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# **Enhancing Student Decision Making in Technological Practice**

A thesis submitted for the degree of PhD Education

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## ABSTRACT

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This research focused on identifying the influence of conceptual understandings of *technological modelling* on students' ability to make informed decisions when developing technological outcomes. It also explored the relationship between student achievement in the components of Technological Practice (*brief development, planning for practice, and outcome development and evaluation*) and their concepts in *technological modelling*.

An emancipatory action research design was adopted for this study due to its responsiveness to the context in natural settings, and focus on critical reflection with intent to improve understandings and practice within social settings (Elliot, 1981; Poskitt, 1994). Quantitative and qualitative data were gathered using a mixed methods approach, consisting of a questionnaire, portfolio evidence and interviews. These data were gathered over three research cycles from 27 student participants who were in years 12 and 13 in 2008 and 2009 respectively.

Category labels were developed from literature and an initial exploration of the data, to describe the 'nature of reasoning' and the 'nature of practice' students applied when engaged in undertaking technological practice to address a need or opportunity. The category labels allowed exploration of the relationships between the different forms of reasoning students employed when undertaking technological practice. These labels also enabled exploration of how reasoning informed student decision making and supported their justifying that the technological outcomes they developed were 'fit for purpose'.

The research found a positive connection between student understanding of concepts underpinning *technological modelling* and their curriculum achievement in the components of Technological Practice - *brief development, planning for practice, and outcome development and evaluation*. That is, when student understanding of *technological modelling* were enhanced their competency to undertake *brief development, planning for practice, and outcome development and*

*evaluation* also increased. The research also showed that students who held more sophisticated understanding of *technological modelling* (Level 6 or above) could discuss how practical and functional reasoning work together to identify risk, and enable informed and justifiable design decisions to be made. In addition these students could also justify the technological outcomes they developed as ‘fit for purpose in their broadest sense’ (Compton, 2007; Compton & France, 2007b). In contrast, those students who held low curriculum level understanding of *technological modelling* (below Level 5) demonstrated a lack of ability to integrate practical and functional reasoning to inform their decision making when undertaking technological practice. As such, their decision making most often centred on determining the physical description of a technological outcome, with little apparent thought to social-technical considerations that underpinned its development, and later implementation into its intended environment.

This research concludes that when teachers support students to develop their curriculum understandings of *technological modelling* their ability in undertaking technological practice becomes more sophisticated, and they are equipped to develop technological outcomes that they can defend as ‘fit for purpose in their broadest sense’ (Compton, 2007; Compton & France, 2007b). The research findings therefore present a case for teachers to place an explicit emphasis within their teaching programmes on enhancing student conceptual understandings of *technological modelling*.

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# TABLE OF CONTENTS

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	<i>page</i>
<b>Abstract</b>	i
<b>Acknowledgements</b>	iii
<b>Tables and Figures</b>	ix
<b>Acronyms used in Thesis</b>	xii
<b>CHAPTER ONE INTRODUCTION</b>	
1.1 Overview of Chapter .....	1
1.2 Context of Research .....	2
1.3 Rationale for this Research .....	5
1.4 Research Aim and Questions .....	7
1.5 Structure of the Research Report. ....	8
<b>CHAPTER TWO LITERATURE REVIEW</b>	
2.1 Overview of Chapter .....	10
2.2 Technology Education in New Zealand Curriculum .....	12
2.2.1 Background .....	12
2.2.2 New Zealand Curriculum and Marautanga Project .....	14
2.2.3 Technology in New Zealand Curriculum .....	16
2.2.4 Nature of student learning in technology education .....	28
2.3 Technological Practice and the NZC (Ministry of Education, 2007) .....	31
2.3.1 Technological Practice: what is it? .....	31
2.3.2 Technological Practice within Technology Education .....	33
2.3.3 Technological Practice and Technology in the New Zealand Curriculum (Ministry of Education, 2007) .....	35
2.4 Technological Knowledge .....	38
2.4.1 Technological Knowledge: what is it? .....	38
2.4.2 Technological Knowledge within Technology Education .....	39
2.4.3 Technological Knowledge and Technology in the New Zealand Curriculum (Ministry of Education, 2007) .....	50
2.4.4 Technological Modelling in the New Zealand Curriculum (Ministry of Education, 2007) .....	51

	<i>page</i>
2.5	Decision Making and Reasoning ..... 55
2.5.1	Decision making ..... 56
2.5.2	Reasoning ..... 59
2.5.3	Decision making and reasoning in Technology Education ..... 65
2.6	Summary of the Emergent Themes and Issues Identified from the Literature ..... 66
 <b>CHAPTER THREE METHODOLOGY AND RESEARCH METHODS</b>	
3.1	Overview of the Chapter ..... 70
3.2	Educational Research ..... 70
3.2.1	Methodological approaches ..... 70
3.2.2	Research methods ..... 75
3.3	Approaches used for this Research ..... 78
3.3.1	Methodological approach ..... 78
3.3.2	Action research design ..... 79
3.3.3	Rationale for using Action Research for this study ..... 86
3.3.4	Data collection tools ..... 91
3.3.5	Coding and Categorising Data ..... 95
3.3.6	Indicators and Category Labels for Components of Technological Practice ..... 96
3.3.7	Indicators and Category Labels for evaluating student reasoning and decision making within technological practice ..... 109
3.3.8	Validity and reliability ..... 113
3.4	Research Participants ..... 117
3.4.1	Profile of schools and participants ..... 117
3.5	Ethics ..... 119
3.6	Summary ..... 120
 <b>CHAPTER FOUR RESEARCH FINDINGS: CYCLE ONE</b>	
4.1	Overview of Chapter ..... 122
4.2	Findings by Individual Students ..... 123
4.2.1	Cycle One: Students' achievement in technological modelling, brief development, planning for practice, and outcome development and evaluation ..... 124
4.2.2	Cycle One: Students' reasoning and decision making ..... 125

	<i>page</i>
4.3	Cycle One Findings ..... 127
4.3.1	Cycle One: Student Level of Achievement in technological modelling ..... 127
4.3.2	Cycle One: Student Level of Achievement in brief development ..... 129
4.3.3	Cycle One: Student Level of Achievement in planning for practice ..... 130
4.3.4	Cycle One: Student Level of Achievement in outcome development and evaluation ..... 131
4.3.5	Cycle One: Student Level of Achievement in reasoning and decision making ..... 132
4.4	Relationship between Student Understanding of Technological Modelling and their Achievement of the Components of Technology Practice ..... 133
4.4.1	Cycle One: Relationship between student understanding of technological modelling and their achievement in undertaking brief development ..... 134
4.4.2	Cycle One: Relationship between student understanding of technological modelling and their achievement in undertaking planning for practice ..... 135
4.4.3	Cycle One: Relationship between student understanding of technological modelling and their achievement in undertaking outcome development and evaluation ..... 136
4.5	Relationship between Understandings of Technological Modelling and Reasoning and Decision Making ..... 137
4.6	Summary of Findings ..... 140
4.6.1	What curriculum levels for technological modelling, brief development, planning for practice, and outcome development and evaluation do students exhibit in Cycle One? ..... 140
4.6.2	What evidence of reasoning and decision making can be identified from Cycle One student data? ..... 142
4.6.3	In Cycle One: what is the relationship between student achievement in technological modelling, and their achievement in brief development, planning for practice, and outcome development and evaluation? ..... 143
4.6.4	In Cycle One: what is the relationship between student achievement in technological modelling, and their reasoning and decision making when undertaking technological practice ..... 144



**CHAPTER FIVE RESEARCH FINDINGS: CYCLE TWO and THREE**

5.1	Overview of Chapter .....	145
5.2	Interventions Focused on Enhancing Student Concepts of Technological Modelling: Cycle Two and Three .....	146
5.2.1	Cycle Two and Three: description of interventions	147
5.2.2	Cycle Two and Three: Students' achievement in technological modelling, brief development, planning for practice, and outcome development and evaluation	153
5.2.3	Cycle Two and Three: students' reasoning and decision making	157
5.2.4	Cycle Two and Three: student level of achievement in technological modelling	161
5.2.5	Cycle Two and Three: student level of achievement in brief development	162
5.2.6	Cycle Two and Three: student level of achievement in planning for practice	164
5.2.7	Cycle Two and Three: student level of achievement in outcome development and evaluation	166
5.2.8	Student Level of Achievement in reasoning and decision making	167
5.2.9	Relationship between student understanding of technological modelling and their achievement of the components of technology practice	172
5.2.10	Relationship between student understanding of technological modelling, and decision making and reasoning	182
5.3	Summary of Findings .....	188
5.3.1	What impact did interventions have on student achievement in technological modelling, brief development, planning for practice, and outcome development and evaluation?	188
5.3.2	What impact did interventions have on student reasoning and decision making when undertaking technological practice?	190
5.3.3	What is the relationship between student achievement in technological modelling, and their achievement in brief development, planning for practice, and outcome development and evaluation?	191
5.3.4	What is the relationship between student achievement in technological modelling, and their reasoning and decision making when undertaking technological practice?	192

	<i>page</i>
<b>CHAPTER SIX DISCUSSION AND IMPLICATIONS</b>	
6.1 Overview of Chapter .....	195
6.2 Contribution to Research Literature .....	196
6.2.1 Reasoning and decision making category labels	198
6.3 Relationship between student conceptual understanding of <i>technological modelling</i> , their achievement in the components of Technological Practice, and their reasoning and decision making when undertaking technological practice .....	201
6.4 Implications of the research findings on the design of classroom based technology curriculum .....	204
6.5 Suggestions for Future Research .....	207
6.6 Conclusion .....	210
 <b>REFERENCES</b>	 212
 <b>APPENDICES</b>	 226
Appendix A Information Sheet for Research Participants .....	227
Appendix B Student Questionnaire .....	236
Appendix C Interview Questions - Sample .....	239
Appendix D Indicators of Progression for Technological Practice .....	241
Appendix E Indicators of Progression for Technological Modelling .....	251

## TABLES AND FIGURES

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### TABLES

	<i>Title</i>	<i>page</i>
Table 1	Research Cycles	89
Table 2	Examples of Category Labels: brief development	97
Table 3	Examples of Category Labels: planning for practice	100
Table 4	Examples of Category Labels: outcome development and evaluation	101
Table 5	Examples of Category Labels: technological modelling	105
Table 6	Category of reasoning and drivers underpinning decision making	111
Table 7	Individual student level of achievement in technological modelling; brief development, planning for practice, and outcome development and evaluation	124
Table 8	Individual student reasoning and decision making	126
Table 9	Combined student participant data Cycle One: technological modelling	128
Table 10	Combined student participant data Cycle One: brief development	129
Table 11	Combined student participant data Cycle One: planning for practice	130
Table 12	Combined student participant data Cycle One: outcome development and evaluation	131
Table 13	Combined student participant data Cycle One: reasoning and decision making	132
Table 14	Cycle One: student understandings of technological modelling and their achievement in undertaking brief development	134
Table 15	Cycle One: student understandings of technological modelling and their achievement in undertaking planning for practice	135
Table 16	Cycle One: student understandings of technological modelling and their achievement in undertaking outcome development and evaluation	136

	<i>Title – cont.</i>	<i>page</i>
Table 17	Cycle One: student understandings of technological modelling and their decision making and reasoning	138
Table 18	Individual student level of achievement in technological modelling; brief development, planning for practice, and outcome development and evaluation	153
Table 19	Individual student reasoning and decision making	158
Table 20	Combined student participant data Cycle One, Two and Three: technological modelling	161
Table 21	Combined student participant data Cycle One, Two and Three: brief development	163
Table 22	Combined student participant data Cycle One, Two and Three: planning for practice	164
Table 23	Combined student participant data Cycle One, Two and Three: outcome development and evaluation	166
Table 24	Combined student participant data Cycle One, Two and Three: reasoning and decision making	168
Table 25	Cycle One, Two and Three: student understandings of technological modelling and their achievement in undertaking brief development	173
Table 26	Cycle One, Two and Three: student understandings of technological modelling and their achievement in undertaking planning for practice	176
Table 27	Cycle One, Two and Three: student understandings of technological modelling and their achievement in outcome development and evaluation	179
Table 28	Cycle One, Two and Three: student understandings of technological modelling and their decision making and reasoning	182

## FIGURES

	<i>Title</i>	<i>page</i>
Figure 1	Diagrammatic definition of technology and technological practice	31
Figure 2	Lewin's Scheme of Action	87
Figure 3	Cycles of the research	88
Figure 4	Combined student participant data Cycle One: student understandings of technological modelling	128
Figure 5	Combined student participant data Cycle One: student achievement in brief development	129
Figure 6	Combined student participant data Cycle One: student achievement in planning for practice	130
Figure 7	Combined student participant data Cycle One: student achievement in outcome development and evaluation	131
Figure 8	Combined student participant data Cycle One, Two and Three: understandings of technological modelling	162
Figure 9	Combined student participant data Cycle One, Two and Three: brief development	164
Figure 10	Combined student participant data Cycle One, Two and Three: planning for practice	165
Figure 11	Combined student participant data Cycle One, Two and Three: outcome development and evaluation	167
Figure 12	Cycle One, Two and Three: practical reasoning	170
Figure 13	Cycle One, Two and Three: functional reasoning	171
Figure 14	Cycle One, Two and Three: integrated reasoning	171
Figure 15	Cycle One, Two and Three: decision making	172

## ACRONYMS USED IN THESIS

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<i>Acronym</i>	<i>Definition</i>	<i>page</i>
TiNZC	Technology in the New Zealand Curriculum	2
NZC	New Zealand Curriculum	2
LA	Learning Area	2
ECEC	Early Childhood Education Centres	2
NZQF	New Zealand Qualifications Framework	3
NZQA	New Zealand Qualifications Authority	3
MoE	Ministry of Education	3
NCEA	National Certificate in Educational Achievement	3
NZCMP	New Zealand Curriculum and Marautanga Project	4
IoP	Indicators of Progression	5
TKNoT: Imps	Technological Knowledge and Nature of Technology: Implications for teaching and learning	5
NMR	National Moderator Report	5
ELA	Essential Learning Areas	12
NZCF	New Zealand Curriculum Framework	12
MiNZC	Mathematics in the New Zealand Curriculum	13
TAiNZC	The Arts in the New Zealand Curriculum	13
NSSS	National School Sampling Study	14
TKMoA	Te Kaupapa Marautanga o Aotearoa	15
DeSeCo	Definition and Selection of Competencies: Theoretical and Conceptual Foundations	15
LAS	Learning Area Statement	16
TEALS	Technology Education Assessment in Lower Secondary	19
TKNoT	Technological Knowledge and Nature of Technology	19
BoT	Board of Trustees	119

# CHAPTER ONE

## INTRODUCTION

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### 1.1 Overview of Chapter

Technology education in New Zealand is a compulsory part of school curriculum for all students in years 1-10, and is an optional subject in senior secondary school at years 11-13. First introduced as *Technology in the New Zealand Curriculum* (Ministry of Education, 1995), it was reframed in 2007 as a part of a revision of the total New Zealand Curriculum. This thesis reports on research that explored if students were better able to justify the technological outcomes they developed as ‘fit for purpose’ when their understanding of *technological modelling*, a component of technology introduced in the 2007 *New Zealand Curriculum* (Ministry of Education, 2007), improved.

I had prior experience in conducting classroom based research (Compton & Harwood, 2003; 2004a; 2005; Compton, Harwood & Compton, 2007; Harwood, 2007), and in contributing to the development of technology national curricula<sup>1</sup> and resource materials to support their implementation into New Zealand classrooms. This exploration was therefore of significance to me, particularly to see if placing a focus on a specific Technological Knowledge curriculum component, *technological modelling*, resulted in a change in student achievement when undertaking technological practice. I was also motivated to gain a better understanding of how students applied reasoning to support their decision making when undertaking technological practice. In addition, my experiences in teacher professional development initiatives (Compton & Harwood, 2001; 2004b; 2005; Harwood, 2005; Harwood, 2006; Harwood, 2009; Harwood, 2012) provided opportunity to conduct this research using an action research methodology focused on supporting and evaluating shifts in teachers’ pedagogical practices.

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<sup>1</sup> Design and Technology (Department of Education, 1987); Graphics and Design (Department of Education, 1991); Technology in the *New Zealand Curriculum* (Ministry of Education, 1995 & 2007).

The remainder of this chapter provides an introduction and background to my thesis. Section 1.2 introduces the context in which the research was conducted. This Section includes a brief overview of the New Zealand secondary school structure and the history of technology education therein. An overview of technology education in New Zealand is presented with a synopsis of the 1995 technology curriculum, *Technology in the New Zealand Curriculum [TiNZC]* (Ministry of Education, 1995) and a discussion of how technology is now defined in the revised *New Zealand Curriculum [NZC]* (Ministry of Education, 2007). A description of senior secondary (years 11-13) qualifications for technology are also presented in this section. Section 1.3 provides a rationale for this research, Section 1.4 introduces the research questions, and Section 1.5 provides an overview of the thesis structure and a discussion on the significance of this research.

