachers' clarity of purpose was conveyed to students who developed similar clarity. Students' comments related to why they were undertaking specific activities illustrate their clear understandings about task purposes.

> We're going to make a strong package so the biscuits won't break and they'll be fresh. (Kathleen, 6 years)
> Today we're looking at materials to see which ones would be good for hanging our birdfeeders. (Stephanie, 7 years)
> We're looking at different masks to see what design features they have, what materials they're made from and whether they look good. (Tim, 8 years)
> Our task is to design tools for people who have arthritis in their hands. (Ollie, 10 years)
> The containers in our maths corner are breaking. They look messy and don't fit very well. We're making a container that is portable, durable and attractive and the right size. (Michael, 7 years)

Students did not think the main purpose of tasks was to develop their social skills or managerial abilities in 1999 as in 1998. They understood the technological task goals.

Having a clear purpose and secure understanding of task goals meant students were able to think about the whole task throughout the technological process. Instead of concentrating on some aspects, deciding not to include some variables, or becoming confused about the task as occurred in 1998 (Section 5.3.3), students were more aware of all aspects from the beginning and all through their technological process. This was as a result of teachers consistently focussing on whole-task aspects and encouraging students to do likewise. As a teacher commented:

> I tried to encourage linking backwards and forwards between learning experiences, consistently reminding children of the overall purpose of task. For example, what was completed yesterday, where are we going today? There was a constant reminder of design specifications. It meant they had a clear picture of what was required and they could think of it all. (Tina)

Heather's conversation, already reported in this chapter in section 8.3.1, shows how very young students can evaluate inter-related variables, discarding some because of their impact on others.

> I learnt that washing line is good in a way and bad in a way. Good cos it's quite strong and bad cos it's a bit slippery, cos like chain is quite strong, that's good, but the bad thing is it might rust. String is quite strong as well but it's actually quite thin and it's quite light so your bird feeder will actually just turn round and round and round. You have to choose the one that is actually much more best. (Heather, 6 years)

Besides considering the appropriateness of particular materials Heather thought about weatherproofing and stability, two other aspects she needed to consider. She was thinking of the whole task, not just material aspects.

With effective means to consider the whole task, students were also able to make a justifiable overall judgement about the progress that they had made. For example:

> I think my hanging birdfeeder was successful because it worked and could go on any branch. (Kane, 7 years)
>
> My mask matches all our design specifications. It can be used for singing, dancing and speaking. It fits. It has a large area for sticking decorations on. The fastenings work. I can make several copies all the same and the material will stand the rip test and is flexible. (Dan, 8 years)
>
> Our final construction sort of functioned properly. It was successful because it was very durable and safe. The best part is that no one can cheat. It was a bit unsuccessful because the base and the board were not even and the Velcro didn't stick to the cork. (Emily and Chantel, 9 years)
>
> My design was good. My design was successful because most people said that they liked my design and I liked my design too because the lunch box compartment was very good and also I liked the way my bag looked. I liked the way the compartments folded out to make more room. I could make a bigger handle. (Ben, 10 years)

These comments show student understanding of the whole task and their ability to assess holistically and to back this with corroborating detail. Clear purposes and secure understanding of task goals impacted on student ability to think about the whole task throughout the technological process. Students were very aware of the whole task, task goals and the purpose of the activities they were undertaking.

8.4.3 Identifying and closing technology gaps

In 1999 students showed effectiveness in identifying their own technology gaps. They were able to ascertain whether they had met task goals and how well. Conversations with students showed they were aware of what they did not know and were prepared to seek advice. In 1998, they were less aware of their gaps as the focus was often related to general designing and making, social and managerial aspects and hazy task purposes (Section 5.3.3).

The giving of descriptive feedback by the teachers was essential for helping students identify and close technology gaps. Teachers focussed on the qualities of student work and specific ways in which work could be improved. This feedback was very beneficial as it identified the strengths and weaknesses of student work enabling them to be directly involved. Students could then see for themselves where their difficulties lay and could seek assistance if needed. The following conversations illustrate students' effectiveness in defining their own technology gaps and confidence in seeking assistance if necessary. The first between Kathy and Fu-ling, 10-year-olds in Ally's class, occurred when they were examining existing kites to glean ideas for constructing their own.

> Kathy: I think we'll change the fabric.
> Ally: Why?
> Kathy: Because the plastic ripped in the middle. This nylon will work better.
> Fu-ling: If we change the fabric will we have to change anything else?
> Kathy: It might be too heavy. We might have to shorten the tail.
> Fu-ling: We'll have to try it I suppose.
> Ally: Is anyone else thinking of the same change?
> Kathy: I'm not sure, but we could go and see because they might be able to help. (Kathy and Fu-ling, 10 years)

Kathy and Fu-ling understood the need to change then test and acknowledged they were unsure what effects the change would have. Ally's idea to check with others and their willingness to do so indicated their inclination to find out.

In the next example Sam, a 9-year-old in Ernie's class discussed the beginning development of his ideas for designing a school bag.

> I was pleased we looked at all the school bags. I just wanted to get started on the drawing my own even though I had no idea what I was going to do. But then I could see the different materials. Then when I started writing it down I had more ideas and more ideas. (Sam, 9 years)

Sam understood he knew little about designing school bags and indicated this. He also recognised the importance of examining existing bags to get ideas to reduce his knowledge gaps.

Michelle, a 6-year-old student worked with Penny, her teacher while constructing her hanging bird feeder. Her hanging supports kept pulling through the roof of the feeder. She thought she had solved her problem.

> Michelle: See, I'm going to tie my rope to a button so it won't pull through the roof. The button will stop it going through the hole I made.
> Penny: Have you looked carefully at the rope and the button you've got?
> Michelle: Not really.
> Penny: Will the rope fit inside the button?
> Michelle: I don't know, I'll have to try. I'll be able to find the right size. (Michelle, 6 years)

Michelle understood her difficulty in joining supporting ropes to the roof and decided to fix it by using buttons. She had nearly solved her problem but needed teacher guidance to think it through entirely. Penny's feedback was beneficial as it identified a weakness in her solution. Michelle then saw the difficulty for herself, so she could then attempt to solve it.

Student self-assessment worksheets also showed evidence of students' ability to identify the technological weaknesses in their solutions and appropriate ways to rectify them. For example Penny's students wrote how their skipping rope handle designs could be improved.

> Next time I would use better materials and show more of the inside and I will make it powerful. (Sarah, 6 years)
> Next time I will use wood, rubber, plastic, staple and sponge. Wood is stronger, rubber is comfortable, plastic is waterproof, staples will keep the rubber and stopper together and strong for grip. So the difference is wood with plastic covering on the outside to keep the wood waterproof. (Heather, 6 years)
> Next time I would show how to hang it up. I would also make it easier to use so you don't have to tie a knot. Next time I would use sponge, plastic and wood. I would glue plastic onto the wood with a hot glue gun. (Carl, 7 years)

Ernie's students wrote how their schoolbag designs could be improved.

> Personally I think I would put a cover over the velcro. But the interview person said nothing. (Kaine, 10 years)
> I liked the way the compartments folded out but I need to make more room in the bag and have a bigger handle. (Ben, 10 years)
> I would have more padding to make it more comfortable and more colour. (Joanna, 10 years)

These self-assessments show how students thought they might have worked differently and how they might make improvements.

8.4.4 Summary of students effective ways of working

Teachers were aware of the need for students to work iteratively and encouraged them to do so. Students developed better connections between different stages in developing artefacts and processes. Of importance were teacher formative interactions as these ensured students worked iteratively throughout their technological problem solving process.

Teachers also helped students understand the purpose of activities and reasons for undertaking particular tasks. Teachers clearly outlined task goals, which were often created jointly between teachers and students. Task goals were restated often and this concentration helped students become clear about their goals. Having a clear purpose and secure understanding of task goals meant students were able to think about the whole task throughout the technological process. Students tried to see how the different aspects impacted on each other, balanced them and included all in their solutions. With an enhanced ability to consider the whole task, students were also able to make a justifiable overall judgement about the progress that they had made.

Finally, students were able to identify their own technology gaps. Teacher feedback was essential for enhancing student identification and closing of gaps. Teachers' beneficial feedback identified the strengths and weaknesses of student work enabling them to be directly involved with seeing for themselves where their difficulties lay and whether they needed to seek assistance.

8.5 Summary of Chapter 8

Chapter 8 has described effective student learning evident in 1999. Students demonstrated increased enthusiasm and interest in technology, which contributed to a general buzz in classrooms and success in learning technology. Teachers' enhanced understandings about technology education and student learning in technology, their improved pedagogical approaches and assessment practices resulted in more effective student learning throughout 1999. In comparing student learning in 1998 and 1999 important differences were evident. There was evidence of effective student understanding of the nature of technology, effective conceptual and procedural understanding, and effective ways of working in technology.

- ***Effective understandings about the nature of technology***

In 1998, students had limited understanding about the nature of technology. Throughout 1999 there was a broadening of concepts fostered through developing views about the nature of technology. This broadening was mostly brought about through teachers explicitly engaging their students in planned, recurring opportunities to discuss the nature of technology. The narrow definition of technology as the current activity they were undertaking evident in 1998 was far less evident in 1999. Instead more young students viewed technology as the design and construction of many artefacts. They included critical ideas related to improvement and betterment; ideas not focussed on in 1998. Technology was also viewed as specific, purposeful designing and making. The 1998 more restricted view of technology being about making particular artefacts was less evident. Instead views were broader and more comprehensive.

- ***Effective conceptual and procedural understandings***

Throughout 1999 more specific, complex and sophisticated technology conceptual and procedural understandings were evident in student conversations and their work. Teacher focus on enhancing student understanding and use of appropriate technological aspects fostered this development. Student work showed a much greater emphasis on incorporating more complex and sophisticated technological

principles and concepts. Students' effective understandings were evident in their planning, manufacturing, testing, reflection and self-assessment.

As teachers focussed on specific conceptual and procedural aspects in their formative interactions students had more opportunities to develop and use appropriate technological vocabulary. Teachers explicitly targeted specific technological vocabulary and assisted students to incorporate this in conversations and work. Technological concepts and procedures were embedded in activities through constant articulation and exploration. Teachers actively involved students in the learning situation through dialogue. This meant students began to understand their strengths and weaknesses and how to deal with them. Teacher engagement in conferring, consultative technological conversations, overt cueing and continual support and reinforcement led to effective student learning.

With teachers targeting specific conceptual and procedural technological aspects throughout student technological problem solving, students were more able to target those aspects themselves. Students became very clear of task goals and a technological emphasis was seen in all phases of their work. Students were able to successfully undertake extended tasks in technology and incorporate a large number of variables. They had a better understanding of the role and place of models, conceptually complex ideas for young students. They understood that models could be used for testing some aspects and could be used to show ideas in a 3-dimensional form.

Finally, in 1999 students were no longer constructing any artefact. Planning, construction and testing was strongly tied to conceptual understandings. Teachers had assisted students to make stronger links between the conceptual and procedural considerations of tasks when they were engaged with planning, constructing and testing. Students therefore manufactured with conceptual aspects in mind and could incorporate the main conceptual aspects in solutions. This was an improvement on 1998 where often a practical dominance overshadowed conceptual foci.

In summary, it was seen that effective conceptual and procedural understandings in technology throughout 1999 were shown in student conversations and work. Students' technological understandings were evident in all phases of their learning such as planning, constructing, testing, reflection and evaluation.

- ***Effective ways of working***

With teachers more mindful about the need to encourage students to work iteratively, students developed an ability to make strong connections between different stages in developing artefacts and processes. Of importance were teacher formative interactions based on descriptive feedback, as these assisted students to work iteratively throughout their technological process.

Teachers also helped students understand the purpose of activities and reasons for undertaking particular tasks. Clear purposes and understandings of task goals meant students were able to think about the whole task throughout the technological process. With teachers encouraging students to keep in mind all task aspects, students were less likely to fragment task requirements or to assign higher importance to some at the expense of others. Students became very aware of the whole task, task goals and the purpose of the activities they were undertaking.

Finally, students were better at identifying their own technology gaps. They could decide whether they had met the task goals and how well. Teacher feedback was essential as it focussed on the qualities of student work and specific ways in which work could be improved. This beneficial feedback enabled students to be directly involved with seeing for themselves where their difficulties lay and whether they needed to seek assistance.

Chapter 8 described effective student learning in technology. There was evidence of more effective understandings about the nature of technology, more effective conceptual and procedural understandings, and more effective ways of working in technology. Chapter 9 discusses the significant findings of the study and provides the concluding remarks.

9. DISCUSSION AND IMPLICATIONS

9.1 Introduction

The major conclusions of the study are discussed in this chapter and the implications for technology education and further research are considered. Section 9.2 summarises findings related to the first research question. It describes primary teachers' 1998 technology education teaching and assessment practices and how these impacted on student learning. The findings indicate teachers' technological pedagogical content knowledge (PCK), which includes understandings of assessment and technology education, and understandings of young students' learning in technology, directly influences their classroom practices. PCK influences teachers' formative interactions and ability to provide descriptive feedback (Bell & Cowie, 1997; Black & Wiliam, 1998a; Sadler, 1998; Shulman, 1987).

Section 9.3 addresses the 1999 research questions. It describes how teachers' enhanced technology PCK impacts on planning, teaching, assessment and the enhancement of student learning (Bell & Cowie, 1997; Black & Wiliam, 1998a; Fleer, 1999; Sadler, 1998; Shulman, 1987). Teachers' enhanced PCK was constructed through a collaborative, ongoing, teacher development programme with accompanying classroom support and guidance (Bell & Gilbert, 1994). Important for helping teachers' planning, teaching and assessment in technology was the use of a planning framework based on the essentials of technology. Further, embedding formative assessment in technology and undertaking it in a sociocultural, transactional, conversational and future oriented way strengthened student technological learning (Gipps, 2002; Torrance & Pryor, 2001). Providing descriptive feedback helped students to be more effective technology learners (Gipps, 2002). Section 9.4 discusses the implications of the findings and section 9.5 discusses the implications for further research.

9.2 Primary teachers' 1998 technology teaching and assessment practices

The first research question, the focus of section 9.2 was:

> What are primary teachers' emerging planning, teaching and assessment practices in technology education and how do these influence students learning in technology?

Chapters 4 and 5 outlined the 1998 research findings and showed a strong correlation between teachers' understandings of technology and technology education and the ways they planned, taught and assessed technology in their primary classrooms. Their understandings of technology and understandings and practices in technology education, their understandings of young students' learning in technology and their difficulties with technology assessment impacted on their teaching, especially their formative interactions and the provision of descriptive feedback. In consequence all impacted on student learning.

9.2.1 Understandings of technology and technology education

This study showed that in 1998 teachers had broadened their understandings of technology and technology education from earlier research (Jones & Carr, 1992; Jones & Compton, 1998; Moreland, 1998) as they were now able to choose technology tasks appropriate to particular technological areas and their students. Technology education was established as a separate learning area in both schools, allocated separate teaching time and included in school plans. Teachers had developed reasonably consistent views about the nature of technology, which included notions of design, innovation, problem solving, creativity, and creating new and improved products. Technology was seen as part of the real world and a practical pursuit. However, a detailed understanding of appropriate technological knowledge and principles was absent. The influence of subject subcultures and background experiences was evident in their views and they ways they taught technology (Jones & Carr, 1993a; Paechter, 1992) and they often veered away from teaching technology towards other more familiar learning areas.

Teachers understood the need to address different technological areas, were developing confidence in teaching across the areas, and understood that all three technology curriculum strands should be included in a unit of work. Yet Strand B, technological capability, which included hands-on, making aspects, received the most weighting. Technology education was viewed as a practical subject prioritising multiple solutions and student creativity. Students were expected to draw, construct and test when creating artefacts and teachers concluded that when students were involved with these aspects they were teaching technology. Teacher views were broader than the surveys of 1992 (Jones & Carr, 1992, 1993a), and 1994 (Jones, 1995) but were still a restricted view of technology and technology education.

9.2.2 Difficulties teaching technology education to young students

The findings of this study showed that teaching technology in 1998 presented many difficulties. Though a nucleus of broadened understanding was developing, teachers' confidence and practices when teaching technology often wavered. Technology was very much an unformed subject area, lacking robustness and assumed somewhat amoeba-like fluctuating configurations. Like other research (Jones & Carr, 1993a; Paechter, 1992) this study showed that other more established learning areas overtook technology when difficulties arose, influencing teachers' technology practices and resulting in a loss of central focus on technology. Better-established existing subject subcultures, such as language and science, influenced their technology teaching. Technology had yet to become an integral part of the talk of classroom teachers and the community, with little development of a shared, specific language of technology, which Black (1998) states is vital for undertaking relevant assessment consistent with the particular learning area.

Yet despite teachers' problems in planning, teaching and assessing technology, students showed high levels of engagement and enjoyment through the units, indicating teachers' enthusiasm for technology and overall ability to engage with and teach young students. General pedagogical practices and classroom organisational aspects were very good. As technology teachers though, they were novice-like, being newcomers to the technology education community of practice

(Lave & Wenger, 1991; Rogoff, 1990). As Black, et al. (2001) argue, misunderstandings related to the specific nature of the subject influenced knowing how to teach it successfully. Insecure technology subject knowledge lead to somewhat restricted classroom practices (Harlen, 1999) and teachers' rather precarious PCK affected their ability to develop and enhance student technological learning (Askew, et al. 1997; Shulman, 1987). Difficulties were shown in attempts to identify appropriate learning goals, develop ongoing iteration between different stages of the technological process, assist students to realise their ideas and create suitable technology classroom environments for fostering student learning.

- ***Difficulties identifying appropriate learning goals***

Teachers' developing concepts of technology and technology education had led to their identification of suitable technology tasks for students. However, as in Jones & Carr's research (1993a), technology concepts were not yet robust enough to retain subject integrity. Coupled with ideas that technology is a learning area particularly suitable for integration with other learning areas (Jarvis, 1993; Solomon & Hall, 1996; Stables, 1997) this meant technology changed shape and focus, often disappearing altogether. Details of the different technological areas, including the associated knowledge bases acknowledged as essential by Jones & Carr (1993a), were not well articulated or understood by teachers. Therefore, they showed some confusion in identifying technological learning outcomes and progression in learning within the chosen technology tasks. Technology direction and focus shifted and faded with teachers unsure of where next to take learners.

Difficulties in identifying suitable technology learning goals often meant tasks were very closed in nature or alternatively extremely open. Teachers were not fully aware of how different kinds of tasks influenced student learning. The complex thinking and execution students required to undertake and solve technology problems were not well understood. Misunderstandings meant teachers did not foresee many problems that students might encounter. Thus teachers conformed to Anning's (1997) research being unsure of what was occurring and how to best assist. When closed tasks were defined student learning was affected in a number of ways. For example, students produced

similar artefacts, undertook tasks in similar ways and were afforded few opportunities to develop divergent ideas. As Solomon & Hall (1996) found, over-specification led to lack of student ownership and control. When tasks were openly defined, learning was also influenced. For example, students were unsure of task guidelines, sometimes adding unnecessary features to artefacts. They were unsure of direction and at times disengaged from learning, no longer clear of where they were going or what to do next. Finally, they were not sure when they were finished, waiting for the teacher to tell them. With teachers not sure of task technological directions and requirements they had difficulties assisting student technological development and there were decreased opportunities to directly intervene and model ideas and skills to accelerate student learning (Anning, 1997). Formative assessment could not be a collaborative enterprise (Pryor & Torrance, 1996) as there was not a mutual understanding or appropriate collective action on the part of teachers and learners (Sadler, 1989).

- ***Problems fostering iteration***

All teachers underestimated difficulties students would have in relating and transferring understandings and skills from one learning area to another and from one technological activity to another. As with the research of Anning (1994) and Jones and Carr (1993a) the result was the development of a linear, discrete technological process. Students did not understand the need to make connections between previous activities, current activities and future activities. In consequence student learning became piecemeal and disjointed. Thus students did not always work iteratively between developing 'thought' skills and 'action' skills, a process considered crucial for developing technological understandings and skills (Anning, 1993; Benson & Raat, 1995; Kimbell, et al. 1996). As found by Anning (1994) and Jones & Carr (1993a), evaluation as a key feature of the process was often bolted on, rather than interwoven into the process. Few opportunities were provided for iterative reflection, so students rarely assessed or reviewed throughout the technological process (Stables, 1997). Additionally, appropriate technological language was often sidelined by teachers, so student technological progress was inhibited by students' inability to express ideas and to convey iterative thinking (Anning, 1993, 1994; Solomon & Hall, 1996).

Like the research of Jones and Carr (1993a) this research showed that the structuring of lessons influenced how students undertook their technological process. Students were not always cued by teachers to, for example, think about materials, or fixing and joining devices and mechanisms before they started design drawings (Anning, 1994, 1997). No teachers used a holistic approach to teaching, learning and assessment as advocated by Jones, et al. (1994). Rather, focus was given to atomistic goals and tasks. This meant that students did well on some parts but their overall performance was not as strong as on the parts, corroborating the findings of Jones and Carr (1993b).

Student technological conceptual development received limited attention, especially the impact that conceptual development has in linking thought to action. The importance of developing conceptual understanding alongside procedural aspects was somewhat ignored (Kimbell, et al., 1996; McCormick, 1997) which meant that the complex interactions of understanding and building, modelling and idea-generation were not attended to.

- ***Problems assisting students to realise their ideas***

All teachers understood the importance of students realising their ideas (Stables, 1997). However, they were unaware of the difficulties young students face when trying to envisage their thinking in 2 or 3 dimensions (Anning, 1994, 1997; Jones & Carr, 1993b). Concurring with Jones' and Carr's (1993a; 1993b) findings, this was particularly evident when teachers wanted students to make models rather than the real thing. For example, measurements and appropriate materials were ignored. Drawing was also a minor mode of communication in classrooms. Teachers were therefore unsure of how to teach drawing and how graphicacy promotes technological learning (Anning, 1997). As with the findings of Anning (1993), the teachers' limited drawing arsenal meant that they found it problematic to give students guidance and appropriate feedback on how to improve.

Teachers omitted to plan and teach graphicacy and technical skills. Analogous to Rogers' research (1998) a fragile link was often found between students' design intentions and their subsequent constructions. Teacher support was not strong enough in promoting correlation between what students intended to do and what

they produced (Fleer, 2000). Direct instruction in necessary technical skills was often not given. Teachers expected students to acquire technical skills ad hoc, rather than through deliberate planning and teaching (Anning, 1994). With a lack of procedural knowledge themselves, teachers expected students to acquire such knowledge through their own 'doing'.

- ***Understanding how to enhance student learning in technology through suitable classroom environments***

The findings demonstrate that all the teachers believed practical activity was at the core of student technological capability (Kimbell, et al. 1996; Stables, 1997) and set about to create classroom environments that fostered opportunities for practical involvement. They understood that the classroom culture and student expectations influenced the way students undertook technological activities (Jones & Carr, 1993a). They discussed the need for students to be involved with authentic activities (Brown, Collins & Duguid, 1989), believing authenticity meant child-centred and child-appropriate activities. This was in contrast to Hennessy, et al. (1993) and Jones' and Carr's (1993a) view of technological authenticity, which is based on technological practice and technological problem solving principles as practiced by technologists.

Teachers developed supportive and challenging environments, fostering positive attitudes of self-esteem and motivation (Stables, 1997). Risk taking and failure were viewed as positive dispositions for fostering technological capability. However, teachers were reluctant to intervene in direct ways with students, believing adult intervention hindered student creativity. Affirming Anning's (1997) research, this meant students learnt that drawing, making and testing were often self-help zones.

Teachers also developed environments that encouraged collaborative and individual ways of working. Problem-solving approaches were highly regarded which meant students were motivated and involved in risk-taking situations (Kimbell, et al. 1996; Stables, 1997). Being group and socially-based, technology learning benefitted from the sharing of ideas which impacted on the problem-solving situation (Lave & Wenger, 1991; Rogoff, 1995). Missing from the

problem-solving situation was a focus on issues and values surrounding the technological decisions. User considerations, for example, were often afforded tacit emphasis, which resulted in less meaningful student decision-making (Stables, 1997).

Like Jarvis (1993) teachers viewed technology as an ideal vehicle for making cross-curricula links and they devised environments which fostered this approach. Also like Jarvis (1993) they saw this as unproblematic. The cautions of Jones and Carr (1993a) against novice teachers teaching technology in an integrated way with other subject areas were unknown. Consequently technology was often subsumed by other more familiar subject subcultures (Paechter, 1992).

9.2.3 Difficulties with formative and summative assessment

- ***Formative assessment***

As these teachers were not able to articulate in detailed terms technological and procedural aspects, they were unsure of desired technological goals for their particular students. This influenced their formative interactions as they found it difficult to know what detailed action to take in the classroom, as they were unsure of current positions of students and where students were going (Gipps, 1994; Harlen, 1998; Torrance & Pryor, 1995). It was found that teachers did not hold such a well-developed sense of progression in technology as they held in other subject areas, for example reading, for which there is an established assessment culture in primary schools. Impacting on teacher technology assessment practices were the existing assessment subcultures in schools, school-wide policies, teacher experiences and teacher subject expertise. What teachers relied on for technology assessment became largely dependent on their practices in other curriculum areas. With teachers having limited technology subject knowledge, they found it difficult to change it so that it was suitable for classrooms and assessment (Bell & Cowie, 1997; Black & Wiliam, 1998a; Sadler, 1998; Shulman, 1987).

Beginning with their planning, teachers often focussed on activities and broad achievement objectives rather than on specific learning outcomes. In addition, the identified learning outcomes were often not technological. So their planning focus

translated to formative interactions with a widespread, generalised focus. This meant it became almost impossible to provide descriptive feedback to enhance student performance at the detailed technological conceptual and procedural level (Black & Wiliam, 1998). Feedback was often not in terms of technology and therefore the action required by the students following the assessment was not technology-related (Hargreaves, et al. 2000). Because of teachers' difficulties identifying the important detailed conceptual and procedural technological aspects, opportunities to build on these were under-valued and interactions at the organising technological principle level were also minimised (Crooks, 1988; Harlen, 1998). A detailed technological model for informing formative assessment had yet to develop.

As well, guidance about the ways students might progress in learning linked to clear understandings of the technology curriculum and its learning goals had not developed (Black, 1998). This meant that the important conceptual, procedural and attitudinal technological aspects that could have been taught were not considered (Driver, 1989). Instead, teachers focussed on giving praise, task completion and social and managerial aspects. These aspects have been found to have a negative effect on learning as they may draw attention away from the task and towards student self-esteem (Black & Wiliam, 1998a; Crooks, 1988).

Formative assessment lacked detailed and specific focus for helping students identify their strengths and weaknesses, ways to reach next steps and how to take them (Tunstall & Gipps, 1996). This meant students had fewer opportunities to take control of their own learning (Butler, 1987; Harlen, 1998; Mavrommatis, 1997). Also lacking was a consistent emphasis on detailed technological conceptual and procedural aspects, aspects that form the basis of descriptive feedback. This resulted in teacher difficulties enhancing student progress as providing descriptive feedback is considered a key act in formative assessment to enhance progress (Hargreaves, et al., 2000; Tunstall & Gipps, 1996). Teachers wavered between giving praise, task completion, social and managerial aspects and broad conceptual and procedural aspects in their formative assessments. So students often became confused about the main task purposes. The need to focus

on the technological qualities of students' work, technological goals and specific ways in which students work could be improved was minimised.

As technological problem solving is set in complex learning situations and undertaken over consecutive days rather than as one-off, small, piecemeal tasks, goals need to be clearly set and feedback very sophisticated. Assessment in technology is therefore dependent on confident, informed assessors able to interpret observations, conversations, interactions and student outcomes with assurance (Sadler, 1998). Clearly, as novice technology teachers, this was not the case in 1998. The detailed, focussed assessment strategies conducted in continuous, connected, day-to-day ways, as part of normal classroom routines, were absent (Blenkin, 1992).

Difficulties were also evident when teachers tried to establish students' current technology positions based on previous achievements. Though teachers advocated this prospective view of education, emphasising student strengths in order to see what qualities there are to learn with (Lally & Hurst, 1992), they had difficulties carrying out their intentions. As the starting point for young learners is what they can do, this needs to be determined so learning can be extended from that point. Being unable to determine or describe the technological strengths of students, it was difficult for teachers to build on them.

- ***Student self-assessment***

The teachers valued student self-assessment and encouraged self-evaluation and self-direction. In extended technology problems self-assessment becomes very important, as students usually work over many days on multiple, connected tasks, often self-monitoring and self-deciding on next problem-solving directions. If students relied solely on teachers' comments about their work they would become somewhat immobile. Students assessing their own progress, taking responsibility for and managing their own learning was the goal encouraged by teachers (Black, et al. 2001). Student difficulties arose when they were unsure of how to interpret teacher feedback, when teachers confused task goals and when students were uncertain of task goals. Guidelines and criteria for helping students

did not always have consistent technological meanings for students and teachers (Wiliam, 1998).

With teachers struggling to have clear understandings of technological learning goals and possible paths of progression towards them, difficulties in recognising where students were with their technological learning, the provision of descriptive feedback to help students close gaps and the fostering of self-assessment were somewhat haphazard (Sadler, 1989). However, all teachers recognised the importance of building a positive, collaborative classroom culture with some student involvement in assessment (Harlen & James, 1997; Gipps, 2002).

- ***Summative assessment***

As with formative assessment, summative assessment was viewed by these teachers as a low-stakes undertaking embedded in classroom programmes. It involved interpretive summaries of student learning (Delandshere & Petrosky, 1998) and was carried out at intervals when achievement needed to be summarised and reported (Harlen, 1998). Like formative assessment teachers had difficulties with summative assessment in retaining a reliable and valid technological focus. All teachers acknowledged their difficulties. Practices from other learning areas and school-wide guidelines influenced practices in technology.

A range of aspects became the focus for summative assessment, including task completion, social and managerial aspects, and the broad technology achievement objectives, all constituting individual items of assessment. The problem became one of selection and making decisions on which information to sum up (Harlen & James, 1997; Harlen, 1998). Often the focus was not consistently held. As the information gathered was not usually technological and was often untidy, incomplete and contradictory, it was difficult for teachers to smooth out the ups and downs in order to look across the range of work in a holistic way (Harlen & James, 1997). Specific technological conceptual and procedural aspects that related to particular technological areas were not addressed. In addition, teachers were not able to undertake a balanced reflection of the whole of student

technological learning (Jones, et al. 1994). Therefore effective technological information was not gleaned for use to enhance future learning.

Making holistic judgements as advocated by Jones, et al. (1994), Kimbell (1994) and Wiliam (1998) was not part of teachers' assessment strategies. No teachers attempted to make judgements related to summing up all the learning involved with the extended tasks. Therefore, summative assessment was not a fair summing up of student achievement, as no attempts were made to sum up all that occurred. A skewed view was presented thus misrepresenting students' actual achievement. This was not surprising given that technology education was still in its early years and had yet to establish a well-defined community of practice (Lave & Wenger, 1991) with shared constructs of quality (Wiliam, 1998). Instead teachers selected a few particular aspects or events for attention. This meant assessment of student learning was not well matched to the learning undertaken. It meant a biased, partial view of performance, which described only certain slices of what students had undertaken and achieved was described. Progress was described as the development of atomistic individual skills, knowledge and procedural quality (Kimbell, 1997). No teachers were able to deconstruct work to look for evidence of quality, nor put it back together again to see how the parts worked together (Kimbell, 1997).

However, teachers did attempt to make anecdotal summative assessments to help them see some learning intentions, content and quality (Jones with Hawe & Mather, 1995; Kimbell, 1997). Also in their favour was the focus on positive enquiry with an emphasis on providing information to take learners' achievements further through describing opportunities for new learning (Duschl & Gitomer, 1997; Lally & Hurst, 1992). They just had problems understanding the specific technology for focus and how to holistically assess.

Though these teachers were gaining practical experiences in teaching technology, they had yet to develop the level of understanding required to be competent, confident teachers in all technological areas. A deep understanding of technology PCK had yet to develop. Doubt was ever present, especially in deciding on suitable learning outcomes, appropriate technology pedagogy and relevant

assessment practices. Descriptive feedback, with an emphasis on valued specific technological learning goals and a focus on tasks and their substance, was absent. In becoming effective technology teachers they were in the early stages. However, they demonstrated an ability to reflect on their own practice and recognised gaps in their understanding and teaching of technology. They were willing to learn more about technology in order to enhance and refine their technology teaching.

9.3 Enhanced teaching and assessment practices and the impact on student learning

The second and third research questions are the focus for section 9.3. They were:

> What can assist teachers to develop their teaching, learning and assessment practices in technology?
>
> In what ways does teachers' enhanced pedagogical content knowledge in technology impact on planning, teaching and assessment practices and what is the impact on student learning?

The data related to the 1999 professional development programme concentrating on the second question were presented in Chapter 6. The professional development programme contributed to successful change. With a focus on the improvement of teachers' pedagogical content knowledge student technological learning was more effective. The focus had been on planning, teaching strategies, assessment strategies, understandings of students' learning in technology and formative interactions, especially the provision of descriptive feedback. Teachers no longer expected activities to do the teaching on their own (Rhine, 1998). Instead, teachers' formative interactions with students were guided by their detailed planning which assisted them to make informed instructional decisions. The findings of this study clearly demonstrate that articulating technological aspects of tasks means a more sustained focus in formative interactions on those aspects.

A number of aspects contributed to the development of teachers teaching, learning and assessment practices in technology. These included the initial examination

and reflection of personal case studies of their own teaching practice in technology, a beneficial beginning point. The extended timeframe with ongoing opportunities to get-together with other teachers and researchers was also helpful for challenging, extending and consolidating ideas (Shulman, 2001; Treagust & Rennie, 1993). Teachers became metacognitive about their own teaching, a key attribute in bringing about successful change (Bell & Gilbert, 1994). Of particular importance was the use of the planning framework and the focus on technological learning in conceptual, procedural, societal, technical and overall dimensions as this keyed teachers to think about how to transform their own subject knowledge into suitable student learning goals (Bennett, 1997; Shulman, 1987).

In becoming more expert in the field of teaching technology, these teachers learnt how to apply teaching knowledge in particular technological, social and organisational contexts (Sternberg & Horvath, 1995). Repeated use of the planning framework resulted in teacher change, which included a clearer understanding about intended learning goals. This helped teachers learn what to listen for (Rhine, 1998) and be surer about the formative interaction foci with their students. Used as a guide, the planning framework assisted teachers to work with a more planful and self-aware approach (Sternberg & Horvath, 1995). The planning framework provided a detailed, organisational model closely related to the technology curriculum and learning outcomes and it guided teacher focus for making decisions about student progress (Black, 1998a).

Chapters 7 and 8 outlined the 1999 findings from teachers and students working in technology classrooms and so presented data related to the third research question. Like the findings of 1998, a strong correlation between these teachers' understandings of technology and technology education and the ways they planned, taught and assessed technology was shown. Increasing PCK positively influenced their competence and confidence in undertaking technology education. Growing understanding and practices in technology education including improved understandings of young students' learning in technology and more appropriate technology assessment influenced their teaching, especially formative interactions and the provisions of descriptive feedback. Changed understandings and practices impacted on student learning.

9.3.1 Enhanced understandings and practices in technology education

- *Planning technology*

Black, et al. (2001) asserted the need to analyse the interplay between learning and assessment, views of the nature of subject matter and the selections and articulations of goals and subject matter that follow. To assist this analytical process the planning framework was utilised well by teachers. The findings show that in 1999 all teachers made significant gains in their ability to plan technology tasks based on detailed technology goals and in anticipating student technological direction. Completing the planning framework allowed them to forecast what they wanted their students to achieve technologically and assisted in facilitating change with technology planning. Instead of defining technology goals through the broad technology curriculum achievement objectives, a shift was made to defining technology in specific conceptual, procedural, societal and technical categories, along with a description of key aspects of technological practice and the identification of task definitions to indicate general technological direction. The relationship between all three was evident with their robust interconnections. Enhancing teacher knowledge of technology and technology education helped teachers provide better directions for learning (Black, 1995).

The strong detailed focus on technological aspects was in contrast to 1998 where little detail was evident, no categorisation was undertaken and no specifics for technological learning were itemised. Improvement from 1998 was seen in teachers' ability to match tasks and activities with learning outcomes. They were able to identify learning outcomes alongside the tasks and activities in an iterative manner always keeping technology and their students in mind. A clearer conception of the technology curriculum, its learning goals and ideas about how students might progress in technology ensured detailed, planning with articulate goals matched to the task and their substance. Hattie and Jaeger (1998) and Black and Wiliam (1998a) argue that goal setting together with descriptive feedback enhances learning. With teachers' enhanced planning, the first aspect of clear goal setting was being achieved.

The process of translation employed by teachers in 1999 where they identified learning outcomes suitable for their students distinct from teacher understanding

of learning outcomes was also a departure from 1998. Translating different aspects of tasks into aspects suitable for particular students clarified at the planning stage how teachers might assist students to develop particular technological concepts in the classroom. The translation helped teachers to think about what students should be aiming for in student terms (Harlen, 1998). The blending of technology content and a planning pedagogy was evident and indicated increased PCK (Shulman, 1987).