## 1.2 Context of this Research

### *The New Zealand Secondary School*

Secondary schools were established in New Zealand to educate students from school years 9-13<sup>2</sup>. In rural communities and schools of special character (for example private schools, schools founded on religious ideologies) secondary schools may also include students in years 7-8. Up to and including year 10, secondary school students receive a compulsory core curriculum, defined by the *NZC* (Ministry of Education, 2007). This includes study in each of the seven *Learning Areas [LA]* – English, The Arts, Health and Physical Education, Mathematics with Statistics, Science, Social Sciences and Technology along with an option to study another language in an eighth *LA* - Learning Languages. From years 11-13 New Zealand secondary schools offer a variety of specialist focused subjects to prepare students for ongoing tertiary education and/or entry into the workplace.

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<sup>2</sup> New Zealand children begin their compulsory education at age 5. Prior to this they may enrol in Early Childhood Education Centres [*ECEC*]. Children usually enrol in *ECEC* from age 3.



Senior secondary students (year 11-13) are provided access to qualifications listed on the *New Zealand Qualifications Framework*<sup>3</sup> [NZQF]. The NZQF was introduced to provide a “system for organising and understanding the relationships between, and purposes of, qualifications across the education sector” (Ministry of Education, 1999, p.4). As such, the NZQF offers a ‘seamless’ opportunity for New Zealanders to be credited with qualifications in secondary schools that connect with post-school education and training qualifications.

The *New Zealand Qualifications Authority* [NZQA], a government department that is independent of the *Ministry of Education* [MoE], administers the NZQF. The qualifications on the NZQF specifically available for secondary school students include the *National Certificate in Educational Achievement* [NCEA] at Level 1, 2 and 3, and Scholarship. Students access these qualifications by demonstrating a set of competencies that are described by either ‘achievement standards’ and/or ‘unit standards’<sup>4</sup>.

### ***Technology in Secondary Schools***

In 1999, *Technology in the New Zealand Curriculum* (Ministry of Education, 1995) was gazetted as a compulsory learning area in New Zealand’s national curriculum for all students from years 1-10, and as an optional subject for study in senior secondary school (year 11-13). The aim of technology education as identified in the *TiNZC* was that students would work towards attaining technological literacy through developing their understandings and abilities within three inter-related learning strands:

- technological knowledge and understanding
- technological capability
- technology and society (Ministry of Education, 1995).

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<sup>3</sup> The NZQF is comprised of 10 levels – Level 1 is the least complex and Level 10 the most. Standards written for Levels 1-3 of the NZQF are for senior secondary education and basic trades training. Levels 4 - 6 are for advanced trades, technical and business qualifications, and Levels 7 and above for advanced qualifications as graduate and postgraduate degrees.

<sup>4</sup> *Achievement standards* assess competencies which align with senior secondary school subject achievement objectives and award students for either an achieved, merit or excellence achievement. *Unit standards* assess competencies that align with either senior secondary school subject achievement objectives, including those defined by the *New Zealand Curriculum* (Ministry of Education, 2007) Learning Areas, or industry defined skills and knowledge. These standards predominantly only have one achievement level – achieved.

In 2004, *TiNZC* (Ministry of Education, 1995) was reviewed as part of a Ministry of Education Curriculum Stocktake. This Stocktake reviewed all compulsory and optional curricula taught in New Zealand schools. As a result of this review, the *New Zealand Curriculum and Marautanga Project*<sup>5</sup> [NZCMP] was undertaken and a revised NZC was released in 2007. The LA statement<sup>6</sup> for technology in the NZC (Ministry of Education, 2007) reframed technology education into three inter-related but distinct learning strands - understanding the Nature of Technology, developing Technological Knowledge and understanding and undertaking Technological Practice (Ministry of Education, 2007). The aim of these curriculum strands was to provide opportunity for students to develop a deep, broad and critical technological literacy (Compton, 2007; Compton & France, 2007a) so that they may “participate in society as informed citizens and give them (better) access to technology-related careers” (Ministry of Education, 2007, p.32).

In 2008, the *Curriculum Alignment Project*<sup>7</sup> was initiated by the Ministry of Education, in association with the NZQA to align earlier technology achievement standards that had been developed for NCEA qualifications at Level 1-3 and scholarship<sup>8</sup> to the NZC (Ministry of Education, 2007). Under this project the technology achievement standards were reviewed and rewritten to align with the 2007 technology LA statement (Ministry of Education, 2007) at curriculum levels 6, 7 and 8. A number of these rewritten achievement standards require students to develop a technological outcome. The assessment focus of these standards is on students either being able to justify their technological outcomes as having the ‘potential to be fit for purpose’ (where students develop and modelled a concept of a technological outcome), or ‘fit for purpose’ (for standards that require students to implement a technological outcome).

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<sup>5</sup>*Marautanga* is the Māori name for the Curriculum Framework which umbrellas the Essential Learning Areas written in Te Reo Māori – New Zealand’s indigenous language.

<sup>6</sup> The New Zealand Curriculum Project reframed, refocused and revitalised the New Zealand curriculum by clarifying what is important for student to learn within identified Learning Areas, placing importance on quality teaching, promoting flexible approaches to curriculum and explaining the curriculum to parents. The project released its revised curriculum in 2007 and was implemented in 2010.

<sup>7</sup> This project reviewed and aligned all general education achievement and unit standards registered on the NZQF with the NZC (Ministry of Education, 2007).

<sup>8</sup> These achievement standards were implemented beginning 2002; Level 1 in 2002, Level 2 in 2003, and Level 3 and scholarship in 2004.

### 1.3 Rationale for this Research

Technology in the *NZC* (Ministry of Education, 2007) introduced three new strands – Technological Practice, Nature of Technology and Technological Knowledge. Understanding how students' progress in the Technological Practice strand components: *brief development*, *planning for practice*, and *outcome development and evaluation*; and how these support learning in technology education were researched inside New Zealand classrooms to inform the development of the 2007 technology *LA* statement and its objectives (Compton & Harwood, 2003; 2004b; 2005). An outcome of this research was the development of the *Indicators of Progression [IoP]* for Technological Practice (Compton & Harwood, 2010b). These *IoP* describe student competencies, and the nature of teacher support required to ensure that students are provided authentic opportunities to engage with the strand components, at achievement objective levels 1-8 of technology in the *NZC* (Ministry of Education, 2007).

Research to develop similar understanding of progression for the components of Technological Knowledge and the Nature of Technology strands was not conducted until post the release of the *NZC* (Ministry of Education, 2007). This research, funded by the *MoE*, called *Technological Knowledge and the Nature of Technology: Implications for classroom practice [TKNoT: Imps]* was conducted during 2008 and 2009<sup>9</sup>. The focus of this classroom-based research was on identifying student understandings of the components of these two strands in order to define their *IoP* from levels 1-8 (Compton & Compton, 2010b). The components for Technological Knowledge include: *technological modelling*, *technological products* and *technological systems*; and for Nature of Technology: *characteristics of technology* and *characteristics of technological outcomes* (Ministry of Education, 2007).

The *National Moderator Report [NMR]* is an annual report written by the *NZQA* National Moderator. This report discusses student achievement against the internally assessed technology achievement standards listed on the *NZQF*. The report describes the strengths and weaknesses found in the student evidence that

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<sup>9</sup> For findings and discussion of this research see Compton and Compton, 2010a; 2010b; 2011, and 2012).

has been assessed and moderated against technology achievement and unit standards. It makes suggestions on areas that teachers should focus on, to better support students to demonstrate the competencies expected to be awarded achievement grades for internally assessed standards. The *NMR* has consistently highlighted that student evidence presented for assessment against the internally assessed technology achievement standards does not show how student decision making, when undertaking technological practice, influenced their developed technological outcome(s) (New Zealand Qualifications Authority, 2004; 2005; 2006; 2007; 2008). In addition, the *Technology Scholarship Examiners Report*, also written annually, has commented on a weakness in the evidence students provide in justifying that their technological outcomes are 'fit for purpose'.

Therefore the research I have undertaken and report in this thesis sought to better understand and improve student decision making and outcome justification. To do this it specifically explored the relationship between students' conceptual understanding of *technological modelling* and their achievement in the components of Technological Practice. It also investigated the link between students' conceptual understanding of *technological modelling* and their decision making when undertaking technological practice.

No research has been conducted to date in New Zealand that specifically looks at the link between student conceptual understandings of *technological modelling* and student achievement in the components of Technological Practice. Nor has there been research undertaken that refutes or supports that when students have a sound conceptual understanding of *technological modelling* that their decision making and technological outcome justification is enhanced. This study therefore seeks to address this gap in the literature. The findings of this research will be of interest to technology teachers, and providers of technology teacher education (both pre-service and in-service providers). Findings from the research will also be useful to inform future planning and policy making for the delivery and assessment of technology at senior secondary school by teachers, the *MoE* and the *NZQA*, as well as offer a contribution to the international literature on technology education.

## 1.4 Research Aim and Questions

This research sought to determine the relationship between students' conceptual understanding of *technological modelling*, their achievement in the components of Technological Practice, and their decision making. To ascertain this relationship, student achievement in the components of Technological Practice (*brief development, planning for practice, and outcome development and evaluation*) and their concepts in *technological modelling* were also explored over three cycles by adopting an action research design. My research question was:

What is the relationship between student conceptual understanding of *technological modelling*, their achievement in the components of Technological Practice, and their reasoning and decision making when undertaking technological practice?

To allow evidence to be gathered and valid conclusions to later be drawn that answered this research question, a series of sub questions were developed. The sub-questions were:

1. What curriculum levels for *technological modelling, brief development, planning for practice, and outcome development and evaluation* do students exhibit in Cycle One?
2. What evidence of reasoning and decision making can be identified from Cycle One student data?
3. What impact did interventions in Cycles Two and Three have on student achievement in *technological modelling, brief development, planning for practice, and outcome development and evaluation*?
4. What impact did interventions<sup>10</sup> in Cycles Two and Three have on student decision making when undertaking technological practice?
5. What is the relationship between student achievement in *technological modelling*, and their achievement in *brief development, planning for practice, and outcome development and evaluation*?

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<sup>10</sup> Post-intervention data were collected twice – once after the 2008 cycle (Cycle Two) and then following the 2009 cycle (Cycle Three).

6. What is the relationship between student achievement in *technological modelling*, and their reasoning and decision making when undertaking technological practice?

## 1.5 Structure of the Research Thesis

*Chapter One* provided an introduction and background to my research, introduced the aim and objectives of the research, and presented the structure of this report.

*Chapter Two* provides a review of relevant literature upon which my research is based. This review of literature presents an overview of *Technology Education in the New Zealand Curriculum* (Ministry of Education, 1995) and the revised technology statement, as described in the 2007 NZC (Ministry of Education, 2007). It also considers international and New Zealand research that supported the inclusion of the technology curriculum strand: Technological Knowledge in the revised NZC (Ministry of Education, 2007) and why technological modelling was included as a component of this strand.

The chapter also discusses programme design that enables students to develop a technological literacy that is liberatory in nature and concludes with a review of the literature on decision making, and functional and practical reasoning. This review explains how developing student understanding of these forms of reasoning supports them to consider ‘social’ and ‘ethical’ factors when developing design ideas, and to determine whether a conceptual design should be developed further and if so, how to make it happen.

*Chapter Three* explores the literature concerning methodological approaches in educational research. This literature establishes action research as the appropriate methodological framework for this study. The chapter concludes with an overview of the participants and discusses the ethical considerations that underpin my research.

*Chapter Four* presents Cycle One research findings, obtained from 27 senior secondary school student research participants from three secondary schools. Both quantitative and qualitative findings are presented from data that were analysed

using statistical analysis, and a pattern coding approach. Such coding allowed common themes or patterns that emerged from student responses to a structured questionnaire and portfolio evidence, to be identified categorised and labelled. This chapter ends with a summary of the findings and answers sub research questions 1 and 2. It also discusses initial finding implications for sub research questions 5 and 6.

*Chapter Five* presents Cycles Two and Three research findings. Data from the structured questionnaire, follow-up interviews with participants (Cycle Three) and portfolio evidence were analysed to establish the findings, which were categorised under the labels identified in Chapter Four. The chapter concludes with a summary of the research findings and answers the remaining sub questions 3, 4, 5 and 6.

*Chapter Six* addresses the overall aim of my research; that is, what is the relationship between student conceptual understanding of *technological modelling*, their achievement in the components of Technological Practice, and their reasoning and decision making when undertaking technological practice. It does this by analysing the research findings in Chapter Four and Five in relation to the literature presented in Chapter Two. This chapter presents a discussion on how the research findings could influence the design of classroom based technology curriculum; particularly those which emphasise supporting students to justify their decision making when developing technological outcomes, and create defensible arguments as to why their developed outcomes are ‘fit for purpose’. Chapter Six also discusses the impact that these findings could have on future initiatives focused on enhancing the delivery of technology education inside New Zealand classrooms and how student learning outcomes can be enhanced. The chapter ends with suggestions for future research and a concluding statement.



# CHAPTER TWO

## LITERATURE REVIEW

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### 2.1 Overview of the Chapter

This chapter will demonstrate that no research has been conducted to date in New Zealand classrooms to determine the influence of the component *technological modelling* on students' ability to make informed decisions when they undertake Technological Practice. This component is featured in the Technological Knowledge strand of technology in the *NZC* (Ministry of Education, 2007). As of 2010, all technology programmes taught in New Zealand schools from years 1-10 are required to provide students opportunity to build conceptual understandings of this curriculum component. It is expected that this component, when taught alongside the other curriculum components in technology programmes from years 1-13, will allow students to develop their technological literacy (Ministry of Education, 2007). This expectation is founded on a belief that student's technological literacy is enhanced when they develop sound philosophical insights about technology, alongside robust understandings about technological knowledge, and an ability to undertake technological practice. Compton and France (2007a; 2007b) promote this view when they suggest that whilst undertaking technological practice is still seen as important, there is also a need to understand the philosophy of technology as a domain and develop understandings of key technological knowledge. Compton (2009) further promotes the inclusion of these components when she states that they are "required for the development of a broad, deep and critical technological literacy" (p.25). This stance is akin to international literature that highlights the importance of students developing technological knowledge alongside sound philosophical understandings about technology (Dakers, 2006; de Vries, 2003a; Mitcham, 1987).



Research conducted in New Zealand to date has not sought to understand the relationship between student understandings of technological knowledge and their decision making abilities when undertaking technological practice. Rather, it has examined student's initial conceptual understandings of the components of Technological Knowledge (Compton & France, 2006b; Compton, Harwood & Compton, 2007) and Nature of Technology (Compton & France, 2006b), and how these understandings progress from curriculum levels 1-8 (Compton & Compton, 2011; 2012). The research has also explored how the curriculum components for all three strands, Technological Practice, Technological Knowledge and Nature of Technology, work together to support the development of student technological literacy (Compton & Compton, 2011; 2012; Compton, Compton & Patterson, 2011; 2012). This study therefore sets out to address a gap in the literature and determine if there are relationships between student achievement in *technological modelling* and the components *brief development, planning for practice* and *outcome development and evaluations*. It also seeks to explore if there is a relationship between student conceptual understandings of *technological modelling* and their decision making when undertaking technological practice.

In Section 2.2 an overview of technology in the *NZC* (Ministry of Education, 2007) is presented. It discusses the research undertaken during the development of technology in *NZC*, and subsequent research to support its implementation. The nature of student learning promoted by technology in the *NZC* (Ministry of Education, 2007) is discussed along with its underpinning learning theory(s). This section also discusses programme design and how this may enable students to develop a technological literacy that is 'broad, deep and critical' in nature (Compton, 2007; Compton & France, 2007a).

Section 2.3 presents an overview of 'technological practice' and discusses how this is reflected in the Technological Practice strand of technology in the *NZC* (Ministry of Education, 2007). It introduces the 'indicators' that enable improvements (or not) in student technological practice to be judged, following intervention.

Section 2.4 outlines the literature on 'technological knowledge' and discusses how this is reflected in the Technological Knowledge strand of technology in the *NZC* (Ministry of Education, 2007). It places an emphasis on *technological modelling*,

the component of Technological Knowledge that is the focus of intervention in this study. Indicators for *technological modelling* are also introduced in this section.

Section 2.5 presents a discussion on ‘decision making’ and explores how this influences students’ ability to justify design decisions in technology. The relationship between decision making and theories on practical and functional reasoning, and how these are exhibited by students in technology education will also be explored to support this discussion.

Section 2.6 provides a summary of the emergent themes and issues identified from the literature. These themes are used to justify the purpose for this research.

## 2.2 Technology Education in New Zealand Curriculum

### 2.2.1 Background

In 2007, technology in the *NZC* (Ministry of Education, 2007) was published and released in its final form. Technology as described in this document was implemented as a part of the compulsory New Zealand school curriculum for years 1-10 in 2010 to replace its predecessor, *Technology in the New Zealand Curriculum [TiNZC]* (Ministry of Education, 1995). The *NZC* was a result of the *New Zealand Curriculum and Marautanga Project*, an initiative undertaken by the Ministry of Education [*MoE*] to revise the previous *New Zealand Curriculum Framework [NZCF]* (Ministry of Education, 1993a).

#### *The New Zealand Curriculum Framework (Ministry of Education, 1993a)*

The *NZCF* (Ministry of Education, 1993a) was the umbrella document for all curricula taught in New Zealand schools, from years 1-13 from 1993 until 2010. It contained seven interrelated *Essential Learning Areas*<sup>11</sup> [*ELA*] (Ministry of Education, 1993a) that were identified as important for all New Zealand students to

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<sup>11</sup> The *Essential Learning Areas* defined in the *NZCF* (Ministry of Education, 1993a) were Science, Social Sciences, Mathematics, The Arts, Languages and Language, Health and Physical Well-being, and Technology.

study from years 1-10<sup>12</sup>. Rather than prescribing the knowledge and skills teachers were required to deliver to students, each *ELA* defined a set of achievement objectives. These objectives described broad learning goals, providing teachers' flexibility to develop student tailored learning programmes. The *NZCF* (Ministry of Education, 1993a) therefore was underpinned by a post-modernist view of teaching and learning, where curricula were presented as frameworks (Shearer, 1997) that allowed teachers' to develop classroom programmes to best meet their students learning needs. This 'learner-centred' (Print, 1993) approach to curriculum design enabled teachers to develop classroom curricula and adopt pedagogical delivery strategies that were 'outcomes based', focused on the 'learner' and their learning needs, rather than solely on the curriculum itself (Harwood, 2007).

The *NZCF* (Ministry of Education, 1993a) provided a guiding framework for the development of the seven *ELA* curriculum statements. However, due to each of them being developed individually over seven years<sup>13</sup>, and there being changes over this period of time in interpretation of what an *ELA* curriculum statement needed to contain, details within the statements varied. These variations led to there being a considerable difference between the first *ELA* statements developed and those which followed later. For example, the number of achievement objectives listed significantly reduced from the first *ELA* curriculum statement developed to the last. This reduction in the number of achievement objectives is highlighted when the *Mathematics in the New Zealand Curriculum [MiNZC]* (Ministry of Education, 1993b) is compared with *The Arts in the New Zealand Curriculum [TAiNZC]* (Ministry of Education, 2000) which was gazetted<sup>14</sup> seven years after the *MiNZC*. The *MiNZC* (Ministry of Education, 1993b) contained 281 achievement objectives that were required to be addressed within compulsory mathematics education while *TAiNZC* (Ministry of Education, 2000) had only four common

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<sup>12</sup> Year 10 marks the end of compulsory education in New Zealand where all students must be provided opportunity to study each of the seven *ELA* described in the *NZCF* (Ministry of Education, 1993a). In years 11-13 students are offered an opportunity to specialise their learning, and are offered a choice of subjects to study.

<sup>13</sup> The first *ELA* curriculum statement developed was Science, published in 1993. The last statement developed was The Arts in 2000. The curriculum statement for technology under the *NZCF* (Ministry of Education, 1993a) was drafted in 1993, released in its final form in 1995 and gazetted to become a part of the compulsory school curriculum from years 1-10 in 1999.

<sup>14</sup> When curriculum statements for the *ELA* were 'gazetted' they became a part of compulsory school curriculum from years 1-10. They also framed the delivery of school based curriculum and assessment for qualification in years 11-13.

generic achievement objectives that were contextualised across the four disciplines of Art (e.g. visual art, drama, dance and music). Other notable differences included later gazetted *ELA* curriculum statements reducing the amount of teacher advice and guidance provided on how to deliver curriculum, and a removal of the section that provided teacher's guidance on assessment.

To address differences in *ELA* curriculum statements, and also gauge the effectiveness of their implementation, a 'curriculum stocktake' was undertaken in 2001 by the *MoE*. This stocktake included a review of the *ELA* curriculum statements, evaluations by international curriculum experts, and an analysis of teachers' experiences in delivering curricula aligned to the *ELA* curriculum statements (Jones, Harlow, & Cowie, 2004). Teacher sampling was accomplished through a *National School Sampling Study [NSSS]*. Key aspects were investigated by the *NSSS* using national focus groups, questionnaires and case studies. These aspects included: the background and experience of teachers; professional support offered to teachers; the usefulness of the curriculum documents; general issues related to curriculum implementation; practice; and impact and compliance issues (Jones, Harlow, & Cowie, 2004). Along with other learning areas, the *NSSS* provided an opportunity for teachers who had been involved in implementing *TiNZC* (Ministry of Education, 1995) to share their experiences (Jones, Harlow, & Cowie, 2004). The major outcome of this stocktake was a decision to develop the *NZCF* (Ministry of Education, 1993a) and define new curricula for all learning areas under the *New Zealand Curriculum and Marautanga Project [NZCMP]*.

### **2.2.2 New Zealand Curriculum and Marautanga Project**

The goals for redeveloping the *NZCF* (Ministry of Education, 1993a) under the *NZCMP* included:

- clarifying and redefining the intended learning outcomes for each of the *ELA*
- placing a focus on quality teaching
- strengthening school ownership of curriculum

- better supporting communication and strengthening partnerships between the education sector, and parents, whānau<sup>15</sup>, and communities.

(Ministry of Education, 2005)

As a result of the redevelopment of the *NZCF* (Ministry of Education, 1993a), two new curriculum frameworks were written – *The New Zealand Curriculum* (Ministry of Education, 2007) developed for schools delivering curricula in the English medium, and the *Te Kaupapa Marautanga o Aotearoa [TKMoA]* which set the direction for teaching and learning in Māori medium primary and secondary kura<sup>16</sup>. The *TKMoA* curriculum followed the same goals and premise as the *NZC*, however those perspectives pertinent to Māori, including key competencies, values and attitudes were highlighted within this curriculum.

The *NZC* (Ministry of Education, 2007) incorporated:

- an ‘essence statement’ (descriptive statement) that encapsulated the fundamental ideas and important student learning outcomes for each *ELA*.
- an eighth *ELA* called *International Languages*
- a revision of the previous Language and Languages *ELA* to only include *English* and *Te Reo Māori*
- the removal of the 1993 curriculum *Essential Skills*<sup>17</sup> and inclusion of *Key Competencies*<sup>18</sup>
- a revision of the 1993 section on *Attitudes* and *Values*<sup>19</sup> to provide a clear expectation that schools and teachers will promote a broad set of *values* identified as important to all New Zealanders (Ministry of Education, 2005).

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<sup>15</sup> Whānau is a term used by New Zealand Māori to refer to an extended family or group of extended families living in the same area.

<sup>16</sup> A *kura* is a state school where the principal language of instruction is Te Reo Māori.

<sup>17</sup> The *Essential Skills* identified in the *NZCF* (Ministry of Education, 1993a) were *Communication, Numeracy, Information, Problem solving, Self-management and Competitive, Social and Cooperative, Physical* and *Work and Study* skills.

<sup>18</sup> *Key Competencies* is a term that describes the desirable competencies all students should aim to attain as a result of participation in learning. This term was first identified in an OECD project called: *Definition and Selection of Competencies: Theoretical and Conceptual Foundations (DeSeCo)*.

<sup>19</sup> *Attitudes* and *Values* were not specifically defined in the *NZCF* (Ministry of Education, 1993a). Rather *attitudes* were identified as “positive dispositions towards things, ideas or people” and *values* as “internalised beliefs, or principles of behaviour held by individuals or groups” (Ministry of Education 1993a, p.21).

In 2010, the *NZC* (Ministry of Education, 2007) was gazetted and so became the compulsory framework for writing *all* school curriculum from years 1-10. Unlike the 1993 *NZCF* post-modernist underpinning, the 2007 *NZC* emphasised a view of teaching and learning focused on educating students for ‘democratic citizenship’ (Compton, 2007). This shift in focus was in response to contemporary learning theories, such as constructivist and socio-cultural learning theories, that highlighted the need for a re-conceptualisation of ‘knowledge and learning’ in educational policies and practices to align with contemporary 21st century societies (Chamberlain, 2008; Richard & Usher, 1994). This re-conception meant that the *NZC* (Ministry of Education, 2007) developed as an ‘outcomes-oriented’ curriculum, placing emphasis on ‘substance’ (*knowing*) and ‘processes’ (*doing*). As such, the *NZC* (Ministry of Education, 2007) did not prescribe content to be taught, rather it provided teachers and schools flexibility so that students could develop “a broad technological literacy that equips them to participate in society as informed citizens and give them the access to technology related careers” (Ministry of Education, 2007, p.32). The *NZC* (Ministry of Education, 2007) therefore was positioned as the overarching framework for teachers’ to develop classroom programmes to best meet their student learning needs. It did this by “set[ting] direction for student learning” and providing “guidance to schools as they design and review their curriculum” (Ministry of Education, 2007, p.6). To enable teachers to enact this framework, the *ELA* defined in the *NZC* (Ministry of Education, 2007) state “succinctly what each learning area is about and how learning is structured” (Ministry of Education, 2007, p.4), and prescribes a set of achievement objectives that describe broad learning goals.

### **2.2.3 Technology in New Zealand Curriculum**

As part of the *New Zealand Curriculum and Marautanga Project*, *TiNZC* (Ministry of Education, 1995) was reviewed and a *Learning Area Statement [LAS]* that redefined technology was developed. This *LAS* describes technology as providing students opportunity to “learn to be innovative developers of products and systems and discerning consumers who will make a difference in the world” (Ministry of



Education, 2007, p.17). It further defines technology as:

*Intervention by design: the use of practical and intellectual resources to develop products and systems (technological outcomes) that expand human possibilities by addressing needs and realising opportunities.*  
(Ministry of Education, 2007, p.32)

While seven technological areas<sup>20</sup> had previously been defined as important for students to experience in the *TiNZC* (Ministry of Education, 1995), classroom practice and research had showed that learning in technology often crossed a number of these technological areas (Compton & Harwood, 2003). The defined technological areas in *TiNZC* (Ministry of Education, 1995) were therefore replaced in the technology *LAS* (Ministry of Education, 2007) with a list that describes a broad range of related technology areas “associated with the transformation of energy, information, and materials” (p.32). This list includes control, food, information and communications technology, and biotechnology. To allow students to develop technological literacy the curriculum requires that student’s experience a wide range of these technologies in a variety of contexts across the three technology *LAS* curriculum strands: Technological Practice, Technological Knowledge, and Nature of Technology (Ministry of Education, 2007).

### ***Changes to Curriculum Strands***

The overall aim of technology as defined in *TiNZC* (Ministry of Education, 1995) was stated as allowing students to develop ‘technological literacy’ through undertaking technological practice. This aim was retained in the technology *LAS* (Ministry of Education, 2007) however, the concept of technological literacy, and how it is attained, was extended so it was no longer solely related to technological practice (Compton, 2009). This change was in response to limitations found during implementation of the *TiNZC* (Ministry of Education, 1995). *TiNZC* (Ministry of Education, 1995) contended that supporting students to undertake technological practice from a strong sociological focus enabled them to “move their technological literacy away from a ‘functional’ orientation to a literacy that was ‘liberatory’ in

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<sup>20</sup> The *seven technological areas* were: information and communications technology, food technology, materials technology, electronics and control technology, structures and mechanisms, production and process technology, and biotechnology.

nature” (Compton & Harwood, 2008, p.1). While this argument was in keeping with contemporary sociological understandings of technology and technological practice at the time (Barnett, 1995; MacKenzie & Wajcman, 1985; Pacey, 1983; McGinn, 1990), evidence gained from senior secondary examination results<sup>21</sup> indicated that the nature of students’ technological literacy was limited (Compton, 2009; Compton & France, 2007b; Compton & Harwood, 2008). It was identified that this limitation was due to student knowledge and skill development being solely immersed within technological practice (Compton, 2010a; Compton & Harwood, 2008). Research findings from the *NSSS*, across all year levels, also suggested that students were not achieving the level of informed criticality that *TiNZC* (Ministry of Education, 1995) had aimed for (Jones & Compton, 2009). It was hypothesised that this situation was also due to technology programmes focusing on “developing students’ understandings of and about technology almost exclusively within the context of their own technological practice” (Compton & Harwood, 2008, p.1). Therefore, it was argued that the *TiNZC* (Ministry of Education, 1995) failed to support students to develop generic technological concepts, and philosophical understandings about technology and the outcomes of technological development. To redress this situation it was argued that a stronger curriculum focus needed to be placed on the ‘philosophy of technology’ and on the ‘generic concepts’ underpinning technological practice (Compton, 2004; Compton & Jones, 2004). The revised 2007 technology *LAS* (Ministry of Education, 2007) therefore restructured the curriculum around three new strands: Technological Practice and the newly defined Nature of Technology and Technological Knowledge (Compton & France, 2007a)<sup>22</sup>; and eight new components were identified with defined achievement objectives for curriculum levels 1-8. These new strands and components were included to allow “students to develop a broad technological literacy that will equip them to participate in society as informed citizens and give them access to technology-related careers” (Ministry of Education, 2007, p.32).

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<sup>21</sup> At senior secondary school (Years 11, 12 and 13) students participate in national examinations. These examinations are administered by the *New Zealand Qualifications Authority [NZQA]*, a Crown Entity who are responsible for managing all nationally prescribed assessments and examinations registered on the *New Zealand Qualifications Framework*.

<sup>22</sup> An explanation of the research that informed the defining of the Nature of Technology and Technological Knowledge strands for technology *LAS* (Ministry of Education, 2007) is presented below.



### ***Achievement Objectives Changes***

The ‘achievement objectives’ and their corresponding *progression statements*<sup>23</sup> presented in the *TiNZC* (Ministry of Education, 1995) document were written on a ‘projected belief’ rather than ‘absolute knowledge’ of what students could achieve in technology education (Compton & Harwood, 2000; Compton & Harwood, 2004b; Compton & Harwood, 2005). This was not the case for technology in the *NZC* (Ministry of Education, 2007). The ‘achievement objectives’ and ‘progression statements’ written for the Technological Practice strand of technology in the *NZC* (Ministry of Education, 2007) were based on findings from twelve years of research conducted inside New Zealand classrooms. This research had focused on developing an understanding about what students could achieve in technology when provided an opportunity to engage in technological activity (Compton & Harwood, 2004b; Compton & Harwood, 2005; Moreland & Jones, 2000; Moreland, Jones & Northover, 2001). The Indicators of Progression for technological practice were developed out of the *Technology Education Assessment in Lower Secondary [TEALS]* (TEALS 1999; 2000) research (Compton & Harwood, 2003; Compton & Harwood, 2005), and provided to the *MoE* in 2005 to support the development of Technological Practice strand achievement objectives. The ‘achievement objectives’ for the Technological Knowledge and Nature of Technology strands however were not informed by the same level of classroom research (Compton & France, 2007a). Their Indicators of Progression were initially developed from research undertaken inside New Zealand classrooms during the *Technological Knowledge and Nature of Technology (TKNoT)* research project (Compton & France, 2007b) and later refined by the *Technological Knowledge and Nature of Technology: Implications for teaching and learning (TKNoT Imps)* research project (Compton & Compton, 2011; 2012).

### ***Technological Knowledge and Nature of Technology project***

To identify the components and develop descriptors for the strands Nature of Technology and Technological Knowledge for the technology *LAS* (Ministry of Education, 2007), a research project was commissioned by the *MoE*. This project, called the *Technological Knowledge and Nature of Technology [TKNoT]*, was

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<sup>23</sup> Statements that describe eight levels of student competency for each achievement objective - Level 1 being the lowest level of competency and level 8 the highest.

conducted by Dr Vicki Compton and Dr Bev France from the Faculty of Education, The University of Auckland.

The overall goal of the *TKNoT* research project was to identify the key components for Technological Knowledge and the Nature of Technology strands that were to be included in technology in the *NZC* (Ministry of Education, 2007). Initial indicators of how these key components progressed in terms of student achievement from curriculum levels 1-8 were identified, and advice and guidance to inform the writing of the technology *LAS* and achievement objectives for these two strands was also provided. To achieve these outcomes, the researchers focused on three research questions:

1. *What are the essential components of Technological Knowledge and the Nature of Technology critical for technology education in New Zealand?*
2. *How does technological knowledge progress across the New Zealand Curriculum framework levels 1-8?*
3. *How does the nature of technology progress across NZCF levels 1-8?*

*(Compton & France, 2007b, p.164)*

The *TKNoT* research was embedded in “contemporary theory - from the philosophy of technology and technology education” and drew on “the knowledge located in the New Zealand technology community of practice, and contemporary technology education practice via teachers and teacher educators” (Compton & France, 2006b, p.2). To ensure that technological sectors significant within New Zealand had an opportunity to have input into identifying strand components, a mix of academic and practising technologists from a broad range of technological areas (for example, biotechnology, engineering, food technology, control technologies, information and communication technologies, architecture, and creative design) were consulted (Compton & France, with Pound & Archer, 2012). Recognised international experts in the field of technology education were also asked for input to ensure developing ideas could be discussed outside the New Zealand context. The inclusion of these experts, in the consultation process, “ensured the research outcomes were relevant to New Zealand but not so ‘insular’ as to render them invalid in the wider global context” (Compton & France, 2006b, p.2). Primary, intermediate and secondary teachers, and their students, also participated in the

later phases of the research project. Their input allowed initial indicators of student achievement and their likely progression from curriculum levels 1-8 to be identified.