Continual use of the planning framework led to alterations in teachers' understandings and practices. Its use by teachers indicated an enhanced understanding of what was to be learned and taught in technology, essentials for sound teaching (Shulman, 1987). Changed practices included a better ability to audit technological activities for the relevant technology, a better ability to ascertain their own technological knowledge gaps and an enhanced ability to decide on valued technological learning goals for their students. Teachers could transform their own knowledge into suitable knowledge and goals for students and focus more readily on technological aspects during planning. A clearer grasp of the subject matter, a pedagogical sense of students' likely understandings and a sense of the conceptual area being explored developed (Duschl & Gitomer, 1997). This led to enhanced planning, which meant teachers could think about how students might bring different conceptual, procedural, societal and technical (CPST) aspects together and how students might put the CPST aspects into action in an holistic manner. Teachers were able to tease out the learning outcomes of tasks in CPST terms and undertake a technology task analysis to ascertain task affordance. Teachers considered potential, intended, negotiated and unexpected learning opportunities. The focus centred on analysing tasks and their substance, a critical pedagogical procedure in which teachers needed to engage, as this helped direct their attention to task-specific descriptive feedback and the aspects perceived to be the most important for the learner from the beginning (Driver, 1989).

Other gains in planning were evident in increased precision in thinking about progression and an improved ability to make stronger linkages between detailed learning outcomes and technological practice. They employed a more iterative

process when developing the task definition, technological practice goals and specific concepts and procedural aspects in technology. They also demonstrated a better balance across conceptual, procedural, societal and technical features of technology. All of this indicated increased PCK.

In planning lesson sequences the most noticeable shift for teachers was in their deliberate planning of opportunities for students to review, shift and modify their thinking and work. No longer were testing, review and self-evaluation planned as end-point activities in lesson sequences as they were in 1998. In 1999 teachers planned so students could operate in an iterative cycle of review and analysis. In fostering student self-assessment teachers were acknowledging the importance of students as self-monitoring, self-regulatory learners (Broadfoot, 1996b; Gipps, 2002; Wolf, et al. 1991), as insiders rather than consumers of education (Sadler, 1989), and as supporting greater student autonomy for their learning (Bell & Cowie, 1997).

Finally, assessment was carefully considered when planning. Teachers' deliberate approach to forward plan for formative, summative and student self-assessment was in contrast to 1998, where only student self-assessment and summative assessment were considered. Teachers believed the clear articulation of learning outcomes assisted them to think with foresight about possible questioning, language to use and their interactions with students. The elevation of attention to formative assessment indicated a belief that a concentration on formative assessment is likely to improve learning (Black & Wiliam, 1998b; Crooks, 1998). Also the 1998 attention to social and managerial aspects for summative assessment was sidelined. Planning for summative assessment was thought out, intentional and focussed on technological aspects. As with summative and formative assessment, student self-assessment, both formal and informal, was attended to when planning. All foreseen assessment practices indicated gains teachers made to embedding assessment in their teaching and a more detailed understanding of technology and technology education. Importance was placed on being informed assessors focussed on detailed technological aspects (Sadler, 1998), yet also able to be conducted on a day to day basis (Blenkin, 1992).

In all, it can be seen that the use of the models heavily impacted on teachers' planning in 1999. The planning framework assisted in teasing out technological learning outcomes; a close relationship was forged between task definition, key aspects of technological practice, and learning outcomes. Planned learning experiences were linked closely to learning outcomes. Potential, intended, negotiated and unexpected learning outcomes were considered. An iterative process of planning included thinking about the task, technological learning outcomes, knowledge of the curriculum and knowledge of students. All teachers became focussed on students' learning of technology and employed a considered approach to planning.

- ***Teaching technology***

The findings illustrated that these teachers improved their technology teaching in their classrooms. They considered that conceptual and procedural aspects and how they relate in different technological areas influences task complexities (Jones & Carr, 1993a). The influence of the nature of the task on learning was taken into account. Tasks were no longer so openly defined that any solution was possible. Instead opportunities were provided and fostered for students to develop and include particular technological concepts alongside procedural aspects (Kimbell, et al. 1996; McCormick, 1997). Though a variety of solutions and ways of reaching them were fostered, solutions needed to be inclusive of intended goals.

Teachers demonstrated a heightened awareness of the importance of a hands-mind balance and were particularly thoughtful in focussing on appropriate technological concepts and principles, as they believed these both helped students develop technological understandings alongside procedural aspects. It was important to link thought to action through the interactive strands of building, modelling, idea-generation and understanding (Anning, 1994; Jones & Carr, 1993a; Kimbell, et al. 1996; McCormick, 1997; Welch, 1997 in Parkinson, 2001).

Teachers developed enhanced practices in dealing with transfer issues. In contrast to 1998, the aspect of transfer was not left to the individual learner or to chance. Teachers' awareness about student transfer difficulties was heightened and they deliberately taught for transfer. They were especially attentive to the transfer of

mathematical and scientific ideas to the technology situation and the transfer of ideas between different technological processes. If teachers are mindful of transfer and they teach for it, the problems associated with conceptual knowledge in a curriculum with a strong emphasis on procedural knowledge are lessened (McCormick, et al. 1994).

All teachers became more mindful of iteration and planned to overcome the linear, discrete process many students had adopted in 1998. Teachers employed a number of pedagogical strategies to overcome disconnected technological processes including written, diagrammatic and verbal means, and appropriate management techniques. It was shown that the combination of strategies guided students to see how stages linked to one another encouraging iterative ways of working. Teachers' targeting of technological aspects encouraged student use of the same, enhancing student ability to express ideas, develop iterative thinking and ways of working and foster technological progress (Anning, 1993, 1994; Solomon & Hall, 1996). In addition, it was shown that when teachers use strategies such as flow diagrams and charts to keep technological processes to the fore, students are likely to connect stages to each other. The visual prompts as well as conversations assisted iteration as students were led to think ahead to next steps and to think back to what had occurred before. Teacher-developed templates also helped for they provided direct, individual prompts keeping the essentials of the technology task to the fore. Management techniques of gathering students together at the beginning and end of sessions to discuss progress-to-date and next steps also contributed to students developing iterative capabilities. Attempts to help students reflect on their experiences by revisiting them as well as to future forecast assisted to solve the transfer problem (The Cognition & Technology Group at Vanderbilt, 1990).

Teachers' views of technology changed from being mostly centred on Strand B, the capability strand of the curriculum, to include an integration of the three strands. Not only were they aware of the integration in their planning, they also ensured balance in their teaching. Teachers and students focussed on the whole task, rather than isolated, disconnected steps. Integrative technological activity was fostered (Jones, et al. 1994). Technological activity was viewed as a complex

and iterative process requiring a range of different approaches to solve any problem (Hennessy, et al. 1993).

Teachers frequently employed demonstrator roles where they modelled drawing in front of students to show how drawing could be used to represent ideas and to show the development of ideas. As part of their tool-kit teachers used notebooks, annotated drawings, orthographic drawings and architectural and engineering drawings to foster student designerly thinking and behaviours. As Anning (1997) advocates, teachers offered examples of what design drawings look like and they showed ways to draw ideas. This all contributed to teachers being able to give students guidance and appropriate feedback, as they became more skilled themselves with drawing. The teachers were modelling effective drawing strategies through demonstrating desirable ways to solve technological problems and were making explicit their tacit knowledge of designerly thinking and behaviour (Hennessy, 1993).

Technical skills were not left to chance development and teachers gave direct instruction when necessary. Teachers acknowledged that procedural knowledge was not simply acquired by learning through doing; it needed to be planned for and taught. As with the findings of Fleer (2000) and Anning (1994, 1997), these findings demonstrate the benefits of giving direct technical instruction to young students. Technical skills, including drawing and manufacturing skills are learnt skills and their acquisition can be enhanced through instruction.

Teachers expected students to actively seek information from a variety of sources to solve problems. As such they provided technology-rich environments within which students could operate. For example, they often began units by examining existing technologies that were relevant to the students' problem. This reflected the idea that actual technological problem solving involves modification and adaptation of existing technologies (Hennessy, et al. 1993) and that student examination of existing technologies helps them to understand the key features of those technologies. From this beginning point they could extent their ideas and build possible solutions. In 1999 their approaches were in direct contrast to their 1998 classroom approaches and those teachers in earlier research (Jones & Carr,

1993a) when they had students beginning their technological processes from scratch.

9.3.2 Enhanced assessment practices

The success of the intervention programme was seen in teachers' enhanced assessment practices. They became more knowledgeable and confident in formative classroom interactions and summative assessment. Assessment became focussed on the process as well as the product. It was undertaken in a dynamic, collaborative manner (Gipps, 2002; Lunt, 1994). Most noticeable was the strong emphasis on technological aspects. Teachers acknowledged the importance of planning and its influence on their formative interactions and summative assessment practices. The auditing and compilation of appropriate technological learning outcomes exerted a considerable influence on assessment practices, as teachers' detailed planning became a guide, prioritising desirable consequences for students (Black & Wiliam, 1998). As their planning outlined more adeptly the technology learning to be undertaken than in 1998, they were more able to recognise and respond to student learning for the purpose of enhancing that learning during the learning process (Bell & Cowie, 2001).

Formative interactions focussed on technological aspects with more assurance and competency. Not only was there more emphasis on providing feedback and assistance to students to develop technological conceptual and procedural aspects, the heavy attention on praise, task completion and social and managerial aspects that occurred in 1998 was no longer the prominent assessment feature in 1999. An enhanced understanding of formative assessment was demonstrated in terms of improved identification and articulation of student technological learning gaps. Feedback concentrated on the detailed technological conceptual and procedural strengths and weaknesses of students so they were more likely to take technological principles into account. It was shown that student gains are made in technology when teachers and students focus on specific aspects and particular qualities of student work, especially if clear advice on how to improve is included. Formative assessment was systematically used to identify next learning steps, an essential formative assessment element considered crucial for advancing student learning (Harlen & James, 1997). It was demonstrated that providing extensive,

descriptive feedback to students leads to greater student engagement and higher achievement when students and teachers plan and respond to such feedback (Black & Wiliam, 1998b; Gipps, 1994; Tunstall & Gipps, 1996).

Sadler (1998) pointed out that the more complex the learning situation the more sophisticated the feedback needs to be. The planning framework used by teachers assisted them to articulate the complexities of the technological problem with which students were dealing. Their detailed planning subsequently guided feedback, which they were able to give in a focussed, detailed and consultative manner (Blenkin, 1992; Sadler, 1998). Teachers deliberately fostered formative assessment as a collaborative enterprise and learners became members of the same community of practice (Wiliam, 1998) as shared understandings developed between teachers and learners. Strong mutual understandings and appropriate actions were built between teachers and learners (Sadler, 1989).

A growing understanding of student progression in technology was also shown. Teachers began to see how they could move students on and how they could build on their previous experiences and existing learning to progress student understanding. For the first time while interacting with students they considered where they might go next technologically based on current understandings and skills. Teachers' clearer conception of the curriculum and its learning goals, linked to ways in which students might make progress, was evident (Black, 1998). Enhanced PCK led to teachers teaching and assessing technology with more confidence. Teachers were more informed about the curriculum, the goals and how students might progress. They were therefore able to provide descriptive feedback guiding learners towards the valued learning goals. Additionally, tasks were well matched to goals and worked towards them, essential requirements for fostering successful learning (Bell & Cowie, 2001).

Unlike 1998, student self-assessment was not treated just as a concluding activity as student self-review became embedded in the technological process. Teachers had shifted responsibility for self-assessment to learners. Providing direct, authentic evaluative experiences for students helps them develop their own evaluative knowledge and this knowledge can be communicated through example

and through explicit provision during the teaching-learning process (Gipps, 2002). Student development of evaluative knowledge meant they could respond more easily to their self-evaluation and utilise the outcomes of their reflective thinking. The findings also demonstrate the importance of assisting students to understand what they should be aiming for and how to develop skills and strategies for making progress (Harlen, 1998). As Butler (1987) and Black and Wiliam (1998a) assert, embedding self-assessment in the technological process and focussing it on technology and towards tasks were powerful ways to assist student progress.

Teachers' summative assessment practices changed to include decisions about next learning possibilities. A future orientation was evident (Gipps, 2002; Torrance & Pryor, 2001). Assessment was no longer viewed as evaluating performance in a series of isolated tasks. Instead assessment was undertaken throughout connected tasks that developed particular technological conceptual and procedural aspects. Holistic assessment was better understood and utilised (Jones, et al. 1994; Kimbell, 1994; 1997), as teachers had a more comprehensive understanding of technology as an integrated activity. Teachers made overall judgements about the effectiveness of students bringing all aspects together when undertaking the technology tasks.

Teachers were summatively assessing throughout their technology units and not just at the end. They could then make decisions about progress students had made to that point, immediately address gaps, and think about next learning steps. Summative assessment within a sociocultural framework was dynamic, integral to teaching and learning and embedded in the social and cultural life of the classroom (Gipps, 2002; Torrance & Pryor, 2001). It focussed on the process of learning and especially conceptual and procedural technological aspects. Teachers' increased knowledge and experiences in technology education, as well as their better understanding of how students think and learn in technology had provided better understandings about appropriate summative assessment practices. Shared constructs of quality (Wiliam, 1998) have begun to be developed between teachers over the year of teacher development and their community of practice has become better-defined (Lave & Wenger, 1991). Teachers' growth in understanding technology in detailed conceptual, procedural,

societal and technical terms influenced all their assessment practices throughout 1999.

The findings demonstrate the importance of emphasising the quality of student work and framing assessments in cognitive rather than affective terms (Black & Wiliam, 1998a; Duschl & Gitomer, 1997). Focus was no longer on social and managerial aspects but on detailed conceptual, procedural, societal and technical learning outcomes. In effect this meant that the achievement objectives were no longer being used to represent one item of assessment as they had in 1998 and task completion was no longer chosen as an appropriate learning outcome for assessment. Instead the main focus was technological.

Pedagogical content knowledge was seen to be significant in the ways teachers taught and assessed. A strong relationship between teachers' subject knowledge, how it is transformed for classrooms and assessment ability was evident (Bell & Cowie, 1997; Black & Wiliam, 1009a; Sadler, 1998; Shulman, 1987). The use of the planning models had influenced teachers' teaching of technology. The framework compelled teachers to think about what and how they were going to teach and assess, impacted on their descriptive feedback and subsequently student learning. Teachers used their knowledge base for decision making and what they were going to do, transforming their content knowledge to be pedagogically powerful (Shulman, 1987). The intervention programme and a focus on careful planning had assisted the change process. The planning framework had evolved into a cognitive tool on which teachers could rely. In all, teachers became more confident, competent, informed teachers and assessors of student learning and achievement in technology. Teachers' enhanced understandings about technology education and student learning in technology, and their improved pedagogical approaches and assessment practices, resulted in effective student learning throughout 1999.

9.3.3 Student learning

This study contributes to understandings about young school students working in technology situations, an under-researched area (Anning, 1994; Fleer, 1999; Solomon & Hall, 1996). A particular contribution is made to understandings about

students involved with extended technology problems over time. Students' demonstrated high enthusiasm and interest in technology, which probably contributed to energetic lively classrooms and enhanced success in learning technology for many students. Differences between student learning in 1998 and 1999 were evident and were described in chapter 8. They included effective understandings about the nature of technology, effective conceptual and procedural understandings and effective ways of working in technology.

- ***Understandings about the nature of technology***

In 1998, few students had a broad and comprehensive understanding of the nature of technology; rather they tended to define technology in terms of the current activity being undertaken. For example, when making a timer, students thought that technology was making timers; and when making games, that technology was making games. The current activity defined concepts of technology. Narrow, construction views of technology predominated. The view that technology was a specific activity also meant students had difficulties generalising about technology and making links from one technology unit to another. Throughout 1999 there was a broadening of concepts fostered through teachers explicitly engaging students in planned, recurring opportunities to discuss the nature of technology. The 1998 narrow definition of technology as the current activity was less evident in 1999. Students began to view technology as designing and constructing many artefacts. As well, they included critical ideas related to improvement and betterment and understood that technology also meant specific, purposeful designing and making. The influence users have on the development and use of all technologies received attention. In all, student views about the nature of technology were more effective in 1999. This research confirms other research (Burns, 1992; Jones & Carr, 1993a; Jones, et al. 1994), showing that student' views of technology impact on their technological practice and learning in technology. Broader concepts about the nature of technology influenced students' understandings of technological concepts and processes.

- ***Effective conceptual and procedural understandings***

Throughout 1999 a greater complexity and sophistication of conceptual and procedural understanding of technology by students was evident in student

conversations and their work. Teacher focus on enhancing student understanding and use of appropriate technological aspects fostered their development by students. Student work showed emphasis of incorporating complex and sophisticated technological principles, concepts and procedures. Students' more effective understandings were evident in conversations and the interconnected phases of their work such as in planning, manufacturing, testing, self-reflection and self-assessment. Some researchers assert that practical activity is central to developing technological capability (Kimbell, et al. 1996; Stables, 1997). The findings of this study show that practical activity *alongside* the specific development of conceptual and procedural understandings is central to developing student technological capability. Hands-on involvement on its own is not enough, as was shown by the limited student capability in 1998. It wasn't until 1999, when teachers targeted specific conceptual, procedural, societal and technical aspects that student capability was more effective. Students no longer constructed any artefact; rather procedural aspects were strongly tied to conceptual understandings. Students therefore planned, constructed and tested with conceptual aspects in mind and were able to incorporate the main conceptual aspects in their solutions, an improvement on 1998 where a practical dominance often overshadowed conceptual focus.

In 1999, as teachers focussed on specific conceptual and procedural aspects in their formative interactions, students had more opportunities to develop and use appropriate technological vocabulary. Teachers explicitly targeted specific technological vocabulary and assisted students to incorporate it in their conversations and work. Technological concepts and procedures were embedded in student learning through constant articulation and exploration. Teachers actively involved students in the learning situation through dialogue. This meant students began to understand their strengths and weaknesses and how to deal with them. Their engagement in conferring, consultative conversations related to technological aspects with the provision of continual support and reinforcement and overt cueing by teachers, led to the enhancement of student understanding. This confirms the work of other researchers (Anning, 1993, 1994; Medway, 1994; Solomon & Hall, 1996) who argue that the ability for students to express technological ideas fosters technological progress.

With teachers targeting specific conceptual and procedural technological aspects throughout student technological problem solving, students were more able to target those aspects themselves. Students became clearer of task goals and a technological emphasis was seen in all phases of work. Teachers' descriptive feedback focussed on the learning goals and the substance of tasks and this assisted students to understand and realise task goals. Empirical evidence is provided to show that providing descriptive feedback and helping students understand what they should be aiming for are beneficial, as these assist students to make progress (Black & Wiliam, 1998a; Harlen, 1998; Hattie & Jaeger, 1998).

Additionally, with teachers' enhanced ability to teach many aspects of technology, students were more easily able to take many conceptual and procedural aspects into account. They were able to successfully undertake extended tasks in technology and incorporate a large number of variables. Descriptive feedback focussed on the strengths and weaknesses of their work and enabled students to take control of their learning (Butler, 1987; Crooks, 1988; Harlen, 1998; Mavrommatis, 1997; Tunstall & Gipps, 1996).