From the *TKNoT* research, three components of Technological Knowledge and two components for the Nature of Technology were identified. Draft indicators of how these components might progress across curriculum levels 1-8 were also written. The components identified were:

<i>Technological Knowledge:</i>	Technological modelling
	Technological products
	Technological systems
<i>Nature of Technology:</i>	Characteristics of technology
	Characteristics of technological outcomes

The Technological Knowledge strand allows students to develop conceptual understandings about knowledge that are generic to all technological undertakings, regardless of the specific context they are studying, or the technological practice they undertake (Compton and France, 2006b). Key understandings incorporated into this strand are *functional modelling* and *prototyping, material use and development*, and *components of technological systems and how they interact*. Students learn:

- how functional modelling is used to evaluate design ideas, and how prototyping is used to evaluate the fitness for purpose of products and systems as they are developed
- the importance of understanding material properties and uses
- how materials can be incorporated or developed into products and systems to allow them to achieve functional and physical requirements
- about constituent parts of systems and how these work together to enable a system to operate the way that it does.

The three strand components, *technological modelling*, *technological products*, and *technological systems* are based on a ‘functional’ epistemology that considers conceptual knowledge belonging to the domain of technology; that is, knowledge

judged as 'key' generic concepts that underpin technological practice and technological outcomes (Compton, 2004; Compton & France, 2006b). Compton and France (2006b) conceived that students who understand these concepts could justify the 'fitness for purpose' of a technological outcome in terms of its physical (e.g. size, colour, shape, chemical or electronic composition) and functional (e.g. what it can do or how it functions) properties and establish the likely acceptance of an outcome in a wider societal sense. Descriptions provided for the three components of *Technological Knowledge* were:

*Technological modelling: refers to modelling practices used to enhance technological developments and includes functional modelling and prototyping. Functional modelling allows for the ongoing testing of design concepts for yet-to-be-realised Technological Outcomes. Prototyping allows for the evaluation of the fitness for purpose of the Technological Outcome itself.*

*Through technological modelling, evidence is gathered to justify decision making within Technological Practice. Such modelling is crucial for the exploration of influences on the development, and for the informed prediction of the possible and probable consequences of the proposed outcome. Technological modelling is underpinned by both functional and practical reasoning. Functional reasoning focuses on 'how to make it happen' and 'how it is happening'. Practical reasoning focuses on 'should we make it happen?' and 'should it be happening?'*

*Decisions as a result of technological modelling may include the: termination of the development in the short or long term, continuation of the development as planned, changing/refining the design concept and/or the nature of the Technological Outcome before proceeding, or to proceed as planned and/or accept the prototype as fit for purpose.*

*(Compton, 2010, p.49)*

*Technological products: are material in nature and exist in the world as a result of human design. Understanding the relationship between the composition of materials and their related performance properties is essential for understanding and developing technological products. Technological knowledge within this component includes the means of evaluating materials to determine appropriate use to enhance the fitness for purpose of technological products. It includes understandings of how materials can be modified and material innovation. Understanding the impact of material selection and development on the design, development, maintenance and disposal of technological products is also included.*

*(Compton, 2010, p.56)*

*Technological systems: are a set of interconnected components that serve to transform, store, transport or control materials, energy and/or information. These systems exist in the world as the result of human design and function without further human design input. Understanding how these parts work together is as important as understanding the nature of each individual part.*

*Technological system knowledge includes an understanding of input, output, transformation processes, and control, and an understanding the notion of the 'black box' particularly in terms of sub-system design. Understanding redundancy and reliability within system design and performance, and an understanding of the operational parameters of systems are also included. Specialised languages provide important representation and communication tools and are therefore included to support developing ideas of system design, development, maintenance and troubleshooting.*

*(Compton, 2010, p.62)*

The Nature of Technology strand provides opportunity for students to develop a philosophical understanding about technology as a discipline and to gain an understanding about how technology differs from other forms of human activity. In studying this strand, students are supported to develop a critical understanding of technology, especially in regards to ethics, values and reasoning. Compton and France (2007a) argue, that when students possess a critical understanding of technology they can undertake informed reflections on both their own and others “technological development and outcomes, and justify their [own subsequent] actions across a range of priorities including the rights and roles of those from other socio-cultural positions and powerbases” (p.162). They hypothesised that possessing such a critical understanding allows students to participate in informed debate on historical and contemporary issues, and future scenarios about technology (Compton, 2007; Compton & Jones, 2003; Compton & France, 2007a). This stance is in keeping with the educational goals discussed by other technology educators, of empowering students to become informed and critical citizens (Dakers, 2006), that not only think about what is happening around them, but who also have the capacity to take action (Keirl, 2006). There are two components to the Nature of Technology strand - *characteristics of technology* and *characteristics of the technological outcomes*. Description for the two components of Nature of Technology state:

*Characteristics of technology: Technology is defined as purposeful intervention-by-design. It is a human activity, known as Technological Practice, that results in Technological Outcomes that have impact in the world. Technological outcomes can enhance the capability of people and expand human possibilities. Technological outcomes change the made world, and may result in both positive and negative impacts on the social and natural world. Technology uses and produces technological knowledge. Technological knowledge is aligned to function, and validation of this knowledge occurs within technological communities when it is shown to support the successful development of a Technological Outcome. Technology is historically positioned and inseparable from social and cultural influences and impacts. Contemporary Technological Practices increasingly rely on collaboration between people within the technology community and with people across other disciplines.*

*(Compton, 2010, p.43)*

*Characteristics of technological outcomes: are products and systems developed through Technological Practice for a specific purpose. A Technological Outcome is evaluated in terms of its fitness for purpose. Technological outcomes can be described by their physical and functional nature. A Technological Outcome can only be interpreted when the social and historical context of its development and use are known. The term proper function is used to describe the function that the technologist intended the Technological Outcome to have and/or its socially accepted common use. If a Technological Outcome does not carry out its proper function successfully it is described as a malfunction. Alternative functions are successful functions that have been evolved by end-users. Technological outcomes work together with non-technological entities and systems in the development of socio-technological environments.*

*(Compton, 2010, p.37)*

To substantiate the draft indicators identified by the *TKNoT* research project for the Technological Knowledge and Nature of Technology strand components, in November 2007 the *MoE* funded an additional two years of research. This additional research sought to gain classroom informed understandings on how teachers could progress student abilities across curriculum levels 1-8 in these two strands. Called, *Technological Knowledge and Nature of Technology: Implications for teaching and learning [TKNoT: Imps]*, this research was conducted by Dr Vicki Compton and Angela Compton from the Faculty of Education, The University of Auckland.



***Technological Knowledge and Nature of Technology: Implications for teaching and learning project***

The *TKNoT: Imps* research project set out to answer the following questions:

- 1) *What does progression within the Technological Knowledge and Nature of Technology strands look like?*
- 2) *What are appropriate and effective pedagogical strategies and associated practices that support student learning in technological knowledge and nature of technology in New Zealand schools?*

*(Compton & Compton, 2009, p.6)*

The researchers employed a ‘critical social science’ methodology for the research. This allowed them to “gain an understanding of complexities of the technology education world in order to make changes in that world” (Compton & Compton, 2009, p.6). ‘Critical social science’ upholds an epistemological view that disciplines validate knowledge according to their own agreed criteria. This view lends support to the application of both sociocultural and constructivist learning theories. By employing a ‘critical social science’ methodology, the researchers were able to change teacher’s current technology programmes, and the activities embedded within these, in order to gather data that centred on the Technological Knowledge and/or Nature of Technology strands of the curriculum (Ministry of Education, 2007). The research was conducted in two phases:

- *Phase One:* adopted a non-interventionist approach and gathered baseline data on student’s conceptual understandings about the components from the strands Technological Knowledge and Nature of Technology. Understandings gained from this phase were used to inform the re-writing of the component indicators of achievement.
- *Phase Two:* teacher’s technology programmes were changed to include specific activities that focused on enhancing student achievement in a component(s) from the Technological Knowledge and Nature of Technology strands. These activities were written, based on the student achievement findings from Phase One, to provide opportunity for student progression according to the revised component indicators of achievement.

As a result of the *TKNoT Imps* research the previous draft indicators of achievement for the strand component for Technological Knowledge and Nature of Technology were significantly revised (Compton & Compton, 2011; 2012). A follow on research project, called *Technological Literacy: implications for teaching and learning [TL: Imps]*, developed progression diagrams for the components of Technological Knowledge and Nature of Technology to illustrate the relationship between indicators and the nature of progression within and across curriculum levels (Compton & Compton, 2010a). Similar diagrams were also developed for the Technological Practice components (Compton & Compton, 2010a).

### ***Technological Practice***

The Technological Practice strand provides students opportunity to “examine issues and existing outcomes [including the practice of others] and use the understandings gained, together with design principles and approaches, to inform their own practice” (Ministry of Education, 2007, p.32). Technology in the *NZC* (Ministry of Education, 2007) expects teachers to offer students opportunity to develop a range of outcomes in technology education. This range includes: conceptual designs, technological models, prototypes, and realised technological outcomes that can be placed in situ and/or taken into multi-unit production. In developing these outcomes, students are expected to consider ethical and legal requirements, and protocols that may impact on the practice undertaken to develop the outcome, and the outcome(s) itself (Compton & Harwood, 2005; Compton, 2007). They are also encouraged to minimise any potential negative impact on stakeholders to the outcome.

There are three components to the Technological Practice strand – *planning for practice, brief development* and, *outcome development and evaluation*. These components were established from earlier research (TEALS<sup>24</sup> 1999; 2000) conducted by Compton and Harwood (2003; 2005). Description for the three components of the Technological Practice strand state:

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<sup>24</sup> TEALS was a Ministry of Education funded research contract, called *Technology Education Assessment in Lower Secondary* that was conducted by Compton and Harwood. When implemented in 2010 it centred on lower secondary school, Years 9-10 and in 2011 was extended to cover Years 1-13.



*Chapter 2*  
*Literature Review*

*Brief development: is a dynamic process that reflects the complex interactions within ongoing technological practice. A brief is developed to clearly describe a desired outcome that would meet a need or realise an opportunity, and takes into account the physical and social environment. It is comprised of a conceptual statement that communicates what is to be done and why it should be done.*

*It also includes specifications that define the requirements of a technological outcome in terms of its physical and functional nature. The specifications provide guidance for ongoing evaluation during the development of an outcome, as well as serving as an evaluative tool against which the final outcome can be justified as fit for purpose. Brief Development can be thought of as the defining practices of technological practice.*

*(Compton, 2010, p.18)*

*Planning for practice: effective planning techniques are critical for informed and responsive technological practice. Planning tools must be fit for purpose if they are to ensure the successful development of outcomes. Planning allows understandings from past and current experiences, as well as those that may be reliably forecast, to be taken into account in a systematic and managed way. Efficient resource management and accessing of stakeholder feedback relies on forward planning. Planning for practice incorporates ongoing critical evaluation and efficient and appropriate documentation. Planning for Practice can be thought of as the organising practice of technological practice.*

*(Compton, 2010, p.24)*

*Outcome development and evaluation: the development of a technological outcome (product or system), or any other outcome of technological practice (concepts, plans, models, etc.), involves the creative generation of design ideas and the refinement of potential outcomes. This is achieved through ongoing research, experimentation, analysis, testing, and evaluation against the specifications of the brief*

*Developments should be based on the evaluation of the functional modelling undertaken during practice, and prior to the realisation of the outcome. Refinement of a realised technological outcome should be informed by evaluations from prototype testing in situ, in order to optimize its fitness for purpose. Outcome Development and Evaluation can be thought of as the trialling and production practices of technological practice.*

*(Compton, 2010, p.29)*

#### 2.2.4 Nature of student learning in technology education

For students to meet the identified aim of technology education and develop technological literacy, they need to be able to competently undertake and understand technological practice within the contemporary technological discourse/s in which they are situated (Compton & Harwood, 2003). Alongside this, they also need to demonstrate understanding of both the nature of technology and technological knowledge (Ministry of Education, 2007). It is recognised however, that there are varying types of technological literacy that a person may possess. This spans from a literacy that is more *functional* in nature (Barnett, 1994; Custer, 1995; Layton, 1987) to one that is ‘deep, broad and critical’ in nature (Compton, 2009; Compton & France, 2006b; Compton & Harwood, 2008). A person who possesses a *functional literacy* is seen to create technological outcomes (products, systems or environments) through undertaking technological practice and demonstrating understanding of technological knowledge and the nature of technology from within the boundaries of their current location (Compton, 2004; Compton & France, 2006a; Compton & Harwood, 2003). Their outcomes, including the technological practices used to develop them, most often replicate that which has been done before. As such, the technological knowledge applied and understandings of the nature of technology most often mimic prior conceptions held within the technological discourse in which their outcome(s) is developed. A person who demonstrates a literacy that is ‘deep, broad and critical’ in nature however, extends beyond the boundaries of their current location and displays an ability to critique and undertake comparative analysis of past and current technologies, and the practices that developed them. They do this by taking apart technologies in purposeful ways, to not only identify their component parts but also expose the “intentions behind their designs, the unanticipated applications of [these] technologies and the relationships between people and [the] technologies” (Keirl, 2006, p.98). A person who possesses a deep broad and critical technological literacy is therefore able to contribute to the determination of our future technological society, through participating as an informed citizen (Compton & Harwood, 2008; Dakers, 2006; Keirl, 2006). Providing opportunity for students to develop a technological literacy of this nature has inherent implications for the sorts

of pedagogical practices teachers adopt, as well as the learning contexts they encourage students to access.

### ***Teachers' pedagogical practices and learning contexts***

To support students to develop technological literacy, the classroom curriculum needs to encourage students to employ diverse and creative practices that explore a range of values, ethics and attitudes. A 'transformative' learning environment that encourages and supports them to be critically aware of their own tacit understandings, and the expectations of others, is essential, particularly for supporting student decision making (Mezirow, 2000). When such an environment is provided in technology education it creates opportunities for students to develop 'intellectual skills' rather than solely 'factual knowledge' (Johnson, 1997). In contrast, a 'transmissive' learning environment encourages a focus on the recall of 'factual knowledge' through replication and is something to avoid, unless it is created for the purposes of skill education that is "taught as empowerment, [and] as a part of personal potential or cultural heritage" (Keirl, 2006, p.96).

Providing a 'transformative' learning environment in technology enables 'problem-centred' (Print, 1993) activities to be undertaken that emphasise 'substance' (*knowing*) and 'processes' (*doing*). When a learning environment is established that uses 'problem-centred' activities bound within the classroom, but connected to the world outside (Ministry of Education, 2007) it allows students to experience and learn from "problems of living that are both individual and social in nature" (Print, 1993, p.101) that are of interest to them, and relevant to real-world settings (Print, 1993; Shepard, 2000). As demonstrated by Harwood (2007), when technology is aligned with real-world settings and technologists work alongside students engaged in problem-centred activities to explore and resolve genuine problems, their learning is enhanced.

Providing opportunity for students to engage in individual and group technological activity is also considered an important pedagogical tool for supporting student learning in technology education (Harwood, 2007). These activities allow students to gain insight into the "complex relationships involved in such things as developing and combining (individual and shared) technological knowledge, skill

and resources, assessing risk, accounting for stakeholder interests, ethics and understandings, [and] adapting to current boundary conditions and challenging these when appropriate” (Ministry of Education, 2005, p.1). To allow students to progress their learning within and across technological activities, teachers need to plan technology programmes that contain a set of coherent educational experiences.

### ***Programme design***

Technology taught under the *NZC* (Ministry of Education, 2007) framework requires students to be presented with a balanced teaching and learning programme that integrate all three technology curriculum strands. Programmes should also provide an opportunity for students to concentrate learning on one or two strand components at a time (Keith, 2007; Ministry of Education, 2007). Essential within the design of a technology programme is space to incorporate the *principles*, *values*, and *key competencies* identified in the *NZC* within authentic learning activities that meet the learning expectations expressed by the technology *LAS* and its achievement objectives (Ministry of Education, 2007). Contexts chosen as suitable technological activities within technology programmes should be built around available school's resources. These resources include the knowledge and skills of teachers, and physical and consumable resources, including access to specialist facilities and available community resources.

To allow student progress to be planned for and monitored across all three strands (and eight components) of technology in the *NZC* (Ministry of Education, 2007), technological activities presented to students must be coordinated within a coherent programme plan. This means that technology programmes from years 1-10 typically span a two-three year time period to ensure full strand (and component) coverage (Compton & Harwood, 2010b). Because of the need for this coverage, programme links across transition points within and between schools need to be established to enable seamless student learning in technology to be achieved. From previous research conducted by Compton & Harwood (2003; 2005), it has been demonstrated that when teachers possess a shared understanding of technology education that includes an in-depth knowledge of the curriculum strands and their components, and knowledge of how the components progress within and across curriculum achievement levels, student progression in technology can be supported.