In 1999 students also had a better understanding than in 1998 of the purposes and uses of models, conceptually complex ideas for young students They better understood that models could be used for testing some aspects and could be used to demonstrate ideas in a 3-dimensional form. Teachers' successful strategies for developing students' understanding of modelling included demonstrations, explanations and the examination of models. This meant students were not confused between what is real and what is not when making their own models as other studies have shown (Anning, 1994; 1997; Jones & Carr, 1993a).

- ***Effective ways of working***

In 1999 students made effective connections between different stages in developing artefacts and processes, as teachers were more mindful of the need for students to work iteratively. Students believed that making connections throughout the technological process was important in achieving solutions in technology. Of importance were teacher formative interactions and the careful

structuring of tasks, for both ensured that students worked iteratively throughout their technological problem solving process.

Teachers were aware of difficulties students encounter when trying to envisage their thinking in 2 or 3-dimensions. In consequence they provided drawing and model-rich classrooms and worked alongside students to enhance their ability to develop mental images into working realities. Teachers also realised that procedural knowledge and skills are not simply acquired through doing. They need to be planned for and taught. This corroborates the findings of Anning (1994, 1997) and Fleer (2000), who advocate the need to give direct instruction. The findings that students' ability to draw and use plans is related to direct teaching, and that drawing abilities are learnt skills (Fleer, 1992; Solomon & Hall, 1996) are supported. It also corroborates Fleer's (2000) findings that young students use designs for making and make strong links between design intentions and subsequent constructions when supported by an informed teacher.

As Anning (1994) advocates it is important for teachers to develop student technological capabilities in a structured way rather than haphazardly. This study provides empirical evidence backing this claim, as teachers worked to ensure students understood the purpose of activities and the reasons for undertaking particular tasks. Having a clear purpose and secure understanding of task goals, meant students were able to think about the whole task throughout the technological process. With teachers encouraging students to keep in mind all task aspects, students were less likely to fragment task requirements or to assign higher importance to some aspects at the expense of others, aspects in evidence in Jones and Carr's (1993a) earlier work in New Zealand schools. In this study students were shown to be aware of the whole task, task goals and the purpose of the activities they were undertaking. Classroom-based evidence is provided to show that students, as young as six years old, can work on extended problems holistically when supported by an informed adult.

Finally, students began to identify their own technology gaps. They were able to ascertain whether they had met the task goals and how well. Teacher feedback was essential for students to identify and close technology gaps, as teachers

focussed on the qualities of student work and specific ways in which work could be improved. This beneficial feedback identified strengths and weaknesses of student work enabling the students to be directly involved with seeing for themselves where their difficulties lay and whether they needed to seek assistance. The findings of this study provide classroom-based evidence of the positive value of teachers using descriptive feedback, as this enabled students to understand what they should be aiming for, ways to get there and what next steps to take.

It was difficult to write about effective student learning without acknowledging the pivotal role of teachers for they played a powerful role in assisting students to understand and do more in technology. Though novices in teaching technology, these were very good classroom teachers. This meant they could grapple with new ideas and take them on board. They were willing to try everything and their success in becoming better technology teachers is attributable to their determination to succeed, willingness to try new ideas and their constant questioning and seeking advice.

9.3.4 Summary

The findings indicate that teachers' technological PCK including perceptions and understandings of assessment and technology education and understandings of young students' learning in technology, directly influences classroom practices, particularly formative interactions (Bell & Cowie, 1997; Black & Wiliam, 1998a; Sadler, 1998; Shulman, 1987).

The contention that teachers' enhanced PCK in technology impacts on planning, teaching, assessment and student learning (Bell & Cowie, 1997; Black & Wiliam, 1998a; Fleer, 1999; Sadler, 1998; Shulman, 1987) is supported. Teachers' PCK was developed through a collaborative, ongoing, teacher development programme with accompanying classroom support and guidance (Bell & Gilbert, 1994). The value of the intervention programme was shown, as teachers were no longer tentative in approaching technology education. Rather they were more confident, competent and knowledgeable practitioners.

Further, it was found that if teachers focus on specific and detailed technological learning outcomes in conjunction with pedagogical approaches that are appropriate for technology, the task and their students, student learning is effective and sustained. The detailed planning directly influenced descriptive feedback teachers used and descriptive feedback enhanced learning. Embedding formative assessment in technology and undertaking it in a sociocultural, negotiable, conversational and future oriented way strengthened student technological learning (Gipps, 2002; Torrance & Pryor, 2001).

Effective student learning in technology included effective understandings about the nature of technology; specific conceptual and procedural understandings; appropriate and prolific use of technological vocabulary; stronger links between conceptual and procedural considerations; iterative ways of working; clear understandings about the purpose of the activities; ability to think of tasks in an holistic manner; ability to identify their own knowledge gaps, and motivation and interest in technology.

9.4 Implications of the findings

The focus of this research has highlighted the importance of teacher knowledge of subject matter, curriculum, learners and pedagogy. Teachers not only need to identify the conceptual and procedural knowledge of technology but they also need to think about technology pedagogy in a flexible and multi-represented way (Shulman, 1990). PCK in technology impacted on teachers' planning, teaching and assessment practices. This study demonstrates how teachers' growing understandings about the nature of technology, knowledge in different technological areas, enhanced understandings about ways to plan, teach and assess technology and growing insights related to students' learning of technology impacts on formative interactions, especially descriptive feedback. The findings therefore have implications for technology in-service and pre-service teacher education and development, as the improvement of formative assessment in particular subjects is not a simple matter (Black & Wiliam, 1998b). No easy addition to existing ways of teaching will bring about rapid change.

Rather lasting change will take time and requires professional development and support.

It has been claimed that teacher practices in technology are often incomplete (eg. Anning, 1994; 1997; Jones & Carr, 1993a, Kimbell, 1997) and that teacher formative assessment practices are inadequate (Black & Wiliam, 1998b; Tunstall & Gipps, 1996). The idea that formative assessment needs to be task-focussed, detailed, goal-directed and operated in a transactional, dynamic and positive way raises questions about why and how teachers might change their practices in a relatively new subject area. Torrance and Pryor, (1995) and Harlen and James (1997) believe that the process of formative assessment is very complicated and is not an obvious, easily understood activity. The development and use of a planning framework detailing the key intended learning outcomes of technology, along with the examination of appropriate ways of teaching and assessing in technology, and the examination of ways students learn in technology provided ways forward for teachers in this study. A complex mix of specialist knowledge was required for teachers to become competent, confident teachers of technology. They needed to make decisions about appropriate learning outcomes for their students. This act of transforming their understandings of technology to that suitable for their students proved to be crucial. Practical implications then include the need for teachers to understand technology learning goals and the possible paths of progression towards them, to be able to recognise where students are in their technological learning, and to be able to provide feedback that helps close technological gaps and fosters self-assessment. This has serious implications for in-service and pre-service teacher development, as often at primary levels generalist notions over-ride specialist subject considerations.

It was found that focussing on teacher knowledge of specific and detailed technological learning outcomes in conjunction with appropriate pedagogical approaches enhances and sustains learning in technology. Many strategies were used to assist teachers to enhance their pedagogical content knowledge in technology. These included teachers reflecting on case studies of their own and others' classroom practices, using a planning framework and planning with potential, intended, negotiated and unexpected learning in mind, teachers and

researchers negotiating interventions in the classroom, teachers trialling ideas in classrooms and reflecting on the results, teacher involvement in workshops over a year and researchers providing classroom support. The implications for teacher development are that time, knowledgeable support and significant buy-in by teachers is required for change to be successful and sustainable.

The importance of interconnections between formative assessment and learning, with formative assessment embedded in a pedagogy of which it is an essential part, were demonstrated. As such, technology classrooms involve teachers and students generating opportunities for developing and challenging understandings and skills during learning activities (Black & Wiliam, 1998; Duschl & Gitomer, 1997; Gipps, 1994; Sadler, 1998). Accepting this view means that teachers need the knowledge, skill and flexibility to encourage students to explore their own technological ideas. Knowledge of overall task goals becomes crucial for both teachers and students. Teachers as more knowledgeable and technically competent can accelerate student development through informed formative interactions. The implication is that teachers need to know when to intervene and by how much. The perils of non-intervention are well documented by Anning (1997) with reference to student graphicacy. Students need to be involved in making decisions about what needs to be taken into account when solving technological problems using their analytical and speculative abilities. The solving of technological tasks becomes a dynamic relationship between teachers and students and allows for the promotion of values such as multiple perspectives, judgement and interpretation. An interactive teaching style emphasises student potential and highlights the sophisticated levels students can reach in thinking. The implication is that teachers need a broad and detailed knowledge base to assist their decision-making during teaching and freedom to respond to student learning and progress. In a teaching world that is becoming increasingly regimented through the need to document classroom happenings for demonstrating accountability, allowance for flexibility in learning becomes problematic.

Another implication is that students require opportunities to participate in formative assessment, as making progress is dependent on the students

themselves. They need to recognise and respond to their own learning for the purposes of enhancing learning (Bell & Cowie, 2001). They need to understand what goals to reach, what the gaps are between their current and desired position, whether to take action to close the gaps and whether to assess the extent to which the gaps have been closed. Formative assessment viewed as an embedded sociocultural activity provides the opportunity for teachers and students to work together to enhance learning. This means a collaborative, negotiable culture needs to be fostered. It also means that teachers need to foster an environment that is supportive and challenging as this fosters positive attitudes of self-esteem, which help create the conditions on which technological capability can thrive (Stables, 1997).

The study raised questions about what might serve as valid technology. It does not make sense to integrate technology with other subject areas. Rather, with technology being a new subject area, it needs to be the main focus, as this prioritises technology (Jones & Carr, 1993a). Teachers perceived the essentials of technology more readily when it was conceptualised as a separate learning area. They were then more easily able to reflect appropriate principles of technological practice in their teaching, an aspect acknowledged to enhance student technological learning (Brown, et al. 1989; Hennessy, et al. 1993; Jones & Carr, 1993a). Students were also able to ascertain the essentials of technology when teachers concentrated solely on them and they were effective in their technological learning. The implication is that technology should be taught as a separate learning area. However, this is not to say that technology could not be taught in an integrated way in the future, once it is established as a coherent learning area and teachers are readily able to define and sustain the focus on technological aspects.

It is not suggested that affective and social consequences of assessment are unimportant. Teachers and students perceived these aspects interrelated with cognitive aspects. Teachers built on student strengths in order to extend what they could already do to include what they could not yet do (Lally & Hurst, 1992). As such they pursued a positive, prospective view of education. Responding to

learning concentrated on positive aspects, rather than negative, was beneficial rather than harmful (Crooks, 2002).

From a student perspective it seems technology is made more meaningful when the task goals and the task substance are made clear and adhered to throughout the technological process. Task goals and the task substance could alter through negotiation once problem solving was underway, but changes needed to be made clear. This poses considerable challenges for teachers as decisions about the degree of task openness impacts on student achievement (Jones & Carr, 1993a). The key implication is that teachers need to foster opportunities for students to become active learners with clear direction. Students may then take responsibility for and manage their own learning (Black, et al. 2001). This then strengthens their commitment to learning (Bell & Cowie, 1997).

The finding that students make effective progress when they tackled tasks holistically challenges some current practices in primary classrooms, where individual items are often prioritised for assessment. Teaching isolated aspects in short single sessions, then marking student attainment against itemised objectives, simply does not progress student learning in technology. Instead a focus on extended problem solving and how students bring all aspects together does. As teachers are the fulcrums for making changes in assessment (Black & Atkin, 1996) the implication is that teachers will need assistance in assessing holistically.

The students in this study provided a special insight into the effects of descriptive feedback on their learning and progress in technology. Viewing learning as a process of enculturation into a domain through participation in shared activities (McCormick, 2000) and the importance of feedback for improvement (Sadler, 1989) contests the current move in primary schools towards national testing as a strategy for enhancing learning. The low-stakes, everyday, co-participating, task and goal-related emphasis of descriptive feedback is at odds with high stakes, one-off testing. The 'where to next', formative nature of descriptive assessment (Hargreaves, et al. 2000) provides go-forward momentum for learners and teachers. On the other hand, national testing provides a snapshot of current standings of a selection of students measuring how well those students have

achieved agreed standards in externally prescribed tests (Black & Atkin, 1996). National testing ignores assessment as a sociocultural activity and the effects of the dynamic relationships and interactions built in classrooms between students, peers and adults. Therefore to use the results of national testing in classrooms as a means to affirm learning is erroneous.

Besides the evidence of the positive influence descriptive feedback has on progressing student learning in technology, the influence of broadening student concepts related to the nature of technology also requires attention. The findings show that broadening students' concepts of the nature of technology impacts on their conceptual and procedural understandings and that these broadened views assist students to make conceptual and procedural connections between different technological tasks. The influence of students' perceptions on their performance in technology was strong (Jones & Carr, 1993a; Jones, et al. 1994). Attending to the nature of technology as a broad concept challenged students' stereotypical views of technology. The implication is that teachers need to have a clear understanding of technology and they need to explicitly assist their students to build a similar understanding. The building of a technology subculture becomes critical as teachers' roles, understandings about the nature of the learning area, the way a learning area should be taught and assessed, and expectations about student learning in a particular learning area are all influenced by the existing subculture (Jones, 1999; Paechter, 1992).

Another implication relates to teachers' understanding of young students learning in technology. The findings show that student learning is effective when teachers understand and put into practice ideas related to: fostering the iterative nature of the technological process (Jones & Carr, 1993a; Stables, 1997); developing conceptual understandings alongside procedural aspects (Anning, 1994; Jones & Carr, 1993a; Kimbell, et al, 1996; McCormick, 1997); building opportunities for student reflection in an holistic technological approach (Anning, 1994; Jones & Carr, 1993a; Stables, 1992); fostering designerly thinking (Anning, 1994, 1997; Jones & Carr, 1993a; Stables, 1995); and fostering a positive, challenging, problem-solving classroom culture. These impact on the way students carry out technological activities (Jones & Carr, 1993a; McCormick, et al, 1994; Stables,

1997). To understand and include these ideas requires informed, knowledgeable teachers. It brings us back to the implication that teacher development should be specifically related to technology education.

9.5 Implications for further research

The research described here provides an insight into several primary school technology classrooms, concentrating on the perceptions and experiences of small group of teachers and the three units they each taught. Given the changes the teachers made to their practices during the two years it would be interesting to undertake a longitudinal study of teachers teaching technology in all the technological areas. This would give deeper insight into the complexities and range of pedagogical content knowledge needed for teachers to be competent across the technological areas.

The study also provides descriptions of the learning and the progress made by some of the teachers' students. Time was not given for following particular students in a longterm manner. Further longitudinal research is needed of young students developing their technological understandings and skills throughout their primary years. Ideas related to progression and assisting student progress in several technological areas could then be ascertained.

In technology students transfer knowledge, understandings and skills from other learning areas to assist technological problem solving. Research specifically examining transfer is needed, as facilitating transfer was still an issue for the technology teachers and their students.

Formative assessment insights were gained through the examination of descriptive feedback, a major determinant in fostering student learning. Learning was effective when descriptive feedback focussed on overall technological practice and conceptual, procedural, societal, technical aspects related to task goals, the task substance and next learning steps. A richer picture could be obtained through a more detailed examination of descriptive feedback, for example a close examination of the types of questions and comments that assist students to move

forward. Additionally, more insights could be obtained with a more detailed examination of student perceptions related to the assistance teachers give in technology. Finally, a longitudinal study following students during their technology experiences throughout their primary years, into middle and senior school years would provide valuable insights into the long-term effects of descriptive feedback.

To conclude, the findings confirm the thesis that improvement in classroom formative assessment, especially descriptive feedback, makes a strong contribution to improving learning. They also confirm that enhancing teachers' PCK impacts on their ability to provide descriptive feedback. This study provides empirical evidence that enhanced teacher perceptions and practices in technology link to the effective technological learning of students. The development and use of a research-based planning framework concerned with technological practice and conceptual, procedural, societal and technical aspects exerted considerable influence on teacher construction of beneficial knowledge and understandings, and on developing a technological knowledge base robust and distinct from pre-existing knowledge bases. The framework became embedded as cognitive tools, so teachers made informed and judicious decisions about planning, teaching and assessing technology. Providing opportunities for trialling and critiquing the framework and providing support by informed facilitators, also enhanced teachers' descriptive feedback. As a result student technological learning was effective. The assumption that authentic technology education programmes can be implemented in New Zealand primary school classrooms through teachers enhancing their knowledge of technology subject content, technology pedagogy and formative assessment in technology was justified.

Appendix 1: Data collection methods and time-line

Phase 1: March – Sept (1998)	• Negotiated access and trial of initial interview questions. • 9 teachers semi-structured initial interviews gathering data about current teaching practice, assessment practices, views of technology and technology education. • 54 classroom observations in 8 classrooms. • Unstructured and semi-structured interviews about classroom experiences with 8 teachers throughout unit, semi-structured end of unit interviews with 8 teachers. • Unstructured and semi-structured interviews about classroom experiences with 5-6 students in each of the 8 classes throughout unit, Semi-structured end of unit interviews with same 5-6 students in each of the 8 classes.
Phase 2: March – June (1999)	3 teacher development days
	• 56 classroom observations in 7 classrooms. • Unstructured and semi-structured interviews about classroom experiences with 8 teachers throughout unit, semi-structured end of unit interviews with 8 teachers. • Unstructured and semi-structured interviews about classroom experiences with 5-6 students in each of the 7 classes throughout unit, Semi-structured end of unit interviews with same 5-6 students in each of the 7 classes.
	2 teacher development days
Phase 3: July – Dec (1999)	• 45 classroom observations in 7 classrooms. • Unstructured and semi-structured interviews about classroom experiences with 7 teachers throughout unit, semi-structured final interviews with 8 teachers about classroom experiences and formative assessment in technology education. • Unstructured and semi-structured interviews about classroom experiences with 5-6 students in each of the 7 classes throughout unit, Semi-structured end of unit interviews with same 5-6 students in each of the 7 classes.
	2 teacher development days

Appendix 2: The schools and participant teachers' backgrounds

School A

Rachel, Ernie, Penny, Ann and Burt were from School A, a decile 5 urban primary school with 28 teachers and 600 students from 42 different ethnic backgrounds. The teachers were familiar with working in proximity to researchers, as were the students. Most students lived in close proximity of the school and the school had an excellent reputation amongst the community. Multi-cultural aspects were fostered and enrichment programmes were in place. A 1996 Educational Review Office report highlighted the overall excellence of the school.

The Board of Trustees was positive towards technology allocating a separate budget and supporting technology teacher development. They welcomed the chance to be involved with the research. Technology was treated as a separate curriculum area and the school required that teachers covered a variety of technological areas and reported on each of the technology strands. A curriculum group had been formed for technology and a teacher had been placed in charge of technology school-wide. This meant that the curriculum was centrally led in regards to budget and direction. The curriculum group met on an ad hoc basis as the need arose and were able to inform the Development Teams of any ideas. These Development Teams operated at Syndicate level, meeting once a fortnight where the teams discussed technology as necessary.

Rachel

Rachel was a beginning teacher in her first year of primary teaching in 1998 teaching in a year 3 class with 27 students, 13 girls and 14 boys. Her formal qualifications were a Diploma of Teaching and a Bachelor of Education. Her direct pathway to teaching was from secondary schooling to pre service to teaching. Rachel's teacher development experience in technology education was minimal. Her involvement was confined to a beginning teacher in-service course and a pre-service course related to tele-communication. She wished to be involved in the research because she had had little opportunity to learn about technology education during her teacher education pre-service. Having taken computing in her Bachelor of Education degree, she professed an interest in information technology. She indicated a lack of personal knowledge about other technological areas. She found the curriculum document somewhat confusing in layout, though she believed that this was because she lacked knowledge of it.

Burt

Burt had been a primary school teacher for five years. He had a Diploma of Teaching and a Bachelor of Social Science degree. Before teaching he had an involvement in advertising work where he was employed as a cartoonist. His teaching experiences were with year four, five and six students. In 1998 he was a Senior Teacher teaching a Year 5 and 6 class of 34 students, 14 girls and 20 boys. In 1997 Burt was involved with a year long, in-school teacher development programme in technology education. He also had involvement with BP Technology Challenges but believed technology was an area where he required more assistance. He wished to be involved with this research for personal development, believing he had strength in technology, which he wished to build

on. Additionally, he was interested in assessment in technology, particularly in using appropriate assessment strategies. His previous involvement with technology had interested him and he was eager to learn more.

Penny

Penny had been teaching Year 4, 5 and 6 students for four years. She had previously gained a Bachelor of Management Studies and worked as an accountant before deciding to complete her Diploma of Teaching. In 1998 she was a Scale A teacher, teaching in Year 4 and 5 class with 33 students, 18 girls and 13 boys. As a first year teacher Penny had a brief involvement with technology education teacher development in a workshop situation. She had also worked with a technology education adviser during her second year of teaching at staff meeting level. Her teacher development experiences in technology education could therefore be described as minimal. Penny wished to be involved because she saw the research project as an opportunity to develop her understanding of technology education. She professed an interest in the subject and demonstrated a personal responsibility to learning and a constructive attitude to change.

Ernie

Ernie had been a primary teacher for six and a half years, five of those years in England, where he trained. His background was in electronic engineering after which he gained a post graduate diploma in teaching, focusing on teaching seven to twelve year olds. He moved to New Zealand in 1997. Following long term relief work, he gained a permanent, Scale A position and was teaching in a year 5 and 6 class with 30 students, 13 girls and 17 boys. While in England, Ernie's involvement related to the English technology curriculum, particularly in regards to developing his technology skills. As the technology co-ordinator of one school, he had developed a scheme of work that assisted teachers to cover their curriculum. He had been to skills-based workshops in different areas of technology. He had not had any teacher development based on the New Zealand technology curriculum. Ernie wished to be involved in this research for two reasons. Firstly, he saw it as an opportunity to improve his teaching. Secondly, he saw it as an opportunity to take an intensive look at the New Zealand technology curriculum and his assessment practices. He was aware of the influence of his English technology background and realised that to succeed in teaching in New Zealand, he needed to have a better understanding of the New Zealand curriculum.

Ann

Ann had been a primary school teacher for ten years. She had a Diploma of Teaching and a Diploma of Education. She had covered all levels of teaching, from Year One to Year Eight and had taught in small country schools, an area school and large city schools. She had taken time from teaching for her family and had returned to teaching full-time in 1997. In 1998 she was teaching a Year 4 class of 29 students, 14 girls and 15 boys. Ann had not been involved with any specific teacher development in technology education. She had endeavored to use the curriculum independently when planning technology units she was to teach. She wanted to be involved because she wished to extend her knowledge in technology as well as her assessment knowledge. She relied heavily on the

technology curriculum statement and wanted to develop the confidence to nullify this dependency.

School B

Tina, Ally, Joan and Sarah were from School B, a decile 10 urban primary school with 17 teachers and 345 students. The teachers and students were familiar with researchers working in their school. There were 14 classrooms with a preschool nearby. Most students lived in close proximity of the school and were generally from a higher socio-economic background. The school had no enrolment policy and catered for mainstreamed students. Three to four percent of the students identified as Maori and 12% Asian. Students were described as average to above average in ability. In response to this, enrichment programmes were in place. An ERO report from 1996 highlighted the overall excellence of the school and the teachers' ability to make a difference to student achievement.

Budgetary support for technology had come from the Board of Trustees who were supportive of Ministry of Education technology education contracts and welcomed the opportunity to be involved in the two-year research programme. Technology was treated as a separate subject area and allocated separate teaching time. All learning areas had a curriculum committee including technology and this committee structure had assisted in targeting learning needs in technology. As a result of being involved with Ministry contracts in technology, resources had been purchased. Professional development was continuing at a syndicate level.

Tina

Tina had been a primary school teacher since 1970. She had a Diploma of Teaching and a Bachelor of Education. She had taught in Australia, England and Auckland in classes from year one through to year five and briefly at secondary school level. Following her teaching in Auckland, she took time out for her family. Other work experiences were related to horticulture and volunteer work associated with Playcentre, Parents Centre and a geriatric hospital. In 1998 she was a full time, Scale A teacher, teaching in a year 2 and 3 class with 28 students, 13 girls and 15 boys. In 1996 Tina was involved with a year-long Ministry teacher development contract in technology education. Her teacher development experiences in technology could therefore be described as moderate. She wanted to be involved because she was interested in the issue of assessment in technology. She expressed some difficulties in assessing in technology and believed that assessment in technology was challenging because of the integrated nature of the three technological strands of knowledge, capability and society. She was hoping that her involvement in the research could assist with the school's policy formulation in assessment.

Ally

Ally had a Diploma of Horticulture, a Bachelor of Science and a Diploma of Teaching. In 1991 she completed her Diploma of Teaching and subsequently was employed as a long-term relief teacher. She had been permanently employed in her current position for the past two years. Her teaching experiences included teaching Year 3 to Year 8 classes. In 1998 she was a full-time, Senior Teacher teaching a Year 5 and 6 class with 34 students, 18 girls and 16 boys. In 1996, Ally was involved with a year-long Ministry teacher development contract in

technology education. In 1997, she had also been involved with a few days of in-service. Her teacher development experiences could therefore be described as moderate. She wished to be involved because she was interested in technology having already completed some papers in information technology. She believed that she was a practical person and she thought that other New Zealanders needed encouragement to use their practical skills as well as their intellectual skills. Technology education afforded these opportunities.

Sarah

Sarah had been a primary school teacher for 5 years. She had a Diploma of Teaching and a Bachelor of Education degree. Before teaching she had work involvement in soft furnishings as a salesperson and as a sewing teacher and she had worked in insurance. She had also been heavily involved with volunteer community work. In teaching, she trained as an adult student and had held a number of long-term relieving positions in various schools. She had taught at all levels from year one to year eight. In 1998 she was a long-term reliever teaching a Year 4 class with 33 students, 18 boys and 15 girls. In 1996 she had been involved with a year-long, in-school development in technology education. She was involved with writing the school policy and the school implementation plan for technology. In 1997, at a different school, she was again involved with an in-school development programme. Her experiences could be described as moderate. She wished to be involved with the research because she thought it worthwhile for her own professional development. Her previous involvement with technology meant that she was eager to learn more about the subject.

Joan

Joan had been a primary teacher for 16 years teaching in various schools. She had 6 years as a Scale A teacher, also teaching reading recovery. She gained promotion to a Senior Teacher and whilst a Senior Teacher she was seconded twice to University to lecture in reading and language. She gained her position as Assistant Principal in 1996. She believed that her particular strength areas were reading and language, particularly in the Junior School, where she had had most of her teaching experience. She had a Diploma of Teaching and a Bachelor of Education degree. She had had a year working in an accounting firm before beginning her teacher training and had been in teaching ever since.

Joan had been involved in a year-long Ministry of Education teacher development contract in technology and as a lead teacher for her school. Her experiences could therefore be described as moderate. She wished to be involved in this research because she thought it was an ideal way to keep abreast with changes to the curriculum. She was also interested in assessment and was involved with co-ordinating a school-wide review of assessment practices. She viewed this research project as an ideal means for her to gain some knowledge and expertise in technology assessment procedures, reporting systems and school-wide policy development.

Appendix 3: Overview of classes

Overview of classes 1998

Teacher	Year level	Class, gender numbers	Ethnicity	Ages - as at 1.1.98
Rachel	3	27, 14 F, 13 M	4 Maori, 20 Pakeha NZ, 1 Somali, 1 Chinese, 1 Taiwanese, 1 Indian	6.11 – 7.7
Ernie	5/6	30, 13 F, 17 M	9 Maori, 17 Pakeha NZ, 1 Somali, 1 Taiwanese, 2 Chinese, 1 Israeli	8.9 – 10.8
Burt	5/6	34, 14 F, 20 M	7 Maori, 23 Pakeha NZ, 2 Chinese	8.9 – 10.9
Penny	4/5	33, 18 F, 15 M	4 Maori, 16 Pakeha NZ, 3 Chinese, 1 Somali, 2 Rarotongan, 1 Iranian, 1 Russian, 1 South African, 2 Solomon Islanders, 1 Fijian, 1 Taiwanese	7.10 – 9.7
Ann	4	29, 14 F, 15 M	11 Maori, 14 Pakeha NZ, 1 Japanese, 1 Taiwanese, 2 Tongan	7.7 – 8.7
Tina	2/3	28, 13 F, 15 M	21 Pakeha NZ, 4 Chinese, 1 Canadian, 1 English, 1 Indian	5.6 – 7.6
Ally	5/6	34, 18 F, 16 M	1 Maori, 25 Pakeha NZ, 2 Chinese, 2 South African, 1 Malaysian, 1 Sri Lankan, 2 Yugoslav	8.2 – 10.8
Sarah	4	33, 15 F, 18 M	2 Maori, 22 Pakeha NZ, 4 Chinese, 2 Korean, 1 Yugoslav, 1 Sikh, 1 Sri Lankan	7.6 – 8.8

Over view of classes 1999

Teacher	Year level	Class, gender numbers	Ethnicity	Ages - as at 1.1.99
Rachel	2/3	30, 20 F, 10 M	6 Maori, 17 Pakeha NZ, 1 Somali, 3 Chinese, 1 Yugoslav, 1 Taiwanese, 1 Indian	5.9 – 7.5
Ernie	5/6	31, 15 F, 16 M	5 Maori, 18 Pakeha NZ, 1 Russian, 3 Chinese, 1 South African, 1 Bangladeshi, 1 Korean, 1 Dutch	8.9 – 10.8
Burt	5/6	32, 17 F, 15 M	5 Maori, 22 Pakeha NZ, 2 African, 1 Taiwanese, 1 Thai, 1 Singaporean.	8.7 – 11.0
Penny	2/3	29, 18 F, 11 M	6 Maori, 17 Pakeha NZ, 1 Iranian, 1 Russian, 1 Bosnian, 2 South African, 1 Taiwanese	5.9 – 7.6
Tina	4	30, 16 F, 14 M	10 Maori, 16 Pakeha NZ, 1 Chinese, 1 Dutch, 1 South African, 1 Scottish	7.0 - 9.0
Ally	5/6	32, 16 F, 16 M	27 Pakeha NZ, 1 Indian, 2 Korean, 2 Taiwanese	7.8 – 10.8
Sarah	4/5	31, 16 F, 15 M	3 Maori, 15 Pakeha NZ, 1 Chinese, 1 Korean, 1 Afrikaans, 1 Sri Lankan, 3 English, 1 Bangladeshi, 1 Japanese English, 3 Taiwanese, 1 Australian	7.11 – 9.6

Appendix 4: Teacher interview questions

Interview questions after unit 1 1999	Interview questions after unit 2 1999
How do you think the unit went overall? What were the positive things? What were the negative things How do you think this unit was reflective of the technology curriculum? What were the strengths and weaknesses? On reflection what changes might you make, if any? Did you make any changes to your assessment practices? Examples? In terms of your classroom practice, what do you think has changed? Examples? How useful were the models we proposed? What you might do next with these students? In terms of student learning? In terms of progression in student learning? In terms of planning? What do you perceive as important for your further development? Is there anything else you wish to add?	How do you think the unit went overall? What were the positive and the negative things? What were the strengths and weaknesses? On reflection what changes might you make, if any? How do you think this unit was reflective of the technology curriculum? In terms of your classroom practice, what do you think has changed? Examples? What was the impact of the intervention? What changes did you make to your assessment practices? Formative, summative, reporting examples? What was the impact of the intervention? How does your assessment inform what you might do next? In terms of planning? In terms of student learning? In terms of progression in student learning? What were the useful strategies you employed to enhance student learning? To make formative and summative judgements? How useful were the models we proposed? What do you perceive as important for your further development? Is there anything else you wish to add?

Appendix 5: Sample of fieldnotes

Sample of Fieldnotes from Book 3, 11.6.99

Descriptive notes	Reflective notes
9.35 am. Penny (the teacher) has individual students come to her to talk about their plans. She points to Steph's (a student) plan and comments on her use of washing line and a staple. Steph nods head in agreement. Penny asks: *Will the staple go through much?* S replies: *No*. Penny then probes: *what might you use instead?* S: *I'm not sure*. Penny suggests Steph goes to see what other student have as solutions. 9.40 am. Penny continues to assist students to think of possible difficulties that they may encounter when they construct.	Penny assisting students to think forward to possible construction difficulties they may encounter while they are still at the planning stage. Iterative process being fostered. Despite having a bad cold and croaky voice Penny adapted her teaching style to take this into account. Had students come to her rather than expending energy by moving around classroom herself. Worked in a very subdued manner and students responded well to her low-key delivery. Good rapport between students and teacher evident.

Appendix 6: Information to principals

Centre for Science, Mathematics and Technology Education Research

The University of Waikato
Private Bag 3105
Hamilton, New Zealand
Ph: 64-7-838 4035
Fax: 64-7-838 4272

J. Moreland
Project Officer
Ph: 8384639

The University of Waikato
Te Whare Wānanga o Waikato

Research in Assessment of Primary Technology (RAPT) Project

Director: Dr Alister Jones
Project Officer: Judy Moreland

RAPT Project Justification
The reasons for undertaking this research project are three-fold:
- To develop strategies for assessment in technology at the primary school level in order to assist teachers to assess technological outcomes in their classrooms
- To provide data and strategies for ways to assess technology
- To give an understanding of student learning in technological principles and concepts, technological capability and the relationship between technology and society

RAPT Project Aim
The research project seeks to address the following aim:
- To develop a framework for assessment of technology education in primary schools

To meet this research aim three broad areas will be the focus for research:
1. Emerging assessment practices of technological activities
2. Assessing technological outcomes
3. Assessment tasks in technology

From the three areas, the details for examination are:

1. Emerging assessment practices
- Influence of subject and assessment subcultures on assessment in technology
- Teachers' perceptions of technology and the ways these influence assessment
- Teacher views of assessing technology and examination of their focus in student interactions
- Explore externalisations of students thinking in technology to examine their concepts of technology to gain a clearer view of progression

2. Assessing technological outcomes
- The nature of assessment and how a better understanding of assessing can be developed
- Developing construct referenced assessment - how to assess the whole rather than parts
- The conflict between assessing potential learning outcomes and assessing a set number of predetermined outcomes
- Assessment for differentiation in technology
- Influence of task specification and assessment on student performance
- Assessment of concepts
- Types of assessment for student and reporting purposes
- What makes a better solution in technology and how it is assessed
- Different types of modelling and different assessment procedures

3. Appropriate assessment tasks
- Enhancing the reliability of multiple indicator perspectives
- Enhancing the validity of assessment in terms of technological practice
- Developing pictures of assessment

- Considering ways different types of tasks will lend themselves to different types of assessment

RAPT Project Phases

In order to address the research project's aim, three main phases of research will be undertaken. They are to:

- Examine existing and emerging approaches in assessing technological outcomes in the classroom
- Develop ways to assess in technology, including ways to improve teacher and student understanding of technological practice and enhance assessment
- Test out assessment procedures and ways of implementing these into the teaching - learning situation

RAPT Project Implications

This research project will have the following implications:

- Help teachers to assess technological outcomes in their classrooms
- Provide data and present strategies for ways to assess technology
- Give an understanding of student learning in all three aims of technology education, rather than only concentrating on technological capability

RAPT Project Timeline

Year One (1998)

Term I :

- Negotiated access

Term II:

- Initial interviews gathering data about current teaching practice, assessment practices, views of technology and technology education
- Analysis of interview data
- Classroom observations

Term III:

- Complete classroom observations, interviews and analysis

Term IV:

- Ongoing analysis, writing of individual case studies

Year Two (1999)

Term I:

- Individual case studies given to teachers for comment
- Group workshop, critique of teaching and assessment practices, co-operative planning of first unit
- Implementation of first unit in classrooms- observation, interviews and analysis

Term II and III:

- Ongoing implementation of first unit in classrooms
- Group workshop, feedback to teachers, critique of assessment and teaching practices, individual planning of second unit
- Begin implementation of second unit, observation, interviews and analysis

Terms III and IV:

- Complete implementation of second units, classroom observations and individual interviews
- Analysis of data
- Final group workshop
- Final interviews and analysis

Appendix 7: Participant letter of consent

Research Ethics and Guidelines for Teachers involved in the Research in Assessment of Primary Technology (RAPT) Project

Centre for Science, Mathematics and Technology Education Research

The University of Waikato
Private Bag 3105
Hamilton, New Zealand

Ph: 64-7-838 4035 (Centre direct line)
Fax: 64-7-838 4272

The University of Waikato
Te Whare Wānanga o Waikato

Dr Alister Jones and Judy Moreland are carrying out this research.

This research will abide by the research guidelines of the University of Waikato's Ethics Committee, in that:

- The University's strict and comprehensive research guidelines ensure the anonymity of persons and institutions involved in this research. All information will be used only for the purpose of this study.
- My participation in the research is voluntary and I have the right to withdraw at any time.
- None of the quotes from interviews and observations or my written comments will be used unless I give prior permission.
- My anonymity will be preserved.
- All information pertaining to me will be kept confidential and securely stored.
- All information pertaining to me will be destroyed three years after the completion of the research.
- The information about me obtained during the research will only be used for the purpose of writing the thesis, published papers, conference presentations and talks.
- My signed consent will be obtained before the interviews, questionnaires and classroom observations commence.

I have read and understand the above research information and guidelines and agree to participate in this research.

Name: .....

School:.....

Signed:.....

Date: .....