The following section (Sections 2.3 and 2.4) review the literature on technological practice and technological knowledge, and discusses its relationship to technological education and technology in the NZC (Ministry of Education, 2007).

## 2.3 Technological Practice

### 2.3.1 Technological Practice: what is it?

Technological practice (or technological activity) refers to the “actions people undertake to create, invent, design, transform, produce, control, maintain, and use products or systems” (Ribas, Kistmann & Trabasso, 2007, p.258). These actions employ ‘creative activity’ to realise solutions to problems that often require competing criteria to be addressed. Examples of such criteria include: aesthetic demands, economic restraints and resource availability. When undertaking technological practice, technologists draw knowledge from a wide range of sources. Hughes (1986) describes technologists as being “no respecters of knowledge categories or professional boundaries” (cited in Layton, 1993, p.26), rather he sees them as drawing knowledge from a ‘seamless web’ of interactive components within a complex ‘socio-technical’ system. This socio-technical system is explained by Pacey (1983) when he states that technological practice relies on *technical aspects* (knowledge, skills and techniques, tools, machines etc), *cultural aspects* (goals, values and ethical codes, beliefs etc) and *organisational aspects* (economic and industrial activity, professional activity etc) being brought together. He argues that all three *aspects* need to be present when artefacts are created. Pacey (1983) captures this diagrammatically in Figure 1.

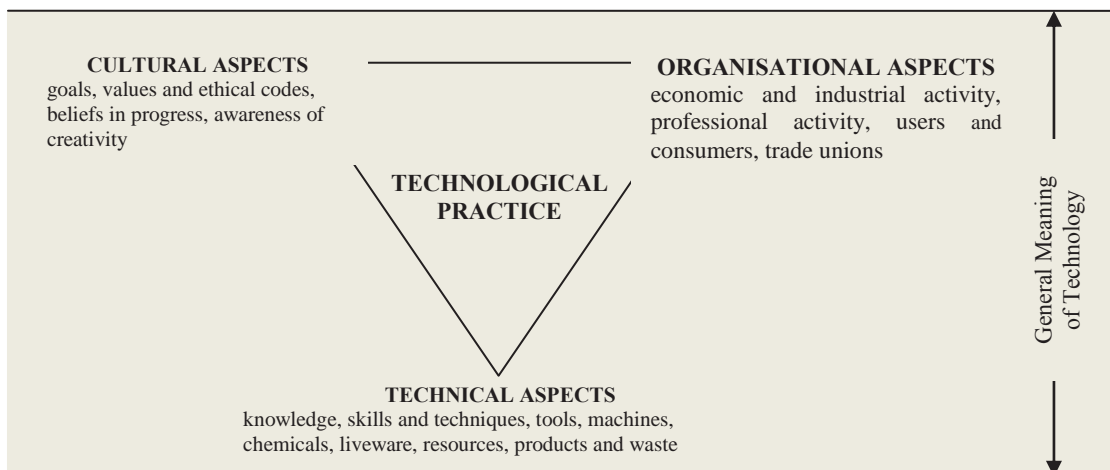


Figure 1. Diagrammatic definition of technology and technological practice (Pacey 1983, p.6)

Feng and Feenberg (2008) question the extent to which a designer's intentions shape the outcomes<sup>25</sup> of technological practice, and whether an outcome is in fact not a compromise between what a designer wants and what the constraints enable. They argue that outcomes of technological practice are socially constructed and hence they are shaped through negotiation, persuasion, and debate; aimed at achieving a rhetorical closure which has community consensus. Feenberg (1999 – cited in Feng & Feenberg, 2008) explains this in terms of 'instrumentalization theory', a version of constructivism that acknowledges that artefacts are "designed to conform not to the interests or plans of the actors (alone), but to the cultural background of the society" (Feng & Feenberg, 2008. P.112). This background, providing 'decision rules' such as beliefs, codified knowledge and procedures that shape the technological practice conducted and in turn influencing the 'form' and 'function' of its outcome(s).

Practicing technologists tend to partition their technological practice into stages. An example of these stages include: clarifying the design task, devising conceptual designs, symbolising a design and its design detail, realising a design and evaluating its 'fitness for purpose' (Garbacz, 2009). While these stages can be useful for describing the actions of a technologist during their practice, they follow no standardised process; rather their practice varies depending on the size, scale and nature of the problem(s) they are attempting to resolve. Best (2006) sums up these differences in practice when she states:

*Design processes are difficult to standardise, in part because of their iterative, non-linear nature, and also because the needs of clients and users are so different. In addition, real life, with its changing market conditions and customer preferences, is much more dynamic, chaotic and fuzzy than any standard model can fully accommodate and often, stages of the design process overlap.*

*(Best, 2006 – cited in Design Council, 2007, p.3)*

What is apparent is that in order to realise an outcome, through undertaking technological practice, technologists need to 'isolate' and 'reconnect' understandings about the functional and aesthetic qualities individual components (e.g. individual materials and/or component parts) offer to a problem's resolution,

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<sup>25</sup> *Outcomes* in this case refers to the products and/or systems that are developed as a result of undertaking technological practice



as well as cultural understandings about the society where the outcome is to be developed and finally located. Such isolation and reconnection enables technologists to determine how individual components may combine to enable a realised outcome to meet required performance (including societal) specifications, and therefore be judged as ‘fit for purpose’.

### **2.3.2 Technological Practice within Technology Education**

There has been much contention surrounding the teaching of ‘technological practice’ in technology education. Much of this contention resides around the pedagogical approaches used by teachers, to support students to develop technological outcomes without losing the ‘creative’ aspects of design. A traditional approach adopted by teachers in many countries to ‘teach technological practice’ has been to provide a series of pre-determined steps that students follow to develop outcomes that resolve ‘known’ problems. Williams (2000) identifies some of these steps as including: identify-design-make-evaluate (UK Department of Education, 1995), define problem-ideas-model-test (USA International Technology Education Association, 1998), and design-make-appraise (Australian Education Commission, 1994). In New Zealand, early design related curricula<sup>26</sup> encouraged students to follow a design-and-make process (Harwood & Compton, 2007). These approaches to teaching technological practice meant that students often systematically worked their way through given steps without thought to the consequences of ‘what comes next’ and/or critical reflection on what ‘had gone before’. Research within education has revealed that the “outcome of a design, or the solution to a problem, involves more variables than can be represented in a sequence of process steps” (Williams, 2000, p. 1). de Vries (1996) also raised concerns of this nature when he stated that teachers must “.... avoid a naive use of generalistic design prescriptions. As in the reality of the industrial practice, we will find out that methods need to be adapted to the needs of the specific product that is being designed ....” (p. 2). This understanding of the iterative ways in which outcomes are designed, according to Williams (2000), does not however mean that students cannot be provided with a framework to structure activities when

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<sup>26</sup> These curricula included: *Workshop Craft* (Years 9-10); *Workshop Technology* (Year 11) and *Design and Technology* (Years 12-13). A focus on a design-and-make process shifted with the introduction of technology in the New Zealand Curriculum (Ministry of Education, 1995; 2007) as describe further in Section 2.3.3.



undertaking technological practice. Those activities used by students, when engaged in technological practice, and the order in which they are used needs to be determined with consideration to the character of the student and the nature of the problem they are addressing (Williams, 2000). Williams (2000) identified such activities as being:

- evaluation
  - documenting
  - generating ideas
  - producing
  - research and investigation
  - modelling
  - communication
- Williams, (2000, p.3)

This ‘activities approach’ to technological practice therefore recognises that different people will use different strategies for designing, often based on their thinking preferences (in pictures or in words, more convergent or more divergent) and that education “should not try to force them to use generalistic strategies that may not fit their personality” (de Vries, 1996, p.2). Williams (2000) and de Vries (1996) believe that there is no justifiable prescribed way of undertaking technological practice, is aligned with Best’s (2006) observations that professional technologists also follow no standardised process when undertaking technological practice.

Both Williams (2000) and de Vries (1996) argue the need for scientific knowledge, along with knowledge from other domains, to be integrated into technological practice and not be separated as theory and practice. Knowledge from other domains in this case referring to: knowledge about social phenomena (values, ethical codes, beliefs, economics, market requirements, laws, patents, political decisions, etc.) and technical knowledge (tools, techniques, material aesthetic and functional qualities etc.). This argument aligns with Pacey’s (1983) construct of technological practice, that draws knowledge on *technical*, *cultural* and *organisational* aspects together in order to create solutions to problems that are ‘fit for purpose’, and Hughes (1986 - cited in Layton, 1993) notion of knowledge being drawn into technological practice from a ‘seamless web’ of interactive components.

Vincenti (1984) points out the need for knowledge to be mediated into technology in order to ensure that it does not remain only at a theoretical level of understanding. According to Lave (1988), ‘real’ design activity, to resolve

authentic socio-technical problems, provides an ideal vehicle for this mediation to occur, by enabling students to engage with knowledge ‘in practice’ rather than it solely residing as an ‘in the head’ experience. A key challenge for teachers mediating knowledge into such activity, or technological practice however, is balancing offering students prescribed ‘chunks’ of knowledge teaching that supports their engagement in the activity, and providing the unstructured freedom which allows them to realise innovative and creative ‘fit for purpose’ outcomes. Thompson (1990) suggests that when teachers impose their own “predigested experience and expectations...” on students this leads to them displaying “... a lack of creative and individual thought through the development of ‘uniformity, dependence and acceptance” (p.104). On the other hand, when students engage in technological practice without appropriate teacher interventions this can also “..... result in ‘learner helplessness’ and the constrained and restraining use of knowledge, skills and practices” (Compton & Harwood, 2001, p.42). If teachers adopt Thompson’s (1990) suggestion and use ‘judicious questioning’, and are discerning as to ‘whether, when and how’ to intervene in students technological practice, then a balance between teacher prescribed and a laissez-faire approach to supporting student practice may entice a display of informed creative and individual thought.

### **2.3.3 Technological Practice and Technology in the New Zealand Curriculum (Ministry of Education, 2007)**

The Technological Practice strand, in technology in the *NZC* (Ministry of Education, 2007), is focused on students undertaking their own ‘technological practice’ to realise solutions to problems that require competing criteria to be addressed. This strand also offers a chance for students to inform their own practice by reflecting on the technological practice of others. The components of this strand, *brief development*, *planning for practice*, and *outcome development and evaluation*, describe ‘subsets’ of technological practice which have been shown to be relevant to all technological contexts and areas, irrespective of the level of practice (Compton & Harwood, 2004b). While these components are intrinsically linked in the act of undertaking technological practice, akin to Hughes (1986 - cited in Layton, 1993) ‘seamless web’ of interactive components, they each have an identifiable ‘outcome’. For example: the outcome of *brief development* is a

‘developed brief’, the outcome of *planning for practice* are ‘plans for undertaking technological practice’ and the outcome of *outcome development and evaluation* is a ‘developed outcome that is evaluated’. These component ‘outcomes’, are explained by their Component Descriptor (for details see Section: 2.2.3). How these outcomes are realised is not defined by a series of ‘pre-determined steps’, or a defined process such as: identify-design-make-evaluate (Williams, 2000) or set sequence of ‘activities’. Instead the ‘key ideas’ underpinning the component are presented within Explanatory Papers<sup>27</sup> (Compton, 2010a). These papers offer teachers (and students) a description of the ‘key ideas’ which define the component, and an explanation of the nature of the practice that underpins it. For example the ‘key ideas’ underpinning *brief development* include:

*A brief in technology is defined as a succinct guiding document that is comprised of a 'conceptual statement' that communicates, via any appropriate means (e.g. through oral, written, graphical means), the focus and justified purpose of the technological practice to be undertaken to develop a technological outcome.*

*A brief also includes specifications that define the requirements of a technological outcome in terms of such things as appearance and performance ..... A brief may also include additional constraints on both the outcome and the practice that must be taken into account within the project work.*

*(Compton, 2010a, p.18)*

The ‘key ideas’ underpinning the nature of the practice required to ‘develop a brief’ include:

*The specifications of a brief are the result of extensive research and reflect the prioritisation of factors that have arisen as part of key and wider community stakeholder consultation, and understandings of the physical and social environmental impacts and influences .....*

*As the brief is developed stakeholder feedback is essential, and the media used to communicate the brief should be chosen to gain feedback in the most effective and efficient manner.*

*(Compton, 2010a, p.18-19)*

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<sup>27</sup> Each strand components of technology in the NZC (Ministry of Education, 2007) has an *Explanatory Paper* that defines the component (a component descriptor), and describes the key ideas underpinning it. These papers also provide illustrative examples of the components from technology and technology education. The *Explanatory Papers* were developed as teacher (and student) support material for technology in the NZC (Ministry of Education, 2007) and can be retrieved from : <http://technology.tki.org.nz/Curriculum-support/Explanatory-Papers>

This approach to explaining strand components means that teachers and students are not ‘told’ the specific sequence or steps to follow when undertaking technological practice. Rather, they are encouraged to select, adapt and modify their practice based on informed decisions so that the artefacts that result out of technological practice can be judged as truly ‘fit for purpose’ in every sense. This approach is therefore in keeping with Best’s (2006), de Vries (1994) and Williams (2000) suggestion that the ‘processes’ underpinning technological practice cannot and should not be prescribed.

The Technological Practice strand of technology in the *NZC* (Ministry of Education, 2007) provides an opportunity for students to “embed the philosophical ideas from the Nature of Technology and generic Technological Knowledge [curriculum strands] in order to better inform their practice” (Compton & France, 2007a, p.172). This strand also provides an environment where knowledge from other disciplines can authentically be brought in and used to support the development of understandings, and the realisation of outcomes that are ‘fit for purpose’. As such, the Technological Practice strand in the *NZC* (Ministry of Education, 2009) presents a place to mediate knowledge into technology (Vincenti, 1984) from science and other domains as an integral part of informing practice.

The Indicators of Progression for the components of Technological Practice (Compton and Harwood, 2010b) that describe expected student levels of achievement at curriculum levels 1-8 are presented in Appendix D: *Indicators of Progression for Technological Practice*. These Indicators, developed through classroom based research conducted by Compton and Harwood (2005; 2004b), and subsequently revised in 2010, describe the nature of the practice that underpins the component at increasing levels of sophistication; therefore allowing “... teachers [and students] to develop a sense of what it is to become more ‘expert’ in one’s technological practice ...” (Compton & Harwood, 2004b, p29).

## 2.4 Technological Knowledge

### 2.4.1 Technological Knowledge: what is it?

There has been considerable debate internationally among technology educators as to the existence of technological knowledge (Baird, 2002; Custer, 1995; Ihde, 1997; Johnson, 1997; Layton, 1987; McCormick, 2004; McGinn, 1990; Ropohl, 1997) and the ability to define its curricular elements (de Vries & Tamir, 1997; Herschbach, 1995; McCormick, 2004; Rowell, 2004). This debate is largely centred on what defines technological knowledge and how it is different from science knowledge. Technological knowledge is considered to arise from and be embedded in human activity (Herschbach, 1995; McCormick, 2004; Ropohl, 1997; Roth, 2009; Rowell, 2004; Stevenson, 2004; de Vries & Tamir, 1997). As such, it is activity that “establishes and orders the framework within which technological knowledge is generated and used” (Herschbach, 1995, p.33). Technological activity therefore can be thought of as not only providing a means to change the world through it developing technological outcomes, but also the instrument which heightens human consciousness and knowledge, which allows them to control and/or manipulate the physical world. In contrast, scientific knowledge is focused on explaining the “physical world and its phenomena” (Herschbach, 1995, p.33) through “observation and predicts in order to confirm theory” (Herschbach, 1995, p.34). Scientific knowledge therefore focuses on establishing a relationship between humans and the world, by connecting their thinking with the world. As a result scientific knowledge provides a means to “assert a fact or develop a detailed picture of how we think things are” (Baird, 2002, p.18). According to Layton (1974), “science seeks to expand knowledge through the investigation and comprehension of reality” while “technology seeks to use knowledge to create a physical and organisational reality according to human design” (p.40). These epistemological differences between scientific and technological knowledge are further argued by Baird (2002) in terms of ‘truth’ and ‘function’. Baird (2002) explains that an artefact, the material outcomes of technological activity, “bears (technological) knowledge when it successfully accomplishes a function” and that this knowledge becomes validated because of the “reliable, regular predictable performances of the artefacts” (p.15). In contrast to his explanation of technological

knowledge, Baird (2002) suggests that scientific knowledge is borne from theories, aligned to 'justifiable true beliefs' or perceived 'truths'. The efficacy of this knowledge is its ability to be detached from context while still holding true until such time that it is debunked. Baird's (2002) contention that technological knowledge is validated in relation to successful function, provides a useful means for defining the curricula elements of technological knowledge; not based on 'truth' but on the materialist nature of artefacts (Compton, 2004).