Appendix 8: Overview of technology topics

Technology topics

Teacher	Technological Area/s	Unit	Duration
Rachel	Structures & Mechanisms, Materials	Mazes	3 weeks, 14 sessions
Ernie	Electronics & Control	Electric Map Games	2 weeks, 6 session
Burt	Structures & Mechanisms	Time Clocks	3 weeks, 10 sessions
Penny	Structures & Mechanisms, Materials	Moneyboxes	2 weeks, 7 sessions
Ann	Structures & Mechanisms, Materials	Moneyboxes	2 weeks, 7 sessions
Tina	Structures & Mechanisms, Materials	Mazes	4 weeks, 13 session
Ally	Food, Materials, Information & Communication	The Greek Restaurant	4 weeks, 14 sessions
Sarah	Structures & Mechanisms, Materials	Fitness Equipment	3 weeks, 11 sessions

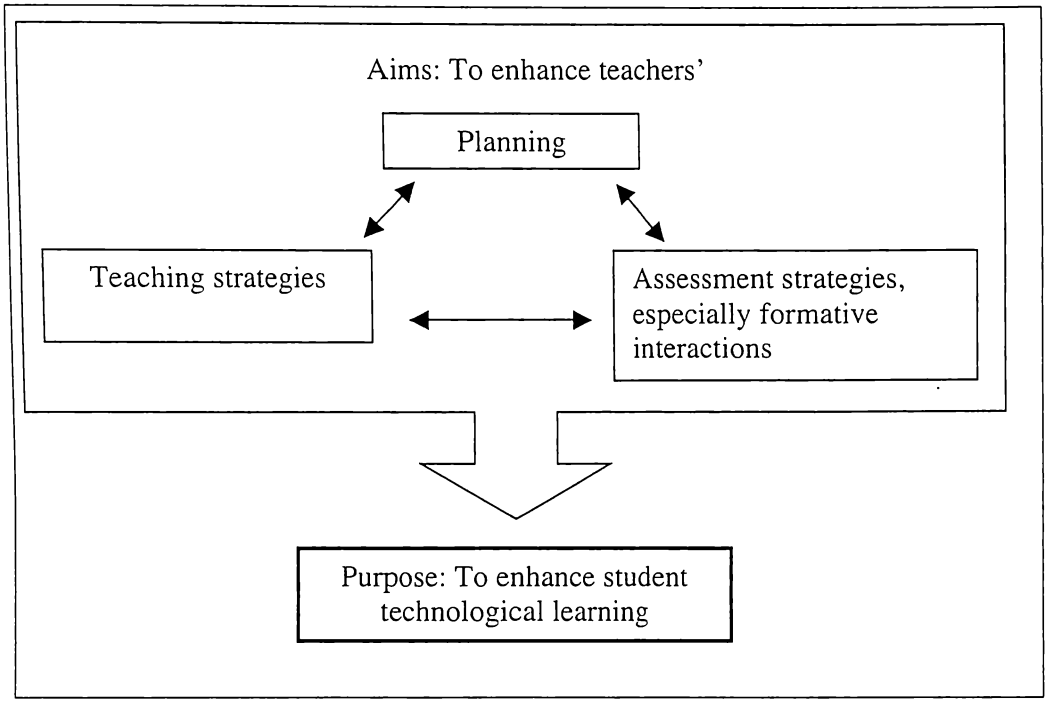
Appendix 9: Teachers' lesson sequence outline

Teacher	Lesson sequence
Rachel	Wk 1:Exploratory activities Wk 2: Introduction to task. Designing, constructing, testing small marble mazes Wk 3: Culminating construction of large class maze, self-assessment
Ernie	Wk 1: Exploratory activities Introduction to task. Designing and constructing games Wk 2: Testing games, self-assessment
Burt	Wk 1: Exploratory activities. Introduction to task. Designing and constructing clocks Wk 2: Constructing and testing clocks Wk 3: Final testing, self-assessment
Penny/ Ann	Wk 1: Exploratory activities. Introduction to task. Designing moneyboxes Wk 2: Constructing and testing moneyboxes. Peer and self-assessment
Tina	Wk 1: Exploratory activities Wks 2-4: Designing, constructing and testing a 3D maze, self-assessment
Ally	Wk 1: Menu planning Wk 2: Design and produce invitations Wk 3: Design and create menus, visit restaurant, table layout Wk 4: Prepare food and restaurant, serve food, self-assessment
Sarah	Wk 1: Exploratory activities Wk 2: Design and construct models of fitness equipment Wk 3: Complete construction, self-assessment

Appendix 10:Assessment of student achievement in developing fitness equipment

	Discuss possible solutions & strategies	Develop a suitable option	Participate in selecting suitable criteria for a model
Student 1	√	√	√
Student 2	√√√	√	√
Student 3	√√√	√√√	√
Student 4	√	√√	√

Appendix 11: Aims of the professional development programme



Appendix 12: Workshop outlines

Workshop 1

Day 1	***Review of current position in technology*** • Overview of case studies • What other literature shows ***Development of guiding principles for assessment in technology*** • Teachers views of guiding principles for assessment • Planning for teaching, learning and assessing technology • Formative assessment principles
Day 2	***Teacher planning*** • Sharing teachers' beginning plans for units • Researcher demonstration of identifying technological learning outcomes • Group discussion of classroom tasks and strategies to ensure technological outcomes are met. • More planning for classroom practice
Day 3	***Focussed technology units*** • Concepts of potential, negotiated and unexpected learning outcomes • Formative interactions with students: cueing, transfer, questioning, modelling, iterative process, student reflection and evaluation • Revisiting planning ***Summative assessment*** • What are summative outcomes? Using the unit: Where and what will you assess summatively? • Revisiting planning *Summing up*

Workshop 2

Day 1: Review & Refinement	***Reviewing and reflections*** • Researchers' evaluation • Teachers' evaluation ***Refinement of models and strategies*** • Models discussion • Formative and summative assessment • Overall judgements
Day 2: Further refinement	***Progression aspects*** • Introduction to ideas • Comparing students work ***Planning*** • For term 3 teaching with new planning format • For summative assessment using overall assessment model

Workshop 3

Day 1: Evaluation	***Introduction*** • Researcher reflections ***Looking back*** • Effectiveness of models for enhancing student learning • Strategies for effectively implementing models • Observations of differences in student learning • Key features of differences • Methods and strategies to identify differences • Impact on other curriculum areas
Day 2: Developing Guidance for Teachers	***Guidance for other teachers*** • Experiences that enhance student learning, improve teaching strategies, enhance recording and reporting • Material for a teacher pack including suitable teacher and student work, key commentary, suggestions for assisting teachers to understand and implement models ***Schoolwide assessment, documentation, reporting*** • Influence of school-wide recording practices • Possible changes to school-wide practices to provide better summative information • Summative information for a student as they progress through school

Appendix 13: Technology units taught in 1999

Teacher	Class	Topic	Duration	Areas	Foci
Tina	Year 4	Sweet-making processes – modifying a hokey-pokey sweet	3 weeks	Production & process, Food	Transformation of food, batch & continuous flow production, target group surveying, food safety, additives
		Mask-making – masks for a school production	2 weeks	Structures, Materials	Prototyping, fail-safe, durability, flexibility, aesthetics
Ally	Years 5/6	Kites – Kites for individual use	5 weeks	Structures & mechanisms, Materials	Failure analysis, product modification, flexibility, structural balance
		Shade structure - Concept drawings for a shade area at school	4 weeks	Structures & mechanisms, Materials	Design portfolio, structural support systems, extensions, weathering, load bearing, OSH, client requirements
Sarah	Years 5/6	Kites - Kites for individual use	3 weeks	Structures, Materials	Pattern modification, best-fit options, material flexibility, strength & weight
		Yoghurt making -flavour modifications	2 weeks	Food, Biotechnology	Palatability, sensory evaluation, failure analysis, yoghurt cultures
Penny	Years 2/3	Hanging devices for bird feeders	2 weeks	Structures, Materials	Durability, fitness for purpose, stability, child-friendly
		Skipping rope handles – concept drawings	3 weeks	Structures & mechanisms, Materials	Ergonomics, storage suitability, modification of existing product
Rachel	Years 2/3	Packaging - Packages for posting a biscuit	2 weeks	Structures, Materials	Durability, aesthetics, protection, product freshness
		Storage solutions for maths equipment	3 weeks	Structures, Materials	Mock-ups, 3D drawings, durability, aesthetics, portability, space effectiveness
Burt	Years 5/6	Games for the visually impaired	3 weeks	Structures, Materials	Fitness for purpose, durability, needs analysis, malleability, material strength
		Aids for arthritis sufferers – design drawings	3 weeks	Structures & mechanisms, Materials	Ergonomics, fail-safe, modification, 3D drawings
Ernie	Years 5/6	Designing school bags	3 weeks	Structures & mechanisms, Materials	Durability, fitness for purpose, waterproofing, focus group surveying, graphical representation, design briefs
		Cereal packaging – design drawings	3 weeks	Structures, Materials	Design portfolio, target group, graphical communication, logos, specification plans, fitness for purpose

Appendix 14: Tina's use of the planning framework for Unit 2 1999

<table>
<tr><td colspan="3">Task definition: Design and make a prototype bird mask for the school production</td></tr>
<tr><td colspan="3">Aspects of technological practice:
• Design to purpose including practical and aesthetic dimensions of masks
• Consistency of design translating into development of a prototype; include fail-safe qualities in relation to design and materials used
• Masks are used for different purposes</td></tr>
<tr><td>Conceptual LOs</td><td>Procedural LOs</td><td>Societal LOs</td></tr>
<tr><td rowspan="2">• Understand design features (eye holes, nose and mouth parts, workable fastening, ease of storage), appropriate materials (durable – won't rip and will last several performances, flexible – easy to put on and off, and aesthetics of different masks
• Relate design features to mask purposes
• Understand appropriate materials and structures, sequence of assembly
• Their purpose for mask defines the task
• How different fastenings work</td><td rowspan="2">• Interview client and evaluate various masks to design their brief for prototype mask
• Develop specifications – measure heads, relate measurements to shape and size of mask,
• Set quality standards - Use rip test and bend test to test materials; fastening must be workable; mask must be flexible; mask must be the right size and fit
• Undertake feasibility report – will it work? Can it be done? What might go wrong?
• Modify design considering size, shape, material, fastening, aesthetics (how well related to character), durability, can it be easily copied for production?
• Write production plan in steps, check progress as mask is created
• Character test mask and evaluate</td><td>• Masks have been used for different purposes by different people – fun, theatre, work, sport, disguise, cultural role in China and Australia</td></tr>
<tr><td>Technical LOs
• scale drawing
• Sketching and rendering
• Pencil drawing
• Cutting
• Fastening
• Measuring</td></tr>
</table>

Tina's task definition summarised the broad boundaries of the task and helped her to think about general technological direction for her students' learning. The main task features included the identification of the key procedural aspects of designing and constructing, a key technological idea of prototyping, and a description of the artefact to be constructed (a bird mask for the school production). The 1999 task definition was in contrast to 1998 where Tina did not define the task. Instead she just entitled her unit 'Mazes'

Tina also defined three key aspects of technological practice although in contrast to Rachel, she did not make a direct match to the three curriculum strands. Similar to Rachel the aspects of technological practice were more detailed than the task definition but were not as detailed as the more specific learning intentions articulated in the conceptual, procedural, societal and technical categories. Also she made a connection between the task definition and the aspects of technological practice. Noted are conceptual identification (knowing about the design process, aesthetics, prototype, fail-safe, practical solutions, and masks for different groups of people and purposes) and procedural identification (being able to design, translate, develop, and account for technological principles). Tina attempted to synthesise conceptual and procedural aspects. For example, an understanding that designing is to incorporate aesthetic and practical dimensions, and that fail-safe techniques are to be taken into account when developing a prototype.

Tina's 1999 planning contrasts with her 1998 work where she did not define key aspects of technological practice but defined student goals using the achievement objectives taken directly from the curriculum. Her 1998 planning included objectives from the entire curriculum strands indicating comprehensive curriculum coverage.

Finally the intended learning outcomes in the four categories are itemised. Like Rachel's planning, Tina has a strong connection between key aspects of technological practice and learning outcomes with all aspects of technological practice referred to within the learning outcomes. The learning outcomes are specific, detailed and itemised. Conceptual learning outcomes are numerous and relate to technological principles (design, durability, flexibility, aesthetics); techniques (sequence of assembly, fastening techniques); and materials and structures (nature of materials, size and shape of mask). Tina's procedural learning outcomes are detailed and relate to procedures and processes to be undertaken. Societal learning outcomes relate to people and finally technical learning outcomes specify the technical skills required to undertake the task. The level of detail and the spread of learning outcomes across all aspects of technology contrast with 1998. Though some detail was shown then, no categorisation was undertaken. Tina detailed three specific learning outcomes in 1998 - understand aesthetic, cultural, historical aspects of maze building; co-operate and work under consensus; set and follow design criteria and understand the positive and negative ramifications of design. Noted is the second learning outcome focussing on social and managerial aspects and the broad nature of the others.

The close connection between the task definition, key aspects of technological practice and the detailed learning outcomes shows Tina employed a process of iteration to complete the planning framework similar to Rachel. Additionally, she had her students in mind when defining the learning outcomes for she defined the meaning of many aspects in terms her students would understand. For example, durable as 'won't rip and will last several performances'; flexible as 'easy to put on and off'; aesthetics as 'how well does the mask relate to the character', and undertake a feasibility report by 'answering questions: will it work? Can it be done? What might go wrong?' She was translating different aspects of the technological task in terms suited to her students. She was clarifying at the planning stage how she and her students could use particular terms in classroom situations, as a guide to possible formative interactions and as terminology and procedures students might use. The translations could also be used as active assessment criteria for students to use. For example, students could judge whether their mask was feasible by testing if it worked, if they could do what they planned to do and thinking about what might go wrong. Tina had not paid attention to this act of translation in 1998.

Appendix 15: Other planning examples

Penny's planning for unit 2 1999

Task Definition: To design a modification to the existing school skipping rope handles for easier, safe use and storage in the classroom			
Aspects of technological practice • Identify appropriate materials, shapes and structures necessary for an effective skipping rope handle • Identify and discuss needs and preferences for skipping rope handles • Develop and evaluate a design plan that modifies existing SR handles with reference to ergonomics, strength, safety, ease of use, materials, structures • Identify issues that teachers need to address when purchasing school equipment – cost, storage, safety, ease of use, comfort			
Conceptual LOs	**Procedural LOs**	**Societal LOs**	**Technical LOs**

• Explore how skipping rope handles are technology
• 2D/3D drawings have separate purposes for showing technological ideas
• plans/designs need to have measurements, labels and different views
• technology terms include ease of use, modify and adapt
• some materials are more suitable for SR handles than others
• handles are shaped for ergonomics (they fit your hand comfortably)
• SR handles have internal mechanisms (workings)
	• Collect and categorise
	  • Egs of SR handles
	  • Egs of other handles
	• Draw and label diagrams of existing handles
	• Undertake a needs-analysis through discussion with users (Room 9 members)
	• Negotiate criteria for design modifications
	• Draw designs
		• Consider what is ease of use for a child and teacher
		• Understand safety and possible hazards in the classroom
		• Understand budget as an influence on purchases of skipping rope handles
			• 2D (maybe 3D) drawings, including labelling and measurements
			• make a drawing to assist in getting ideas to others
			• drawing to show enlargements
			• drawing using measurements
			• orthographic (different views) drawings
			• drawing to show cross-section of designed handle and how it works

Sarah's planning for unit 2 1999

Task Definition: *Modification of plain cultured yoghurt to meet palatability requirements identified by class*			
Aspects of technological practice In producing a flavoured yoghurt product students will: • identify the components of a yoghurt culture and the conditions needed for the culture to grow; • follow and design procedures to make batches of yoghurt and to modify flavour characteristics;. • use a sensory evaluation product rating questionnaire (qualitative) to evaluate the initial and adapted products for palatability to children in the class (target group); and • acknowledge that yoghurt is an ancient food product which is used in different ways by different groups/societies and is considered healthy			
Conceptual LOs	**Procedural LOs**	**Societal LOs**	**Technical LOs**
• Cultures contain living cells and therefore need: food, warmth, oxygen • Describe the best conditions for making and storing yoghurt • Flavourings can be added to make yoghurt more appealing to children • In modifying a food product a slight change can make a large difference • Flavour combinations can affect palatability • Safe food handling practices are necessary when producing food for consumption	• The batch production of yoghurt from an Easi-Yo package • Failure analysis to identify possible reasons for product failure • Use of sensory evaluation questionnaire to evaluate for acceptability of yoghurt product • Use a product development planner to adapt the product taking into consideration conditions for growing cultures • Flavourings can be added at different stages in the process • Use a product rating questionnaire (qualitative)	• Different people have different preferences for flavours of yoghurt • Yoghurt is a healthy food product that is used in different ways by many different ethnic groups	• Follow instructions to complete a food making process • Fluid measurement (transfer from maths) • Tabling and graphing skills to analyse sensory evaluation data (transfer from Maths) • Observing basic food safety protocols such as washing hands, wearing hats, aprons etc. (transfer from Health)

Ernie's planning for unit 2 1999

Task Definition:
The production of a design portfolio of cereal boxes for a target group

Aspects of technological practice
During the development of the cereal box portfolio students will:

- Incorporate key packaging elements;
- Communicate information on cereal packaging for a specific group and develop an understanding of aesthetics;.
- Include specification drawings of a cereal package and evaluate the effectiveness of these and
- Take account of features of a cereal package that will attract particular customers

Conceptual LOs	Procedural LOs	Societal LOs	Technical LOs
Key packaging elements: • Shape, size and form • Materials used • Protection of contents • Relationship between product and material choice • Pictures and diagrams (logos) • Visual appeal • Consumer/sales information • Nutritional labelling Understanding the purpose of portfolios Understanding promotion to a particular group, eg graphics for children, dieters Understand differences between conceptual drawings and specification plans	• Examine existing packaging to identify packaging elements and target group • Interview target group for cereal packaging preferences • Generate a design brief from information gained • Draw packaging net with appropriate fastening methods and size • Produce conceptual 3D drawings accounting for target group findings, safe storage, health requirements, contents • Use information from examination of existing packaging to develop package design • Produce specification plans	• Different people respond to different features of cereal packaging, eg. nutritional information, aesthetics, graphics, contents • Understand and include food labelling regulations	Drawing skills • Scale • Logos • Drawing nets • Conceptual drawings • 2D and 3D annotated drawings

Ally's planning for unit 2 1999

Task Definition:
To develop a design portfolio for a shade structure for a landscape designer for a particular chosen area in the school grounds

Aspects of technological practice
During the development of the shade structure portfolio students will:

- understand portfolios (including concept drawings)
- gain understanding of the key features of the practice of a landscape designer.
- Understand and use appropriate structural support systems for shade area
- Understand and incorporate suitable materials for shade structures
- Take account of features of a cereal package that will attract particular customers
- Consider staff and children's ideas and needs towards the shade area

Conceptual LOs	Procedural LOs	Societal LOs	Technical LOs
• Develop ideas of appropriate structures for a chosen shade area in the school • Develop an understanding of a portfolio • Understand the key features of portfolio design • Learn about structural support systems: extensions, weathering, load bearing, OSH • Learn about suitable materials, lightweight, all-weather	• Explore other shades areas to examine suitable structures and materials • Interview teachers and students to find out preferences - carry out a survey • Question an 'expert' on feasibility, good features of a shade area • Use information to compile a series of concept drawings in a portfolio package design • Produce specification plans • Present selected portfolios to BoT	• People respond to different shade areas and require different needs • Safety issues need to be taken into account	Drawing skills • Scale • Conceptual drawings • 2D and 3D annotated drawings

Appendix 16: Aspects for summative assessment

Ally: Overall effectiveness Design a shade structure for identified are in school grounds Consider appropriate structures for shade structure & staff & children's needs towards shade area Understand purpose of portfolios & include a map of the area & show detailed plans Show knowledge of joining mechanisms – frame to shade cloth, side to top Show understanding of suitable materials
Burt: Overall judgement Explore & modify an exiting technical aid for arthritic sufferers Include ideas from interview of arthritic sufferer Include collected data on ergonomics of hands Set criteria for planning development Use 2D, 3D & exploded annotated drawings
Ernie: Overall effectiveness Identify features of cereal boxes Specification drawings of boxes Features to attract customers Communication of information & notions of aesthetics
Penny: Overall impression Modify an existing school skipping rope handle to include a comfortable shape, ease of use, ergonomic grip & suitable materials Effectiveness of drawings
Rachel: Overall effectiveness Knowledge of design process in developing a solution to classroom storage problems Develop & evaluate a suitable & practical solution incorporating portability, durability, attractiveness Develop drawing & construction skills Identify differing requirements for storing different equipment
Sarah: Identify components & conditions to grow yoghurt culture Follow procedures, make batches of yoghurt with modified flavours Use sensory evaluation to evaluate palatability for target group Understand that in modifying food products a slight change can make a large difference
Tina: Overall judgement Understand & include aesthetic & practical dimensions of mask use Understand concept of design Ability to make adaptations Make a prototype of suitable size, materials, shape, comfort, strength of fastening & for use in school production

Appendix 17: Two written summative assessment examples

Example 1: Penny's statement for Anna a six-year-old student

Anna was successful in designing practical modifications to our existing skipping rope handles, satisfying criteria of comfort, ease of use, strength and grip. She also considered an additional modification that enabled ease of storage. Her drawings showed a clear understanding of ball bearing mechanisms and gave realistic views form end, side and cross-section. Anna listened actively to class discussion and kept reworking her design to justify it fitting criteria and the use of materials.