#### **2.4.2 Technological Knowledge within Technology Education**

In a desire to legitimise technology education as an academic discipline (Herschbach, 1995), that addresses wider perspectives of technology and cultural phenomenon, and not solely "craft, skills-orientated school activity" (de Vries & Tamir, 1997, p.4), technology educators have focused on identifying the curricula elements that define technological knowledge (Baird, 2002; de Vries & Tamir, 1997; McCormick, 2004; Mitcham, 1999; Idhe, 1997; Jones, 1997; Rowell, 2004; Stevenson, 2004). This desire has seen a number of categorisations for curricula elements of technological knowledge suggested, that purport to capture the essence of technological knowledge applicable to technology education. This section provides a brief overview of some of the categorisations, and associated defining constructs, that have been proposed. To do so, it first looks at some of the categories which have been used to define technological knowledge within the domain of technology. It then presents a description of categories that have been identified specifically for technology education.

#### **Categories of technological knowledge**

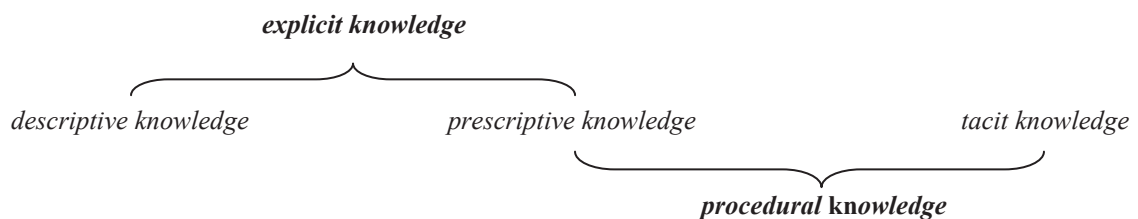
##### ***Vincenti and Technological Knowledge***

Vincenti (1984) identified three categories of knowledge which align to the domain of technology: *descriptive*, *prescriptive*, and *tacit*. He made a distinction between *descriptive* and *prescriptive* knowledge in terms of what they expressed:

- Descriptive knowledge: describing things as they are
- Prescriptive knowledge: prescribing what has to be done in order to achieve a desired result.

Vincenti (1984) envisioned descriptive knowledge as being focused on ‘truth’ or ‘fact’ and it being judged in terms of its “veracity or correctness” (p.573) whereas prescriptive knowledge he identified as the knowledge of “procedure or operation” and “judged in terms of effectiveness, of degree of success or failure” (p.573). He identified these categories of knowledge as being different sorts of ‘explicit’ technological knowledge while his third category tacit knowledge being ‘implicit’ “... wordless, pictureless knowledge essential to engineering judgment and workers’ skills” (p.574). Vincenti (1984) considered tacit knowledge to be personal knowledge that is specific to a context and not often able to be transmitted through written or oral forms of communication, but rather transmitted from one individual to another through contact. According to Vincenti (1984) tacit knowledge therefore is mostly learnt when a person works side-by-side with an experienced technician or craftsperson. Perrin (1990 – cited in Herschbach, 1997) suggests that operational knowledge primarily "remains tacit because it cannot be articulated fast enough, and because it is impossible to articulate all that is necessary to a successful performance and also because exhaustive attention to details produces an incoherent message" (Herschbach, 1997, p. 36).

Within technological practice, the *tacit* and *prescriptive* categories of technological knowledge are closely related due to their focus on procedures. Vincenti (1984) described them as being closely associated with ‘procedural’ knowledge and captured this relationship in the following diagram:



(Vincenti, 1984, p.575)

Vincenti (1984) did not envisage that the categories of technological knowledge were distinct, rather he saw there being cases where knowledge may not fit neatly into just one category. For this reason he described his category labels as being “more in the nature of a framework for thinking about the substantive structure of technological knowledge” (p.575).



Later work undertaken by Vincenti (1990), in the aeronautical engineering field, identified that engineers who successfully develop new devices (artefacts) integrate processes and knowledge in dynamic and complex ways. Vincenti (1990) found that engineers not only needed to stay informed about new and emerging technologies, but had also to be aware of knowledge and skills from other domains. Vincenti (1990) concluded that knowledge is developed when “engineers spend their time dealing mostly with practical problems, and [that] ‘engineering knowledge’ both serves and grows out of this occupation” (p. 200). He reasoned that all “engineering knowledge contributes in one form or another to the implementation of how things ought to be, usefulness and validity being the key criteria for assessing engineering knowledge” (Vincenti, 1990, p. 237). The implementation of how things ‘ought to be’ however, require the use of both procedural knowledge (know-how) and descriptive knowledge (know-that), some of which comes from science, but much of it being generated through and within engineering practice itself. From this work, Vincenti (1990) identified a further six knowledge category labels:

Theoretical tools: this includes knowledge of: mathematical methods and structured knowledge; scientific, engineering, and phenomenological theories and intellectual concepts.

Fundamental design concepts: this includes operational principles and normal configurations. Operational principles describe how the characteristic parts which make up a device (or artefact) fulfil their special function(s) in combination with the overall operation that enables the device to fully function, and normal configurations describe the shape and/or arrangements of a device (artefact).

Criteria and specifications: the technical criteria that describe the physical and functional characteristics of a device (or artefact).

Quantitative data: are the physical properties and quantities required in a formula(s) to enable a device (or artefact) to function. Important in quantitative data are understandings of procedures and processes for producing such properties and quantities.



Practical considerations: tacit knowledge which is typically learnt on the job and often not able to be codified. This includes knowledge such as: rules of thumb, design practice, process-facilitating strategies, knowledge of tool use and strategies for managing projects.

Contextual and normative knowledge: knowledge of values (personal, professional, cultural), norms (what is acceptable, expected behaviour) and contextual factors that describe a devices (or artefacts) qualities.

While these knowledge categories proposed by Vincenti (1990) are considered to be ‘key’ knowledge for engineers, they do not exclusively belong to the domain of technology (Ropohl, 1997). For example, the knowledge categories of *theoretical tools* and *qualitative data* (Vincenti, 1990) are heavily reliant on scientific knowledge (natural knowledge) and therefore cannot be specifically considered to be technological knowledge (Compton, 2007).

### ***Ropohl and Technological Knowledge***

When critiquing the work of Vincenti (1984; 1990), and working on the premise that “technology is not interested in scientific truth, but in practical success” (p.68) Ropohl (1997) devised a framework for categorising knowledge used by engineers. This framework was based on a “systems theory<sup>28</sup> of technics” (Ropohl, 1997, p.67) and identified five different knowledge categories:

Technological Laws: natural laws (scientific laws) which have been transformed to ensure that they are expedient within application. An example of a technological law derived from a natural law, Hooke’s law of elasticity, is the application of a safety coefficient to ensure engineering members within a technological system (artefact) do not fail when subjected to unpredictable eventualities. Technological laws also include empirical generalisations that have been proven to be successful over time within a community of practice, for example, the cutting angles which

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<sup>28</sup> *Systems theory* is used to describe a system. This description includes the relationships between elements (subsystems) that make up a system and their function in relation to the overall system. Four basic laws are used when describing a system: a system is comprised of more than the set of its elements; the structure of a system determines its function; the overall function of the system may be produced by different structures; and a system cannot be described completely on just one level of hierarchy (Ropohl, 1999).

are used on cutting devices such as saws and lathe tools. No coherent theory, derived from natural law exists to explain why these angles are effective; rather this has been determined through experimentation over a period of time to 'best' work.

Functional Rules: define what needs to be done if a "certain result is attained under given circumstances" (Ropohl, 1997, p.68). Functional rules can be expressed verbally, diagrammatically or as a set of instructions. They serve as a 'recipe' that can be followed successfully without necessarily understanding the theory (natural law) that underpins it.

Structural Rules: define the assembly and interplay between components within a technological system. Structural rules are helpful when creating "novel realities" as they enable mental images to be used to "determine spatial and temporal detail that cannot be observed" in "non-existing objects" (Ropohl, 1997, p.69). Structural rules may be derived from natural laws (e.g. OHMs law underpinning how electrical components are assembled) or from traditional or current experiences that have proven to be successful (e.g. rules for reinforcing a framework, rules for laying out a working or construction drawings).

Technical-Know-How: define the "psycho-physical and sensori-motor coordination" (Ropohl, 1997, p.69) skills underpinning application (e.g. driving a car, using a cellphone). Technical-know-how skills are gained through practice. This knowledge either remains at an explicit level or sinks into the subconscious and becomes tacit knowledge which is later referenced to solve problems, "often without (the user) realising explicitly just what is happening" (Ropohl, 1997, p.69).

Socio-Technological Understandings: define the "systematic knowledge about relationships between technical objects, the natural environment, and social practice" (Ropohl, 1997, p.70). Possessing socio-technological understandings enables engineers to not only optimise their technical outcomes (artefacts), but also consider the "ecological and psycho-social context within which the[ir] artefact is located" (Ropohl, 1997, p.70).

### ***McCormick and Technological Knowledge***

McCormick (1997) drew on the work of cognitive psychologists and learning theorists to identify two categories of knowledge applicable to technology education: *procedural knowledge* and *conceptual knowledge*. He distinguished between these two categories of knowledge in terms of the contrast between ‘knowing how’ (*procedural knowledge*) and ‘knowing that’ (*conceptual knowledge*). McCormick (1997) argues that due to the nature of “technology education being primarily rooted in physical action, and in the physical manifestation of thoughts” (McCormick, 1997, p.150) that these two categories of knowledge are intrinsically linked. He sees conceptual knowledge playing an active role in the process, giving “power to thinking about technological activity” (McCormick, 1997, p.143), and procedural knowledge being underpinned by understandings that are conceptual in nature. McCormick (2004; 1997) describes these categories of technological knowledge as:

Conceptual knowledge: relates to the links between knowledge items, to such an extent that when learners identify these links, they can be considered to possess conceptual understanding. This category of knowledge includes knowledge “...drawn from other subjects, such as science, and that unique to technology” (McCormick, 1997, p. 153). Conceptual knowledge according to McCormick (1997) is not simply a “collection of unrelated facts” (p.143), but rather it is concerned with the relationships that exist between ideas in order that meaning within technological activity can be attained. Individuals, according to McCormick, (1997) develop conceptual knowledge that becomes schemata<sup>29</sup> through experience and instruction. Conceptual knowledge in technology is often linked to knowledge of devices or systems (Gott, 1988). An understanding of concepts as they relate to devices and systems (artefacts) enables technologists to apply them to something which is ‘concrete’ rather than to abstract generalities, which is often the case in science (McCormick, 2004). Possessing conceptual knowledge of artefacts enables technologists to design, repair and interact with them as they exhibit within and across particular contexts.

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<sup>29</sup> Schematic refers to knowledge structures that exist in memory.

Procedural knowledge: is concerned with technical ‘knowing how’ or knowing ‘how-to-decide-what-to-do-and-when-to-do-it’ knowledge. McCormick (1997) identifies “design, modelling, problem solving, systems approaches, project planning, quality assurance and optimisation” (p.144) being technological procedural knowledge. Stevenson (1994 – cited in McCormick, 1997) suggests that there are three hierarchical levels associated with the use of procedural knowledge, these being:

*Level One: these are directed to known goals and are automatic, fluid and algorithmic, and include specific skills such as hammering a nail*

*Level Two: these achieve unfamiliar goals, and operate on specific procedures and include strategic skills such as problem solving [e.g. baking a cake by following a recipe]*

*Level Three: this switches cognition between the other two levels and hence it is the controlling function*

(McCormick, 1997, p.145)

McCormick (2004) argues that in contrast to conceptual knowledge, procedural knowledge cannot be learnt through theoretical generalisations; rather he stresses the importance of constructing procedural knowledge within contexts that are domain specific. This argument supports Ropohl’s (1997) concept that the knowledge of skills and their application, “technical know-how, can be gained by thorough practice only” (p. 69). Success in problem solving, the application of procedural knowledge is according to McCormick (2004), dependent “on knowing a lot about the area within which the problem requires solving” (p.26). Procedural knowledge, which is validated by a community of practice and remains explicit, can manifest into standards or rules. An example of this includes “recipe or cookbook engineering” knowledge (Pitt, 2001, p.11).

### ***Rowell and Technological Knowledge***

Drawing on the work of Aoki (1979 – cited in Rowell, 2004), Rowell (2004) identified three categories of technological knowledge that she considered important to technology education – *knowledge-for-technological practice*, *knowledge-in-technological practice* and *knowledge-of-technological practice*. She described each of these as:

Knowledge-for-technological practice: describes what a person needs to know to undertake technological practice. It places a focus on the discrete concepts or skills that are applied when solving a particular type of problem. Knowledge-for-technological practice therefore concentrates on the “practical, conceptual and procedural dimensions of technological knowledge” (Rowell, 2004, p.49) that define and enable ‘technological capability’ (Kimbell, 1994). As a result, this form of knowledge can be defined and formalised within the context of the technological practice to be undertaken.

Knowledge-in-technological practice: recognises the tacit knowledge applied within practice when resolving problems. Such knowledge, often personal in nature, includes the mental conversations that take place when: defining the nature of a problem; distinguishing the features that require attention and; deciding on the actions and their sequence that will be used to address the situation. Schön (1992) identifies this problem resolution as a design situation that is material in nature which is apprehended through mental conversations directed by ‘deliberative inquiry’. He describes the knowledge applied by practitioners when engaged in design and the iterative nature of moving forward using the metaphor “reflective conversations with materials” (Schön, 1983, p.172). A feature of knowledge-in-technological practice is that the actions adopted to address a design problem are not only shaped by the desired features required in the resultant solution (technological outcome) but also by the constraints of the situation in which the problem resides. Knowledge-in-technological practice is therefore situational, which underpins the “interpretive interaction of an individual with materials” (Rowell, 2004, p.51) and treats every problem as “a new problem by virtue of its context” (Rowell, 2004, p.50).

Knowledge-of-technological practice: is focused on knowledge that is “mediated by the use of tools, resources and language within an active community” (Rowell, 2004, p.51), where a community is defined as a group of practitioners engaged in the resolution of a common problem. Being that, knowledge-of-technological practice recognises the knowledge gained from technology as social practice. Knowledge-of-technological practice includes knowledge of the practices that individual members of a community (and the community as a collective) adopt to

such things as: the use of tools and material; the way they devise and articulate strategies (their technological practice) for developing solutions to problems and; the means that they use to assess the worth of their practice and its resulting outcome(s). Undertaking a critical inquiry into knowledge-of-technological practice according to Rowell (2004) affords the use of “authentic discursive practices in technological activity” (p.52) within one’s own technology practice.

### ***De Vries and Tamir, and Technological Knowledge***

De Vries and Tamir, (1997) in identifying the importance of connecting learning about technological concepts with the learning of process skills, identified two concept categories for technological knowledge - those which focus on the ‘nature of technology’ (*concepts of technology*) and those concerned with the ‘theoretical concepts underpinning technological activity’ (*concepts in technology*). They described each of these as:

Concepts-of-technology: categorises learning focused on the “general characteristics that determine when something can properly be called technology” (de Vries & Tamir, 1997, p.5). It places a focus on the concept of technologies being socially constructed and the need for ‘technology’ to be considered as both product and process. Learners are asked to consider the differences between the roles and influences of rational and non-rational factors in technological development. Understanding these differences allows learners to realise that in technology both ‘instinct’ and ‘reasoned decision-making’, are often used by technologists when developing new knowledge, products and/or processes.

Concepts-in-technology: acknowledge that “conceptual knowledge is an essential component in technological design and problem solving processes” and that design processes “combine knowledge about concepts [*conceptual knowledge*] and processes knowledge [*procedural knowledge*]” (de Vries & Tamir, 1997, p.7).

De Vries and Tamir’s (1997) category of concepts-in-technology has a close affiliation to Rowell’s (2004) knowledge-of-technological practice, particularly in relation to ‘process knowledge’. Their category definition however also

acknowledges that ‘conceptual knowledge’ is shared by a community engaged in technological activity.