Example 2: Rachel's statement for Linda, a seven-year-old student

Linda showed skills and understandings in all areas of conceptual, procedural, societal and technical aspects of making a container for a particular purpose. She clearly defined and explained how her storage box was portable, durable and attractive. She used constant use of the iterative process to design and develop her container. She is a perfectionist and her drawings demonstrated this. They were accurate, drawn in 3D and measurements were taken exactly. She carefully detailed and cut out her net. Tabs were included to ensure careful construction of the actual box. She went a step further and developed a lid to fit over her box. She had independently realised that the lid net needed to be slightly bigger than the box net. Her self-assessment acknowledged her reflective thinking ability where she reasoned that to fit in more equipment she would need to make a higher, wider box.

Both comprehensive statements showed teachers' inclusion of an overall statement, conceptual, procedural, societal and technical detail and attitudinal aspects

Appendix 18: Finished products

Five examples of finished products are shown. They include:

(i) a mock-up of a mathematics container made by Amy (6 years)

(ii) a birdfeeder made by Heather (6 years)

(iii) masks made by 7 and 8 year olds

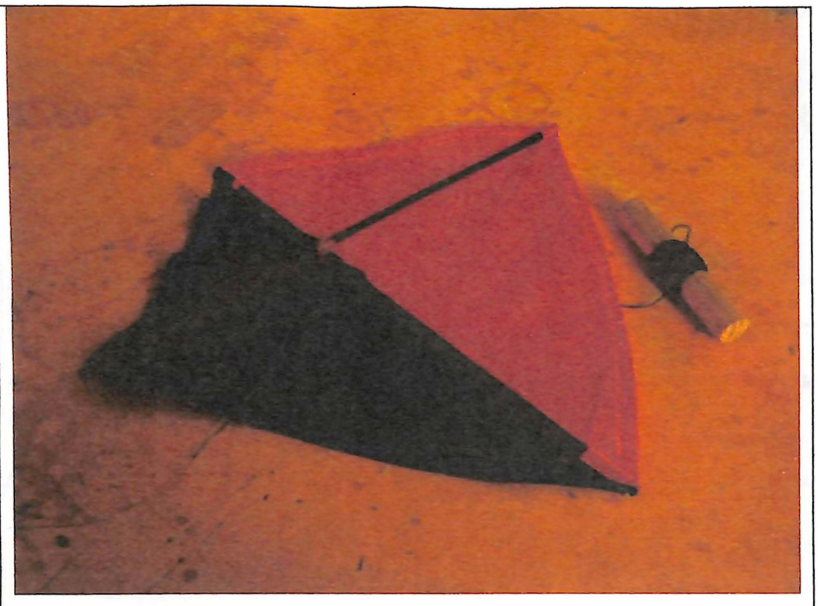
(iv) a kite made by Jane (9 years)

(v) a Tic Tac Toe game for visually impaired people made by Hoi and Damien (10 years)

(i)

(ii)

(iii)



(iv)

(v)

References

Adler, P. A., and Adler, P. (1987) *Blackboards and blackboards*. New York: Columbia University Press.

Adler, P. A., and Adler, P. (1994) Observational Techniques. In N. K. Denzin and Y. S. Lincoln (Eds.), *Handbook of qualitative research.* (pp 377-392). London: Sage Publications.

Alton-Lee, A. (2001) Research ethics, classroom research and educational practice. In M. Tolich, (Ed.), *Research ethics in Aotearoa New Zealand: Concepts, practice and critique.* (pp 87-98). Auckland: Pearson Education New Zealand Ltd.

Anning, A. (1993) Learning design and technology in primary schools. In R. McCormick, P. Murphy and M. Harrison (Eds.), *Teaching and learning technology.* (pp 176-187). Wokingham: Addison Wesley.

Anning, A. (1994) Dilemmas and Opportunities of a New Curriculum: Design and Technology with Young Children. *International Journal of Technology and Design Education, 4,* 155-177.

Anning, A. (1997) Drawing out ideas: Graphicacy and young children. *International Journal of Technology and Design Education, 7,* 219-239.

Askew, M., Brown, M.L., Rhodes, V., Johnson, D.C. and Wiliam, D. (1997) *Effective teachers of numeracy: Final report.* London, UK: King's College London School of Education.

Ball, S. J. (1984) Beachside reconsidered: reflections on a methodological apprenticeship. In Burgess, Robert G. (Ed.), *The research process in educational settings: Ten case studies.* (pp 69-96). London: Falmer Press.

Banister, P., Burman, E., Parker, I., Taylor, M. and Tindall, C. (1994) *Qualitative methods on psychology: A research guide.* Buckingham: Open University Press.

Bassey, M. (1987) Pedagogic research: on the relative merits of search for generalization and study of single events, *Oxford Review of Education, 7*(1), 73-93.

Bassey, M. (1999) *Case study research in educational settings.* Buckingham: Open University Press.

Bell, B. (Ed.), (1993) *I Know about LISP but how do I put it into practice?* Final Report of the Learning in Science Project (Teacher Development). SMTER Centre, University of Waikato.

Bell, B. (1995) Interviewing: a technique for assessing science knowledge. In S.M. Glynn &R. Duit (Eds.), *Learning science in schools.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Bell, B. and Cowie, B. (1997) *Formative assessment and science education.* Research Report, Learning in Science Project (Assessment). Centre for Science Mathematics and Technology Education Research, University of Waikato, Hamilton, New Zealand.

Bell, B. and Cowie, B. (2001) The characteristics of formative assessment in science education, *Science Education, 85*, 536-553.

Bell, B. and Gilbert, J. (1994) Teacher development as personal, professional and social development. *Teacher and teacher education, 10*, 483-497.

Bell, B. and Gilbert, J. (1996) *Teacher development: A model from science education.* London: The Falmer Press.

Bell, Judith (1987) *Doing your research project.* Milton Keynes: Open University Press.

Bennett, N. (1997) Voyages of discovery. In C. Cullingford (Ed.), *The politics of primary education.* (pp 125-142). Buckingham, UK: Open University Press.

Benson, C., and Raat, J. (1995) *Technology in primary education: Examples of technology lessons in Europe.* Delft: Technon.

Beynon, J. (1993) Introduction - learning to read technology. In Beynon, J. and Mackay, H. (Eds.), *Technological literacy and the curriculum.* (pp 1-37). London: The Falmer Press.

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

Biggs, J.B. (1996) Assessing learning quality: reconciling institutional, staff, and educational demands. *Assessment and Evaluation in Higher Education, 21*, 3-15.

Biggs, J. (1998) Assessment and classroom learning: a role for summative assessment? *Assessment in Education, 5*(1), 103-109.

Black, P. (1993) Formative and summative assessment by teachers. *Studies in Science Education, 21*, 49-97.

Black, P. (1995) 1987 to 1995 – The struggle to formulate a National Curriculum for science in England and Wales. *Studies in Science Education, 26*, 159-88.

Black, P. J. (1998) *Testing: Friend or foe? Theory and practice of assessment and testing*. London: The Falmer Press.

Black, P. and Atkin, J. (1996) *Changing the subject: Innovations in science, mathematics and technology education.* London and New York: Routledge.

Black, P., Harrison, C., Lee, C. and Wiliam, D. (2001) *Theory and practice of formative assessment.* Paper presented at AERA Conference, New Orleans, April.

Black, P. and Wiliam, D. (1998a) Assessment and classroom learning. *Assessment in education, 5*(1), 7-74.

Black, P. and Wiliam, D. (1998b) *Inside the black box.* London: School of Education, Kings College London.

Blackmore, J. (1998) *Assessment and accountability.* Waurn Ponds, Vic.: Deakin University Press.

Blenkin, G. (1992) Progression, observation and assessment in early education: the context. In Blenkin, G. V. and Kelly, A. V. (Eds.), *Assessment in early childhood education.* (pp 24-45). London: Paul Chapman Publishing.

Bottrill, P. (1995) *Designing and learning in the elementary school.* VA: International Technology Education Association.

Broadfoot, P. (1994) *Educational assessment: The myth of measurement.* Bristol England: University of Bristol.

Broadfoot, P. (1996a) Assessment and learning: power or partnership? In H. Goldstein and T. Lewis (Eds.), *Assessment: Problems, developments and statistical issues.* (pp 21-40). Chichester: John Wiley & Sons.

Broadfoot, P. M. (1996b) *Education, assessment and society.* Buckingham: Open University Press.

Broudy, H.S. (1988) *The uses of schooling.* New York: Routledge.

Brown, C. (1990) Girls, boys and technology. *School Science Review, 71*(257), 33-40.

Brown, S. (1990b) Assessment: a changing practice. In T. Horton (Ed.), *Assessment debates.* (pp 5-11). London: Hodder & Stoughton.

Brown, A., Ash, D., Rutherford, M., Nakagawa, K., Gordon, A. and Campione, J. (1993) Distributed expertise in the classroom. In G. Salomon (Ed.),

Distributed cognitions: Psychological and educational considerations. (pp 188-228). NY: Cambridge University Press.

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

Bryman, A. (2001) *Social research methods.* Oxford: Oxford University Press.

Burgess, R. G. (1982) Approaches to field research. In R. G. Burgess (1982) *Field research: A source book and field manual.* (pp 1-11). London: George Allen and Unwin.

Burgess, R. G. (Ed.), (1985) *Strategies of educational research: Qualitative methods.* London: Falmer Press.

Burns, J. (1992) Students' perceptions of technology and implications for an empowering curriculum. *Research in Science Education, 22*, 72-80.

Burns, J. (Ed.), (1997) *Technology in the New Zealand curriculum: Perspectives on practice.* Palmerston North: Dunmore Press.

Butler, D.L. and Winnie, P.H. (1995) Feedback and self-regulated learning: a theoretical synthesis. *Review of Educational Research, 65*(3), 245-282.

Butler, R. (1987) Task-involving and ego-involving properties of evaluation: effects of different feedback conditions on motivational perceptions, interest and performance. *Journal of Educational Psychology, 79*(4), 474-482.

Carr, M. A. (1997) *Technological practice in early childhood as a dispositional milieu.* Unpublished DPhil Thesis, University of Waikato, New Zealand.

Carr, M. A. (2001) Seeking children's perspectives about their learning. In Smith, A. Taylor, N. and Gollop, M (Eds.), *Children's voices: Research, policy and practice.* (pp 37-55). Malaysia: Pearson Education New Zealand Ltd.

Carr, M., McGee, C., Jones, A., McKinley, E., Bell, B., Barr, H. and Simpson, T. (2000) *Strategic research initiatives: The effects of curricula and assessment on pedagogical approaches and on educational outcomes,* Ministry of Education, Wellington, New Zealand.

Cazden, C. B. (1986) *Classroom discourse.* Portsmouth, HH: Heinmann.

Cohen, L. and Manion, L. (1994) *Research methods in education.* (4th Edition) London: Routledge.

Cohen, L., Manion, L. and Morrison, K. (2000) *Research methods in education.* (5th Edition) London: RoutledgeFalmer.

Cooper, P. and McIntyre, D. (1996) The importance of power-sharing in classroom learning. In M. Hughes (Ed.), *Teaching and learning in changing times.* (pp 108-128). Oxford: Blackwell Publishers.

Cowie, B. (2000) *Formative assessment in science classrooms,* Unpublished DPhil Thesis, University of Waikato.

Creswell, J. W. (1998) *Qualitative inquiry and research design: Choosing among five traditions.* Thousand Oaks: Sage Publications

Crooks, T.J. (1988) The impact of classroom evaluation practices on students. *Review of Educational Research, 58*(4), 438-481.

Crooks, T. (2002) *Principles to guide assessment practice.* Paper presented to the Waikato Principals Conference, Hamilton.

Custer, R., Valesey, B. and Burke, B. (2001) An assessment model for a design approach to technological problem solving. *Journal of Technology Education, 12*(2), 1-19.

Davies, D. (1996) Professional design and primary children. *International Journal of Technology and Design Education, 6*(1), 45-59.

Davis, R., Ginns, I. and McRobbie, C. (2002) Elementary school students' understandings of technological concepts. *Journal of Technology Education, 14*(1), 35-50.

Delandshere, G., and Petrosky, A.T. (1998) Assessment of complex performances: limitations of key measurement assumptions. *Educational Researcher, 27*(2), 14-24.

Denzin, N. K. and Lincoln, Y. S. (Eds.), (1994) *Handbook of qualitative research.* Thousand Oaks: Sage Publications.

Denscombe, M. (1995) Teachers as an audience for research: the acceptability of ethnographic approaches to classroom research. *Teachers and teaching: Theory and practice, 1*(2), 173-192.

Denscombe, M. (1998) *The good research guide: For small-scale social research projects.* Buckingham: Open University Press.

Dewey, J. (1916) *Democracy and education.* New York: Macmillan

Driver, R. (1989) Students' conceptions and the learning of science. *International Journal of Science Education, 11*(5), 481-90.

Driver, R., Asoko, H., Leach, J., Mortimer, E., and Scott, P. (1994) Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Driver, R., Guesne, E. and Tiberghien, A. (1985) *Children's ideas in science.* Buckingham, England: Open University Press.

Duschl, R.A. and Gitomer, D.H. (1997) Strategies and challenges to changing the focus of assessment and instruction in science classrooms. *Educational Assessment, 4*(1), 37-73.

Eisner, E. (1993) Reshaping assessment in education. *Journal of Curriculum Studies, 25*(3), 219-233.

Erickson, F. (1985) Qualitative methods in research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching (3rd Edition).* (pp 119-161). New York: Macmillan.

Fleer, M. (1992) Introducing technology education to young children: A design, make and appraise approach. *Research in Science Education, 22*, 132-139.

Fleer, M. (1999) The science of technology: Young children working technologically. *International Journal of Technology and Design Education, 9,* 269-291.

Fleer, M. (2000) Working technologically: Investigations into how young children design and make during technology education. *International Journal of Technology and Design Education, 10,* 43-59.

Flocton, L. and Crooks, T. (1996a) Technology assessment results. *National education monitoring project: Report 6.* Educational Assessment Research Unit: University of Otago, New Zealand

Flocton, L. and Crooks, T. (1996b) Reading and speaking assessment results. *National education monitoring project: Report 5.* Educational Assessment Research Unit: University of Otago, New Zealand

Filer, A. (1995) Teacher Assessment: social process and social product. *Assessment in Education, 2*(1), 23–38.

Fullan, M. G. (1991) *The new meaning of educational change.* London: Cassell.

Fullan, M. and Hargreaves, A. (1992) *Teacher development and educational change.* London: The Falmer Press

Galbraith, P. (1993) Paradigms, problems and assessment: some ideological implications. In M. Niss (Ed.), *Investigations into assessment in mathematics education.* (pp 73-86). Dordrecht: Kluwer Academic Publishers.

Geertz, C. (1973) Thick description: towards an interpretive theory of culture. In C. Geertz (Ed.), *The interpretation of cultures: Selected essays.* (pp 3-30). New York: Basic Books.

Gipps, C. (1994) *Beyond testing: Towards a theory of educational assessment.* London: Falmer Press.

Gipps, C. (1999) Socio-cultural aspects of assessment. *Review of Research in Education, 24,* 355-392.

Gipps, C. (2002) Socio-cultural perspectives on assessment. In G. Wells and G. Claxton (Eds.), *Learning for life in the 21st century: Sociocultural perspectives on the future of education.* (pp 73-83). London: Blackwell.

Gipps, C. and Brown, M. (1999) Primary teachers' beliefs about teaching and learning. *The Curriculum Journal, 10*(1), 123-134.

Gipps, C. and MacGilchrist, B. (1999) Primary school learners. In P. Mortimore (Ed.), *Understanding pedagogy and its impact on learning.* (pp 46-67). London: Paul Chapman Publishing.

Glaser, B. (1990) Towards new models for assessment. *International Journal of Educational Research, 14*(5), 475-483.

Goodson, I. F. (1985) *Social histories of the secondary curriculum.* Lewes: Falmer Press

Graue, M. E. and Walsh, D. J. (1995) Children in context: interpreting the here and now of children's lives. In J. A. Hatch (Ed.), *Qualitative research in early childhood settings.* (pp 135-154). Westport, Connecticut: Praeger.

Greeno, J. G., Collins, A.M. and Resnick, L.B. (1996) Cognition and learning. In Berliner, D.C. and Calfee, R.C. (Eds.), *Handbook of educational psychology.* (pp 15-46). New York: Macmillan.

Guba, E. and Lincoln, Y. (1989) *Fourth generation evaluation.* London: Sage.