### ***De Vries and Technological Knowledge in Technology Education***

Later work undertaken by de Vries (2003a; 2003b) set out to identify categories of technological knowledge significant to technology education. To accomplish this, he drew on understandings put forward by Vincenti (1990) and Ropohl (1997). De Vries (2003a; 2003b) proposed four categories of technological knowledge: *Physical Nature Knowledge*; *Functional Nature Knowledge*; *Means Ends Knowledge*; and *Action Knowledge*. De Vries’s starting point for establishing these categories was to focus on the dual nature of technological artefacts which Kroes & Meijers (2000) identified when they described artefacts as “...designed physical structures which realise intentionality-bearing functions” (p. Xxv – cited in de Vries, 2003a, p17). The premise for de Vries (2003a) work was that technological artefacts could not be completely described within their physical conceptualisation, because it left no place to explain their functional characteristics. Underpinning this premise was a belief that an artefact could not be described in detail conceptually, because their function needed to be realised within an appropriate physical structure. De Vries (2003a) four categories for propositional knowledge describe the conceptual knowledge (“knowing that”) which technologists use when developing artefacts and/or describing the artefact itself. The propositions described by de Vries (2003a) within each of these four categories are:

Physical Nature Knowledge: describes propositions about the physical properties of the artefact. While these properties require scientific understandings, within the category physical nature knowledge, they only need to do so in terms of how they are operationalised. De Vries physical nature knowledge category links to Ropohl’s (1997) *technological laws* and to Vincenti’s (1990) *theoretical tools* and *descriptive quantitative data* categories for describing technological knowledge (Compton, 2007; de Vries, 2003a). An example of knowledge of a physical nature is: X knows that an artefact has physical characteristics (i.e. X knows that a cork screw is made out of stainless steel and consists of a helix with a sharp point (de Vries, 2003b))



Functional Nature Knowledge: describes propositions about the function that an artefact can fulfil. This category of technological knowledge links to Ropohl's (1997) *functional rules* in terms of knowing what to do to ensure function and Vincenti's (1990) *fundamental design concepts* and *practical considerations* categories for describing technological knowledge (Compton, 2007; de Vries, 2003a). An example of knowledge of a functional nature is: X is able to propose what an artefact, which may not as yet exist, is capable of doing (i.e. X knows that a cork can be removed from a bottle using a cork screw to grip the cork and pull it out (de Vries, 2003b))

Means Ends Knowledge: describes propositions specifically about the relationships between physical and functional attributes of an artefact. Means end knowledge is used to determine if a material and/or artefact is "fit for its intended function" (de Vries, 2003a, p.13). This category of technological knowledge links to Ropohl's (1997) *structural rules* in terms of knowing 'how' and 'why' things would need to come together, and to Vincenti's (1990) *criteria and specifications*, and *prescriptive quantitative data* (Compton, 2007; de Vries, 2003a). An example of knowledge of a means end nature is: X knows that a physical property of artefact (combination of properties) enables an artefact to perform a specific action (i.e. X knows that the sharp end on the helix of a corkscrew allows it to pierce into the cork when it is turned and that the helix helps to grip the cork (de Vries, 2003b))

Action (or Process) Knowledge: describes propositions in terms of "how to perform actions that lead to desired outcomes" (de Vries, 2003a, p.14). This category of technological knowledge links to Ropohl's (1997) *technical know-how* and Vincenti's (1990) *design instrumentalities* (Compton, 2007; de Vries, 2003a). An example of knowledge of an *action* nature is: X knows that a specific action (or set of actions) will lead to a change (i.e. X knows that the cork can be removed from the bottle, if the helix of the corkscrew is wound into it and the corkscrew handle is then pulled (de Vries, 2003b)).

The categories for knowledge proposed by philosophers and technology educators, as described above, were reviewed and considered by Compton (2004) to inform the selection of those components of Technological Knowledge that were later



defined by Compton & France (2006a; 2007b) and included in the *LAS* for technology in the *New Zealand Curriculum* (Ministry of Education, 2007).

### **2.4.3 Technological Knowledge and Technology in the New Zealand Curriculum (Ministry of Education, 2007)**

The Technological Knowledge strand components of technology in the *NZC* (Ministry of Education, 2007), *technological modelling*, *technological products* and *technological systems*, as argued by Compton (2010b), supports students to develop understandings about ‘key’ generic concepts that underpin technological development, and the outcomes of such developments. According to Compton and France (2006b), when students understand these concepts they are equipped to discern the feasibility of developing technological outcomes and make predictions about their desirability within a wider societal sense. For this to occur however, McCormick (1997) argues that students need to possess conceptual understandings about “relationships among items of knowledge” (p.143). He also argues that allowing students to solely develop conceptual understandings (or knowledge) without procedural knowledge, and an appreciation of the interrelationship between procedural and conceptual knowledge hinders their preparation to engage in problem solving activity (McCormick, 1997). In upholding McCormick’s (1997) argument, if students are to be enabled to present justifications and predictions on developing technological outcomes in ways which are discerning (Compton & France, 2006b) they need to not only possess understandings bound within the curriculum components of technology in the *NZC* (Ministry of Education, 2007) but to also appreciate the cross component links as well.

For this reason, the components of Technological Knowledge defined in technology in the *NZC* (Ministry of Education, 2007) also place emphasis on students understanding and connecting the ‘key’ concepts within and across components, with the knowledge that informs and underpins technological developments (Compton & France, 2006b). For example: a ‘key’ conceptual understanding identified in the component *technological products* is that all materials can be described by their performance properties, and that it is these properties that define how a material can be transformed and manipulated. When this concept is understood and interconnected with procedural understandings

(within technological practice) about how materials are selected for use in technological developments, students are empowered to be able to select material(s) that ‘best’ offer the ability to be manipulated and/or transformed into ‘fit for purpose’ technological products.

The conceptual knowledge that underpins the components of Technological Knowledge; in particular the components *technological products* and *technological systems* (Ministry of Education, 2007); has links with Gott’s (1988) *device knowledge*. When students hold understandings of these concepts, they are able to ‘read’ devices and systems (artefacts) (Compton, Compton & Patterson, 2012), and design, repair and interact with them as they exhibit within and across particular contexts (McCormick, 2004). Understanding the concepts that underpin *technological modelling* supports students to comprehend when ‘fit for purpose’ technological outcomes are designed and when they are not. Possessing these understandings also supports students to defend (justify) the outcomes that they produce (Compton & France, 2006a). In keeping with the aims of this thesis, to identify if Compton and France’s (2006b) belief that students’ who understand concepts underpinning the curriculum component *technological modelling* can better justify the ‘fitness for purpose’ of their technological outcome(s), the following section provides an in-depth look at the concepts that underpin *technological modelling*.

#### **2.4.4 Technological Modelling in the New Zealand Curriculum (Ministry of Education, 2007)**

##### ***Technological modelling***

A ‘model’ is used to represent reality. In technology, modelling is used to represent the physical and/or functional qualities of an outcome that is yet to be fully realised. The use of technological models therefore enables technologists to ‘test’ an “outcome’s potential and probable impact in the world, as it moves from a conceptual idea through to being fully realised and implemented in situ” (Compton, 2010 p.49). For this reason, technological modelling is considered a key concept

underpinning technological development across all domains<sup>30</sup> of technology (Compton & France, 2006b). While the specific knowledge base underpinning the use of a technological model may be particular to a domain, the generic concepts of technological modelling are considered to remain the same across domains (Compton, 2010a; Compton & France, 2006a). Hence, technological modelling was incorporated as a ‘key’ curriculum element of the Technological Knowledge strand for technology in the *NZC* (Ministry of Education, 2007).

The application of concepts of technological modelling in the ‘act’ of modelling assists students to develop an understanding of *knowledge in technological practice* (Rowell, 2004). Such action provides evidence obtained from ‘testing’ that validates or revokes mental conversations that have taken place. These conversations include those which help to: define the problem being resolved, determine the physical and functional features required in a fit for purpose outcome, and the actions and their sequence required to develop such an outcome. Possessing concepts of technological modelling also supports students to develop understandings of the *knowledge of technological practice* which supports them to justify the need to refine and/or undertake additional practice when developing technological outcomes.

Technological models can be grouped into two categories: those that are used to test a ‘design idea’ called *functional models*, and those which are used to test and refine a ‘technological outcome’ called *prototypes* (Compton & France, 2006b).

Functional modelling is used to test and evaluate a design idea(s) so that a justifiable decision can be made regarding its future ongoing development. Such tests include determining the appropriateness of known specifications, suitability of selected material and technique, and the likely socio-cultural acceptance and impact should the idea be realised as a technological outcome. Using functional models therefore, “enhance(s) risk mitigation by providing the means to minimise the unknown or unintended consequences of possible technological outcomes before they are realised” (Compton & France, 2006b, p.8). The medium used for

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<sup>30</sup> The term *domains* in this case has been used to distinguish between of specialist technological areas such as: biotechnology, digital technology, process technology, control technology etc.

functional modelling may include simply discussing a design idea with someone who can provide critical feedback, conceptual drawings and/or written explanations, and three dimensional solid and/or virtual (digital) mockups.

Prototypes are representations of a technological outcome that can be trialled in situ in order to inform further development decisions (Ministry of Education, 2009). Prototyping allows the ‘fitness for purpose’ of a technological outcome to be determined prior to it being further developed for market and/or accepted as the final design solution (Compton & France, 2006b). To ensure that any further development decisions made when prototyping are fully informed, a prototype needs to exhibit the physical and functional qualities that are being proposed for the final design solution. Media and techniques therefore used to produce prototypes need to be those which are being considered for use in the final solution, or as similar as possible to them.

The Indicators of Progression for *technological modelling* for technology in the NZC (Compton and Compton, 2010b) that describe expected student levels of achievement at curriculum levels 1-8 are presented in Appendix E: *Indicators of Progression for Technological Modelling*. As outlined earlier, these indicators were developed through classroom based research conducted by Compton and France (2006b), and subsequently revised during 2008 and 2009 by Compton and Compton (2010a).

Since the development of the *New Zealand Curriculum* (Ministry of Education, 2007), a research study has been completed that established a set of “... overarching, unifying concepts that cut across domains ...” of engineering and technology (Hacker, de Vries & Rossouw, 2009, p.6). This study, a *Delphi Study* titled *Concepts and Contexts in Engineering and Technology Education* gained a consensus of international ‘expert’ opinions, from technologists, technology educators and philosophers of technology, on concepts (and context) they considered ‘foundational’ to engineering and technology education.

***Concepts and Contexts in Engineering and Technology Education Project  
[CCETE Project, 2009]***

Concepts that the *CCETE Project* (2009) deemed foundational for engineering and technology education curriculum included: *design (as a verb)*, *system*, *modelling*, *social interaction* and *optimization*. Other concepts identified as important were: *innovation*, *specifications*, *design (as a noun)*, *sustainability*, *energy*, *materials*, *resource*, *trade-offs*, *technology assessment* and *invention*. Concepts recognised by the experts as belonging to domains of engineering and technology but of lesser importance were: *function*, *technological trajectory*, *practical reasoning*, *tolerance*, *intellectual property*, *complexity*, *algorithms*, *working principle*, *modularity*, and *quality assurance*. The *CCETE Project* (2009) concluded that some concepts identified allow a higher level of abstraction and generality than others. This abstraction was however not attempted by this study. It also acknowledged that numerous connections existed between the concepts, which meant that the concepts could potentially be further categorised into concepts and sub-concepts. This study did not attempt to explore this categorisation due to limitations in the Delphi research method<sup>31</sup>.

The experts however noted that not all concepts identified were specific to engineering and technology and therefore some of these concepts were rejected as not being ‘foundational’. Due to this occurring, some concepts identified in the study may have been lost or categorised as being of lesser importance. For example: while *practical reasoning*, which others have identified as a ‘key’ concept underpinning normative dimensions of technology and engineering (de Vries & Tamir, 1997; Compton & France, 2006b; Compton & Jones, 2004; Keirl, 2009), was identified as belonging to the domains of engineering and technology, it also featured in other disciplines such as science and social science, so was deemed to not be foundational. Similarly, the relationship between *practical reasoning* and constructs of student decision making, and how this may impact on normative dimensions of technology and engineering was not considered. These non

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<sup>31</sup> The Delphi research method seeks to gain a consensus on experts’ opinions. This form of research has both strengths and weaknesses. Its main strength is that a statistical means can be employed to establish whether or not a consensus exists, therefore the study can be objective (even though the choice for the criteria and criterion values are based on expert preference). A weakness of this form of study is that it is totally reliant on opinions rather than facts (Hacker, De Vries & Rossouw, 2009).

identifications, being a less important concept in the *CCETE Project* (2009), therefore brings into question whether relevant concepts may have been lost “not because they were less important but because they were less specific for engineering and technology” (Hacker, de Vries & Rossouw, 2009, p.47).

De Vries (2012) identifies that concepts underpinning technological knowledge are often “context-bound and generalizable only to a limited extent” (de Vries, 2012, p.44). While this difficulty to generalise concepts underpinning technological knowledge may account for concepts being overlooked in the *CCETE Project* (2009), in education however, understanding concepts that underpin technological knowledge is important (de Vries, 2012). According to de Vries (2012), when concepts are defined within curricula, this supports students to capture the essence of technology, and locate context-bound concepts underpinning specialist technological developments within a bigger framework of understanding.

While functional and practical reasoning, were not considered by the *CCETE Project* (2009) to be foundational concepts for technology, technology in the *NZC* (Ministry of Education, 2007) includes these forms of reasoning as key to sophisticated conceptual understanding related to the *technological modelling* component. This is due to the concepts underpinning functional and practical reasoning not being context-bound, and the role they can play in informing decision making and supporting students to justify the fitness for purpose of their evolving design ideas and outcomes.

## **2.5 Decision Making and Reasoning**

This section introduces *decision making*, the nature of *decision problems*, and discusses how these connect with technology education. It also reviews the literature on *practical* and *functional reasoning* to discuss the links between the broader decision making process and more specifically, the process of reasoning within the context of technology education.

### 2.5.1 Decision making

Decision making is often referred to as a mental process that deliberates on multiple options (or alternatives) to select one that best meets the goals of the decision-maker (Hardy-Vallée, 2007; Milkman, Chugh & Bazerman, 2008). The outcome of decision making manifests itself as a conscious action or “opinion of choice” (Bohanec, 2009, p.24), that may in turn lead to a change in a decision maker’s disposition towards a certain topic (Ferrand, 2007). While the deliberation on alternatives may be “explicit and complex or implicit and rapid, ... without consideration of alternatives, no decision making can be said to have taken place” (Galotti, 2002, p.2). Considering alternatives within an informed decision making process is therefore important for determining which alternative or decision to follow.

Several activities (or stages) are involved in a decision making process. Bohanec (2009) defines these as:

- *identification of the decision problem*
- *collecting and verifying relevant information*
- *identifying decision alternative*
- *anticipating the consequence(s) of decisions*
- *making decision (p.24).*

While a ‘key’ stage of any decision making process is making the decision, the outcome(s) of this stage will be affected if the ‘decision problem’ is not well understood in terms of; likely consequences due to a decision(s); what alternatives and potential uncertainties exist; and what outcome(s) need to be achieved (Bohanec, 2009). Collecting and verifying information relevant to the decision problem, to enable alternatives to be identified and sufficiently interrogated so that consequences are uncovered and understood, are therefore key stages in the decision making process.

Decision problems can be classified into *routine* and *non-routine*. Routine decisions are frequently repeated by decision makers, and therefore their underpinning problem(s) is often well defined, with potential uncertainties understood. Non-routine decisions however, due to their lack of regularity, often possess unknown consequences for a decision maker and therefore “tend to be



more difficult, particularly because of the lack of [a decision-maker's] knowledge and experience in taking such decisions" (Bohanec, 2009, p.25). According to Bohanec (2009), the goal for non-routine decisions, which by their very nature tend to be one-time decisions, should be focused on finding and implementing the 'best' alternative. However with decisions that are routine or recurring within a decision makers practice, while it is still important to find the 'best' alternative, a focus needs to also be placed on "finding the most effective method or procedure for choosing alternatives" (Bohanec, 2009, p.26). Identifying if student decisions in technology education are routine and therefore recurring, or non-routine and therefore a one-time decision, may have implications on how the outcomes of student decision making is viewed. For example, when selecting a material and/or technique to use in a specific application within a product is a 'non-routine' decision, the focus will likely be placed on finding the 'best' material and/or technique to achieve the functional and aesthetic qualities desired of the product. However, making decisions about the nature of the technological practice required to achieve an outcome that is 'fit for purpose' is more likely to be a 'routine' decision for students. This is due to their prior experiences in technology and their decision making on the 'best' technological practice approach to follow, when setting out to develop a technological outcome, being informed by a decision(s) they have previously found useful. Equally they can use their understandings about the practice(s) that other students or practicing technologists have found to be useful to inform their decision making. Routine decisions of this nature therefore tend to follow a pattern or process that is known to the decision maker (Klein, 2008). Due to the uniqueness of non-routine decisions, such patterns or processes are not apparent to decision makers. Where patterns are followed the decision maker may intuitively adopt an alternative based on tacit (implicit) knowledge, rather than following a more analytical process of determination.

Klein (2008) describes decision making as following a "blend of intuition and analysis" (p.458) or as occurring when System 1 (*intuitive*) and System 2 (*analytical*) cognitive functioning frameworks (Stanovich & West, 2000) are combined. Decisions based on *intuition*, according to Klein (2008) are formed by aligning the problem situation to patterns (or alternatives) already learnt, while *analysis* requires a deliberate comparison of alternatives, and mental simulations, to



determine how these may enact on the outcome(s) itself or the process undertaken to develop it. In technology it is important that students are encouraged to make intuitive decisions, especially when a decision problem has a similar pattern to those they have previously experienced. For example: when scoping an initial 'plan of action' to address an issue a student may, through past experience, instinctively decide the key stages required to be undertaken and their likely timeframes. However, when determining the 'optimum' material and/or technique to use in a product, then a more analytically informed decision making process may be required. Encouraging students to substantiate their intuitive decision making with more analytical approaches, particularly when confronted with non-routine decisions, may support them to justify why their outcome(s) are 'fit for purpose', and ensure that any intuitive personal bias, due to familiarity, are negated (Milkman, Chugh & Bazerman, 2008). Equally, adopting an analytical approach to routine decisions may mean that a focus is placed on ensuring that the most efficient technological practice is adopted for a specified context, and not just a decision made to follow a practice due to it being successful when followed in the past. Where decision problems contain multiple variables, decision making will often require an analytical process to be followed, whether for a routine or non routine decision, to ensure that the most 'fit for purpose' alternative is selected.