Hargreaves, A. (1992) Cultures of teaching: a focus for change. In A. Hargreaves and M. Fullan (1992) (Eds.), *Understanding teacher development.* (pp 216-240). New York: Teachers College Press.

Hargreaves, E., McCallum, B. and Gipps, C. (2000) Teacher feedback strategies in primary classrooms – new evidence. In S. Askew (Ed.), *Feedback for learning.* (pp 21-31). London: Routledge.

Harlen, W. (1995) To the rescue of formative assessment. *Primary Science Review, 37,* 4-16.

Harlen, W. (1998) *Classroom assessment: A dimension of purposes and procedures*. Paper presented at NZARE, Dunedin, December.

Harlen, W. (1999) Purposes and procedures for assessing science process skills. *Assessment in Education*, *6*(1), 129-144.

Harlen, W., and James, M. (1997) Assessment and learning: differences and relationships between formative and summative assessment. *Assessment in Education*, *4*(3), 365-379.

Hattie, J., and Jaeger, R. (1998) Assessment and classroom learning: a deductive approach. *Assessment in Education*, *5*(1), 111-122.

Hennessy, S. (1993) Situated cognition and cognitive apprenticeship: implications for classroom learning. *Studies in Science Education*, *2,* 1-14.

Hennessy, S., McCormick. R., and Murphy, P. (1993) The myth of general problem solving capability: Design and technology as an example. *The Curriculum Journal*, *4*(1), 73-89.

Hennessy, S., and Murphy, P. (1999) The potential for collaborative problem solving in design and technology. *International Journal of Technology and Design Education*, *9,* 1-36.

Hill, A M. (1998) Problem solving in real-life contexts: An alternative for design in technology education. *International Journal of Technology and Design Education*, *8*(3), 203-220.

Huberman, A.M. and Miles, M. B. (1994) Data management and analysis methods. In N. K. Denzin and Y. S. Lincoln (Eds.), *Handbook for qualitative research.* (pp 428-444). Thousand Oaks, CA.: Sage.

Hughes, M. (Ed.) (1996) *Teaching and learning in changing times*, Blackwell: Oxford.

Jarvis, T. (1993) *Teaching design and technology in the primary school.* London: Routledge.

Jones, A. (1991) *'At school I've got a chance'*. Palmerston North: Dunmore Press.

Jones, A. (1995) Technology education in the New Zealand curriculum: from policy to curriculum. *SAMEpapers 1995*, 186-201.

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

Jones, A. (1999) Teacher subject subcultures and curriculum innovation: the example of technology education. In J. Loughran (Ed.), *Researching teaching: Methodologies and practices for understanding pedagogy.* (pp 155-171). London: Falmer Press.

Jones, A. and Carr, M. (1992) Teacher perceptions of technology education - implications for curriculum innovation. *Research in Science Education, 22,* 230-239.

Jones, A. T. and Carr, M. D. (1993a) *Towards technology education.* Volume 1: Working papers from the first phase of the learning in Technology Education Project. Centre for Science and Mathematics Education Research, University of Waikato, Hamilton, New Zealand.

Jones, A. T. and Carr, M. D. (1993b) *Analysis of student capability.* Volume 2: Working papers from the second phase of the Learning in Technology Education Project. Centre for Science and Mathematics Education Research, University of Waikato, Hamilton, New Zealand.

Jones, A. and Compton, V. (1998) Towards a model of teacher development in technology education. *International Journal of Technology and Design Education, 8*(1), 51-65.

Jones, A. with Hawe, E. and Mather, V. (1994) Assessment in technology education. In *Issues in the practice of technology education.* Vol. 3: Working papers from the third phase of the Learning in Technology Project. Centre for Science, Mathematics and Technology Education Research, University of Waikato, Hamilton, New Zealand.

Jones, A. T., Mather, V. and Carr, M. D. (1994) *Issues in the practice of technology education.* Vol. 3: Working papers from the third phase of the Learning in Technology Project. Centre for Science and Mathematics Education Research, University of Waikato, Hamilton, New Zealand.

Jones, A. and Moreland, J. (1998) *Assessment in technology education: Developing a framework for research.* Working Paper 522, Research in Assessment of Primary Technology Project. Centre for Science, Mathematics and Technology Education Research, University of Waikato, Hamilton, New Zealand.

Jones A. and Simon S. (1991) Strategies for educational change: the work of the OPENS project in the context of a new national curriculum for science. *SAMEpapers 1991*. (pp 15-35). Auckland: Longman Paul.

Kimbell, R. (1994). Progression in learning and the assessment of children's attainment in technology. *International Journal of Technology and Design Education, 4*(1), 65-83.

Kimbell, R. (1997) *Assessing technology. International trends in curriculum and assessment*. Buckingham, Philadelphia: Open University Press.

Kimbell, R. A., Stables, K. and Green, R. (1996) *Understanding practice in design and technology*. Buckingham, UK: Open University Press.

Kimbell, R., Stables, K., Wheeler, T., Wozniak, A. and Kelly, V. (1991) Evaluation and Monitoring Unit: Schools Examination and Assessment Council, London.

Lally, M., and Hurst, V. (1992) Assessment and the nursery curriculum: a review of approaches. In G. V Blenkin and A. V. Kelly (Eds.), *Assessment in early childhood education*. (pp 69-92). London: Paul Chapman Publishing.

Lather, P. (1992) Critical frames in educational research: Feminist and post-structural perspectives. *Theory into Practice, XXXI*(2), 87-99.

Lave, J. (1988) *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge: Cambridge University Press.

Lave, J. (1991) Situated learning in communities of practice, Chapter 4 in Resnick, L. B., Levine, J. M. and Teasley, S. D. (Eds.), *Perspectives on socially shared cognition*. (pp 63-82). Washington: American Psychological Association.

Lave, J. and Wenger, E. (1991) *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lewis, T. (1999) Research in technology education: Some areas of need. *Journal of Technology Education, 10*(2), 41-56.

Linblad, S. (1990) From technology to craft: on teachers' experimental adoption of technology as a new subject in the Swedish primary school. *Journal of Curriculum Studies, 22*(2), 165-175.

Lincoln, Y. S. and Guba, E. G. (1985) *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Locatis, G. N. (1987) Notes on the nature of technology. *Educational Technology*, *27*(9) 13-16.

Lunt, I. (1994) The practice of assessment. In H. Daniels, (Ed.), *Charting the agenda: Educational activity after Vygotsky*. (pp 145-170). London: Routledge.

Mackay, H. (1992) From computer literacy to technological literacy. In J. Beynon and H. Mackay (Eds.), *Technological literacy and the curriculum.* (pp 125-147). London: The Falmer Press.

Malcolm, C. (1994) Structures, force and stability. Design a playground (Year 6). In Fenshaw, P. J., Gunstone, R. F. and White, R. T. (Eds.), *The content of science: A constructivist approach to its teaching and learning*. (pp 59-79). London: The Falmer Press.

Mavrommatis, Y. (1997) Understanding assessment in the classroom: phases of the assessment process – the assessment episode. *Assessment in Education*, *4*(3), 381-399.

Maykut, P., and Morehouse, R. (1994) *Beginning qualitative research: A philosophic and practical guide*. London: The Falmer Press.

McCormick, R. (1992) The evolution of current practice in technology education. In R. McCormick, P. Murphy and M. Harrison (Eds.), *Teaching and learning technology*. (pp 3-14). Wokingham: Addison-Wesley, Open University.

McCormick, R. (1997) Conceptual and procedural knowledge. *International Journal of Technology and Design Education, 7*(1-2), 141-159.

McCormick, R. (2000) *Theoretical and empirical issues of technology education research*. AAAS Technology Education Research Conference 2000. http://www.project2061.org/technology/McCormick/McCormick.htm Retrieved 22.03.01

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

McGee, C. (1997) *Teachers and curriculum decision-making*. Palmerston North: The Dunmore Printing Company.

McGee-Brown, M. J. (1995) Multiple voices, contexts and methods: making choices in qualitative evaluation in early childhood education settings. In J.

A. Hatch (Ed.), *Qualitative research in early childhood settings.* (pp 119-212). Westport, Conn.: Praeger.

Medway, P. (1989) Issues in the theory and practice of technology education. *Studies in Science Education, 16,* 1-24.

Medway, P. (1994) The language component in technological capability: Lessons from architecture. *International Journal of Technology and Design Education, 4,* 85-107.

Mehan, H. (1974) Accomplishing classroom lessons. In A. V. Cicourel, K. H. Jennings, S. H. M. Jennings, K. C. W. Leiter, R. MacKay, H. Mehan, and D. R. Roth (Eds.), *Language use and school performance.* (pp 76-142). New York: Academic Press.

Merriam, S. (1988) *Case study research in education: A qualitative approach.* San Francisco: Jossey-Bass.

Merriam, S. B. (1998) *Qualitative research and case study applications in education.* San Francisco: Jossey-Bass.

Messick, S. (1989) Meaning and values in test validation: the science and ethics of assessment. *Educational Researcher, 18,* 5-11.

Miles, M. B. and Huberman, M. A. (1994) *Qualitative data analysis: An expanded handbook.* Thousand Oaks California: Sage Publications.

Ministry of Education (1993a) *Technology in the New Zealand curriculum draft.* Wellington: Learning Media.

Ministry of Education (1993b) *The New Zealand curriculum framework.* Wellington: Learning Media.

Ministry of Education (1994) *Assessment: Policy to practice.* Wellington: Learning Media.

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

Moreland, J. P. (1998) *Technology education teacher development: The importance of experiences in technological practice.* Unpublished M.Ed Thesis. University of Waikato, Hamilton, New Zealand.

Moreland, J. and Jones, A. (1999) *Case studies of classroom practice in technology.* Working Paper 523, Research in Assessment of Primary Technology Project. Centre for Science, Mathematics and Technology Education Research, University of Waikato, Hamilton, New Zealand.

Moreland, J., Jones, A., and Northover, A. (2001) Enhancing teachers' technological knowledge and assessment practices to enhance student learning in technology: a two-year classroom study. *Research in Science Education, 31*(1), 155-176.

Murphy, P. (1995) Sources of inequity: understanding students' responses to assessment. *Assessment in Education, 2*(3), 249-270.

Newman, D., Griffin, P., and Cole, M. (1989) *The construction zone: Working for cognitve change in school.* Cambridge, England: Cambridge University Press.

Paechter, C. (1992) Subject subcultures and the negotiation of open work: conflict and co-operation in cross-curricular coursework. In McCormick, R., Murphy, P. and Harrison, M. (Eds.), *Teaching and learning technology.* (pp 279-288). Wokingham: Addison-Wesley, Open University Press.

Paechter, C. (1995) "Doing the best for students": dilemmas and decisions in carrying out statutory tasks. *Assessment in Education, 2*(1), 39-52.

Parkinson, E. (2001) Teacher knowledge and understanding of design and technology for children in the 3-11 age group: a study focussing on aspects of structures. *Journal of Technology Education, 13*(1), 1-7.

Perrenoud, P. (1998) From formative evaluation to a controlled regulation of learning processes. Towards a wider conceptual field. *Assessment in Education, 5*(1), 85-102.

Pollard, A. (1990) Towards a sociology of learning in primary schools. *British Journal of Sociology Education, 11*(3), 241-256.

Pollard, A., Thiessen, D., and Filer, A. (Eds.), (1997) *Children and their curriculum: The perspectives of primary and elementary children.* London: Falmer Press.

Poulson, L. (2001) Paradigm lost? Subject knowledge, Primary teachers and education policy. *British Journal of Educational Studies, 49*(1), 40-55.

Powney, J., and Watts, M. (1987) *Interviewing in educational research.* London: Routledge and Kegan Paul.

Pryor, J., and Torrance, H. (1996) Teacher-pupil interaction in formative assessment: assessing the work or protecting the child? *The Curriculum Journal, 7*(2), 205-226.

Ramaprasad, A. (1983) On the definition of feedback. *Behavioural Science, 28,* 4-13.

Rennie, L. (2001) Teacher collaboration in curriculum change: the implications of technology education in the primary school. *Research in Science Education, 31*(1), 49-69.

Resnick, L. B. (1991) Shared cognition: Thinking as social practice. Chapter 1 in L. B. Resnick, J. M. Levine, and S. D. Teasley, (Eds.), *Perspectives on socially shared cognition.* (pp 1-20). Washington: American Psychological Association.

Resnick, L. B., and Resnick, D. P. (1992) Assessing the thinking curriculum: New tools for educational reform. In B. Gifford, and M. O'Connor (Eds.), *Changing assessment: Alternative views of aptitude, achievement and instruction.* (pp 37-76). London: Kluwer Academic Publishers.

Rhine, S. (1998) The role of research and teachers' knowledge base in professional development. *Educational Researcher, 27*(5), 27-31.

Rogers, G. (1998) *The designing stage of design, make and appraise: A case study involving young children designing.* Paper presented to the Australasian Science Education Research Association Conference, July, Darwin, NT.

Robottom, I. and Hart, P. (1993) Towards a meta-research agenda in science and environmental education. *International Journal of Science Education, 15*(5), 591-605.

Rogoff, B. (1990) *Apprenticeships in thinking: Cognitive development in social contexts.* Oxford: Oxford University Press.

Rogoff, B. (1994) Developing understanding of the idea of communities of learners. *Mind, culture and activity, 1,* 209-229.

Rogoff, B. (1995) Sociocultural activity on three planes. In J.V. Wertsch, P. Del Rio and A. Alvaraz (Eds.), *Sociocultural studies of mind.* (pp 139-164). Cambridge, UK: Cambridge University Press

Rogoff, B., Matusov, E., and White, C. (1996) Models of teaching and learning: participation in a community of learners. In D. Olson and N. Torrance (Eds.), *Handbook of education and human development: New models of learning, teaching and schooling.* (pp 388-414). London: Basil Blackwell.

Ryan, A. (1988) Program evaluation within the paradigm: mapping the territory, *Knowledge: Creation, diffusion, utilization, 10*(10), 25-47.

Sadler, D. R. (1989) Formative assessment and the design of instructional systems. *Instructional Science, 18*(2), 119-144.

Sadler, D. R. (1998) Formative assessment: revisiting the territory. *Assessment in Education, 5*(1), 77-84.

Salomon, G. (1989) Technology's promises and dangers in a psychological and educational context. *Theory into Practice, 3*(1), 4-10.

Schön, D. A. (1983). *The reflective practitioner. How professionals think in action.* New York: Basic Books Inc.

Schunk, D.H. and Zimmerman, B.J. (1996) Modeling and self-efficacy influences on children's development of self-regulation. In J. Juvonen and K. R. Wentzel (Eds.), *Social motivation: Understanding children's school adjustment.* (pp 154-180). Cambridge: Cambridge University Press.

Scribner, S. (1985) Vygotsky's uses of history. In J.V. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian perspectives.* 119-145. Cambridge, England: Cambridge University Press.

Shepard, L. (1991) Psychometricians' beliefs about learning. *Educational Researcher, 20*(7), 2-16.

Shulman, L. S. (1987) Knowledge and teaching: foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Shulman, S. (1990) *Pedagogical ways of knowing.* Keynote Address, ICET World Assembly. Institute of Education, Singapore.

Shulman, L. S. (2001) Inventing the future. Conclusion to *Opening lines: Approaches to the scholarship of teaching and learning,* http://www.carnegiefoundation.org/eLibrary/docs/opening_conclusion.htm, Retrieved 17.12.01.

Sizmar, S. and Sainsbury, M. (1997) Criterian referencing and the meaning of national curriculum assessment. *British Journal of Educational Studies, 45*(2), 123-140.

Solomon, J. and Hall, S. (1996) An inquiry into progression in primary technology: A role for teaching. *International Journal of Technology and Design Education, 6*, 263-282.

Stables, K. (1995) Discontinuity in transition: Pupils' experiences of technology in Year 6 and Year 7. *International Journal of Technology and Design Education, 5*(2), 157-169.

Stables, K. (1997) Critical issues to consider when introducing technology education into the curriculum of young learners. *Journal of Technology Education, 8*(2), 1-17.

Sternberg, R. J. and Horvath, J.A. (1995) A prototype view of expert teaching. *Educational Researcher, 24*(6), 9-217.

The Cognition and Technology Group at Vanderbilt (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher, 19*(6), 2-10.

The Science with Technology Project (1994) *Developing Food Products*, The Association for Science Education: Hatfield.

Tolich, M. (Ed.), (2001) *Research ethics in Aotearoa New Zealand: Concepts, practice and critique.* Auckland: Pearson Education New Zealand Ltd.

Torrance, H. and Pryor, J. (1995) Investigating teacher assessment in infant classrooms: methodological problems and emerging issues. *Assessment in Education, 2*(3), 305-320.

Torrance, H. and Pryor, J. (1998) *Investigating formative assessment: Teaching, learning and assessment in the classroom.* Buckingham: Open University Press.

Treagust, D.F. and Rennie, L.J. (1993) Implementing technology in the school curriculum: a case study involving six schools. *Journal of Technology Education, 5*(1), 1-11.

Tunstall, P. and Gipps, C. (1996) Teacher feedback to young children in formative assessment: a typology. *British Educational Research Journal, 22*(4), 389-404.

von Glasersfeld, E. (1993) Questions and answers about radical constructivism. In K. Tobin (Ed.) *The practice of constructivism in science education, 2*(3), 249-260.

Vygotsky, L. S. (1986) *Thought and language.* Cambridge, MA: Harvard University Press.

Waejten, W. (1993) Technological literacy reconsidered. *Journal of Technology Education, 4*(2), 1-5.

Walsh, D. J., Tobin, J. J. and Graue, M. E. (1993) The interpretive voice: qualitative research in early childhood education. In B. Spodek (Ed.),

Handbook of research on the education of young children. (pp 464-476). New York: MacMillan.

Werstch, J.V. (1991) A sociocultural approach to socially shared cognition. In L. B. Resnick, J.M. Levine and S. D. Teasley (Eds.), *Perspectives on socially shared cognition.* (pp 85-100). Washington: American Psychological association.

White, R. T. (1992) Implications of recent research on learning for curriculum and assessment. *Journal of Curriculum Studies*, *24*(2), 153-164.

Wiggins, G. P. (1993) *Assessing student performance, exploring the purpose and limits of testing.* San Francisco: Jossey-Bass Publishers.

Wiliam, D. (1998) *Enculturating learners into communities of practice: Raising achievement through classroom assessment.* Paper presented at the European Conference for Educational Research, University of Ljubljana, Slovenia, Sept 17-20.

Willis, D. (1992) Educational assessment and accountability: a New Zealand case study. *Journal of Educational Policy*, *7*(2), 205-221.

Willis, D. (1994) School-based assessment: underlying ideologies and their implications for teachers and learners. *New Zealand Journal of Educational Studies*, *29*(2), 161-174.

Wolf, D., Bixby, J., Glenn, J. and Gardner, H. (1991) To use their minds well: Investigating new forms of student assessment, *Review of Research in Education*, *17*, 31-74.