The *number of criteria (variables)* bound into a decision problem that need to be considered may also influence the outcome(s) of decision making. Whether a *single variable* requires consideration or *multiple variables* are considered can influence the nature of the decision making undertaken to determine the 'best' alternative (Bohanec, 2009). In technology, consideration of a single-variable most often requires a yes/no decision to be made. In contrast, decision making with multi-variables requires a prioritisation of potential alternatives to ensure an outcome(s) evolves that is 'fit for purpose'. For example: when considering the 'most' suitable material to use in a product, consideration of factors such as a material's availability; sustainability; functional and aesthetic qualities; and cost may all need to be considered. These factors need to be measured in relation to the physical and functional qualities required of a product that is considered 'fit' for its intended purpose. This measurement will often require relationships between factors to be

explored and prioritised in order to decide the ‘most’ suitable material (alternative) to use in the product.

While decision-making is the process of determining what to do or selecting an alternative (Beyth-Marom, Fischhoff, Jacobs-Quadrel, & Furby, 1991), it is *reasoning* that enables considered alternatives to be assessed in terms of their probable success (Fischhoff, Crowell, & Kipke, 1999).

### **2.5.2 Reasoning**

Reasoning’ is a process that allows humans to change (or not change) their views and conclude a proposition that is reflective of their present-day understandings (Harman, 2009). As such, reasoning allows beliefs and desires to be integrated into intentions or actions (Carruthers, 2003). Reasoning is an important aspect of rational thought, in that it leads people to a place where a ‘reasonable’ belief can be perceived (Pollock, 1998) and a decision made. These beliefs however, may not always remain infallible as their ‘truth’ may not always be guaranteed.

In technology in the *NZC* (Ministry of Education, 2007) two forms of reasoning, *functional* and *practical reasoning*, have been highlighted to underpin rational decision making when students undertake technological practice, and critique the practices and outcomes of others (Compton, 2010a). Students are supported to develop conceptual understandings about the importance of these two forms of reasoning by the curriculum component *technological modelling* (Ministry of Education, 2007). As detailed earlier (p.51) this component of Technological Knowledge is focused on developing student’s appreciation of how evidence can be gathered that justifies decisions about the potential of a design idea, and/or the ‘fitness for purpose’ of a prototype, through using technological modelling within technological practice (Compton, 2010b; Compton & Compton 2012).

#### ***Functional reasoning***

Use of *functional reasoning* within technology enables the technical feasibility of design ideas and outcomes to be explored (Compton, 2010a). As a consequence both the practice of 'how to make things happen' and an understanding of 'how it happens' can be captured in a physical description. In design engineering, and

therefore it is proposed in this thesis, physical descriptions can be used to describe the function of a design concept and its potential to be a solution that is ‘fit for purpose’. Such a physical description exposes the ‘intended function’ of the design problem that a solution needs to address (Chakrabarti & Bligh, 2001). According to Chakrabarti and Bligh (2001), knowledge of intended functions should guide and shape any design activity (including technological practice) focused on identifying a physical description of a potential solution.

To enable knowledge of intended function to be communicated within design activity and decisions to be made, technologists need to adopt a common language that allows both the design problem(s) and solution(s) to be described, compared and modified. Chakrabarti and Bligh (2001) propose that functional reasoning [*FR*] approaches provide this common language, through offering a ‘functional description’ of both the problem and its solution.

*FR* is used to explore conceptual design ideas in order to determine their ‘functional’ potential. Use of *FR* allows the ‘behaviour’ and ‘purpose’ of a design idea to be determined and described, prior to its realisation or manufacture into a solution (artefact). Far and Elamy (2005) explain *FR* as enabling “people to derive and explain (the) function of artefacts in a goal-orientated manner” (p.75), through the application of a range of connected theories and techniques. These theories and techniques include those used in ‘design’ to provide a ‘representation format’ that describes the functions desired in an artefact (functional representation), and explain how such functions contribute to the overall performance of an artefact should it be realised (Far & Elamy, 2005). When describing ‘functional representations’ Chakrabarti and Bligh (2001) identify two types of depictions: *natural-language-like representation* and/or *mathematical representation of function*.

Natural-language-like representation: use ‘verbs’ to describe what an artefact (or its component parts) does or should do. For example, a functional description of a *gear train* (artefact or component part) is to *increase* the output speed (function). Whilst this form of representation allows designers to communicate ideas verbally or in written text, it often lacks the degree of precision required to accurately define the verb (increase) (i.e. for this example, what is the increase in the output speed?)

Mathematical representation of function: express the transformation between an ‘input’ and an ‘output’. As this form of functional representation can be formalised and expressed using numerical figures and/or formula, it is more suited to a computational environment that requires precise and unambiguous information to be communicated.

When developing artefacts to resolve a problem, both of these ‘functional representation’ depictions are often employed during *FR* to ensure sufficient information is available and allow successful decision making (Chakrabarti & Bligh, 2001). For example, using the *gear train* example introduced above, the transformation between input and output can be represented in two different forms:

**Natural language representation**      gear train *increases* input speed revolutions per minute (rpm) so that the output rpm is faster than the input rpm

<b>Mathematical representation</b>	<i>Artefact characteristics</i>	<i>Input Characteristics</i>	<i>Output characteristics</i>
	gear train	100 tooth gear rotating at 30 rpm	20 tooth gear rotates at 150 rpm

or  $\text{Output gear/Input gear} \times \text{input speed} = y \text{ (output speed)}$   
 $(100/20 \times 30 = 150 \text{ rpm})$

There have been a number of approaches to *FR* that have been historically defined. Those which focus on engineering (and technology) typically focus on analysing the *function-behaviour-structure* (or state) of artefacts (Chakrabarti & Bligh, 2001; Far & Elamy, 2005). This approach to *FR* explains the overall “function of an artefact in terms of the structure or behaviour of its components and their functions” (Far & Elamy, 2005, p.79). Ideally any approach to *FR* should support decision making and the selection of alternatives that range from the ‘conventional’ to ‘innovative’, and allow such alternatives to be described as solutions with the potential (or not) to be ‘fit for purpose’. According to Far and Elamy (2005), traditional *FR* approaches applied in engineering (and technology) can be grouped into three types:

Planning and design approach: allows engineers (and technologists) to determine how to ‘make things work’ by screening design ideas/concepts against their knowledge of the functional needs of the design problem and its solution, and evaluating the potential of a design idea/concept against these needs. This approach

to *FR* centres on the ongoing *composition*, *decomposition* and *verification* of ‘plans of action’<sup>32</sup> and ‘design ideas/concepts’ within a finite set of constraints. These constraints can be defined by the technologists evolving understandings about the functional needs of a solution, as well as any limitations established by the design problem itself (for example: the resources available to realise a solution, including component parts that can be accessed and used and/or time constraints). A *FR* planning and design approach enables the functionality of components that offer potential to contribute to a fully realised solution to be abstractly and practically explored, through functional modelling and prototyping. Exploration to gain understanding of the functional offerings of individual components, and uncovering how their performance may change due to component interactions should they be combined within a fully realised solution, is an essential part of a planning and design approach to *FR*.

Conceptualisation approach: in this approach engineers (technologists) explore how to ‘make things work’ by defining a hierarchical classification scheme that categorises conceptual ideas (including component parts) according to their potential to contribute to the overall functionality required in a solution to a design problem. The success of this approach to *FR* is dependent upon a technologist’s ability to objectively describe the intended functions required of a solution and its design problem, and then break these down into categories that have a hierarchical order in terms of their overall importance to the realisation of a solution. To allow this hierarchical categorisation to occur, *functional primitives* that describe the required behaviours, including appearances, of identified functions need to first be defined. An example of a conceptualisation approach to *FR* is where a design problem such as a hand tool for a bicycle (a solution or technological outcome) requires functional attributes such as: able to undo/do-up nuts and bolts on a bicycle; be lightweight, compact, adjustable and ergonomic; be easily identifiable. Category labels that could be used to classify and later determine the potential of a concept for and/or a component part to contribute to the overall functionality required in the hand tool include: materials; adjustability; ergonomics; torque;

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<sup>32c</sup> *Plans of action*’ is a collective term used to capture the planning undertaken that supports the generation of design ideas and concepts of potential solutions to a design problem, as well as the planning that is required in order to develop such ideas and concepts into a realised solution to the problem.

colour. How these categories are prioritised in terms of their importance to resolving the problem, and functional primitives established for each category, is dependent upon the overall functional needs of the solution and the design problem itself. For example if the size and type of nuts and bolts found on bicycles is Hexagonal M6, M8 and M10 then the *functional primitive* for the category: ‘adjustability to fit different types and sizes of nuts and bolts’ will be: adjustable to fit hexagonal M6, M8 and M10 nut and bolt heads.

Explanation-based approach: uses *FR* to explain ‘how things work’ in terms of the functionality of existing or yet to be realised artefacts and/or their components. This approach to *FR* is often employed when diagnosing faults in devices or determining failure modes (i.e. under what circumstances/environment is the device likely to fail) and/or explaining how ‘high-tech’ devices (i.e. electronic circuits) function. Engineers (and technologists) who use this form of *FR* rely on their ability to transfer abstract relationships and understandings, often learnt within a specific case or context, into the new context that requires explanation. An explanation-based approach to *FR* is closely associated with *explanation-base learning* techniques (Ellman, 1989 – cited in Far & Elamy, 2005) in that it deductively draws on prior understandings and reasoning to arrive at conclusions that explain the current (or likely) situation/outcome. Pazzani (1991) explains this approach to reasoning using the following example: if you already know that *A* results in *B* when *P* is true; and *B* will result in *C* when *P2* is true, then it can be reasoned that *A* results in *C* when *P*, and *P2* are true (p.167).

These three *FR* approaches identified by Far and Elamy (2005) are presented to support informed decision making and the selection of ‘best’ alternative(s) as physical descriptions of a potential solution. In technology education, *FR* approaches may allow students to make informed decisions about alternatives as they explore concept ideas and designs, and evolve them into realised solutions to authentic (or theoretical) problems using technological modelling (functional modelling and prototyping) practices. The use of such practices may also assist students to argue the potential of alternatives, including those which are discarded, against held beliefs and/or understandings about physical descriptions through using technological modelling to determine their technical feasibility.

Ullman (1992) points out a focus on technical feasibility alone is inadequate, and highlights the importance of deliberating on social considerations such as ‘form features’ and ‘life cycle’ when testing physical descriptions for their potential contribution to a solution(s) for an intended function.

### ***Practical reasoning***

*Practical reasoning* [PR] within technology is focused on addressing social considerations such as moral, cultural and ethical viewpoints surrounding a design idea, and the testing of outcomes (Compton & France, 2006b; Compton, 2010a). This form of reasoning uses normative understandings to regulate action (Railton, 1999). Any actions (or intentions) resulting out of practical reasoning are therefore dependent upon a person’s concept of ‘reasonableness’ or what is ‘appropriate’ (or inappropriate). As a consequence, when normative beliefs are considered by practical reasoning there is no ‘right’ or ‘wrong’ conclusion (Hitchcock, 2002).

Aristotle is credited with first articulating a model for *PR* (Broome, 2001; Hitchcock, 2002). His model of reasoning centred on defining ‘what ought to be done’ and concluded with a decision to perform an ‘act’ to accomplish it. Aristotle’s model of *PR* therefore required “a desire for some end [point] to initiate it” (Hitchcock, 2002, p.249). More recently philosophers such as Bratman (1991), Broome (2001) and Pollock (1995) have questioned Aristotle’s model of *PR*, suggesting that this form of reasoning need not always conclude with an ‘act’. Rather, due to reasoning being a “mental process or mental event” (Broome, 2001, p.1) it is more likely to conclude in an ‘intention’. They argue that while a resulting intention from *PR* may be an act being performed, the actual act itself is not a part of the reasoning process. This view of *PR* explains that even if the process of reasoning draws a conclusion which does not immediately lead to (or ever lead to) an action, this non-action is not the fault of the reasoning process, but rather a failure to act on what was reasoned (Streumer, 2007).

Therefore, when normative beliefs are deliberated over and the outcome of this deliberation leads to an intention, then according to Broome (2001) *PR* has taken place. Broome (2001) describes such *normative practical reasoning* as being “reasoning that has a normative belief ineliminably amongst its premise-states, and



concludes with an intention” (Broome, 2001, p.4). This concluding intention, which may simply result in a change in belief with no intended consequence, therefore distinguishes practical reasoning from simply being a theoretical reasoning paradigm (Broome, 2001; Streumer, 2007).

When technologists use normative practical reasoning, in the act of developing outcomes that are ‘fit for purpose’, it provides them with a framework from which to consider opinions, and the potential impact on, immediate and wider community stakeholders to the outcome under development. When such considerations are deliberated upon through normative practical reasoning technologists are able to determine and implement a “...rational structure to justify ‘what ought to happen’ ...” and determine “.... if it ‘should happen’ ...” (Compton & France, 2006b, p.8).

### **2.5.3 Decision making and reasoning in Technology Education**

According to Fisher (2008) and Ullman (1992) the determination and realisation of the functional needs of a design solution needs to not only address the technical aspects of the solution, but also ensure its social acceptance. A ‘physical description’ of both the design problem and its solution therefore should not only consider the technical feasibility of a yet to be realised design solution, but also recognise and address socio-technical considerations that underpin a solutions development. To support informed decision making towards a design solution (technological outcome) in technology education, and ensure that both the technical feasibility and appropriateness of a developing design solution are considered, both *functional and practical reasoning* should be apparent when students undertake technological practice (Compton, 2010a; Compton & France, 2006b). Justifications for the outcomes of such decisions are supported when both of these reasoning types are used to determine, using data obtained from functional modelling and prototyping, alternatives (design ideas and conceptual designs) that offer potential contribution to a realised technological outcome. In technology education, how students utilise *practical* and *functional reasoning* and therefore make decisions on prioritising alternatives, impacts on the nature of the technological practice they undertake and the potential ‘fitness for purpose’ of resulting technological outcomes.

## 2.6 Summary of the Emergent Themes and Issues Identified from the Literature

This literature review comprised five sections. The first section provided an overview of technology in the New Zealand curriculum. It introduced the *NZCF* (Ministry of Education, 1993a) and technology curriculum, *TiNZC* (Ministry of Education, 1995), and discussed the *NZCMP* (Ministry of Education, 2005) project that reviewed both of these documents. An outcome of the *NZCMP* (Ministry of Education, 2005) project was the re-conception of the *NZCF* (Ministry of Education, 1993a) into a new *NZC* (Ministry of Education, 2007). This new curriculum no longer prescribed ‘content’ to be taught, but rather within integrated Learning Area statements, placed an emphasis on ‘substance’ (*knowing*) and ‘processes’ (*doing*). To support teachers to enact the *NZC* (Ministry of Education, 2007), Learning Area statements, succinctly stated learning intentions, described the structure for learning aligned to the Learning Area and prescribed a set of achievement objectives. The Learning Area statement for technology in the *NZC* (Ministry of Education, 2007), introduced three newly defined strands along with their eight components. This change in strands and components was to address limitations found during the implementation of the *TiNZC* (Ministry of Education, 1995). These limitations included student technological literacy holding to a ‘functional’ orientation when student knowledge and skill development were solely immersed within technological practice (Compton & Harwood, 2008). The new strands and components, and defining of a broad range of related technology areas were introduced in an endeavour to develop student technological literacy that is ‘broad, deep and critical’ in nature (Compton, 2007; Compton & France, 2007a).

The second and third sections of this chapter reviewed literature on two strands of technology in the *NZC* (Ministry of Education, 2007). These strands, Technological Practice and Technological Knowledge are a focus of this thesis.

Section Two reviewed the origins of technological practice, discussing Pacey’s (1983) conceptualisation of how technological practice brings cultural, organisational and technical aspects together to create artefacts that address problems which often have competing criteria. The extent to which a designer’s

intentions shape the outcomes (i.e. products and/or systems) of technological practice (Feng and Feenberg, 2008) was also discussed as was practising technologists' tendency to partition their practice into stages when developing these outcomes (Garbacz, 2009; Best, 2006). This section reviewed how technological practice embeds within technology education, exploring pedagogical approaches traditionally adopted by teachers to 'teach' technological practice to their students and the limitations of these approaches (Williams, 2000). It highlighted the importance of teachers providing supportive frameworks that enable students to enact their technological practice in response to the specific outcome(s) being developed (de Vries, 1996; Williams, 2000), and concluded by introducing the Indicators of Progression for the Technological Practice strand of technology in the NZC (Ministry of Education, 2007). These Indicators, developed through classroom based research by Compton and Harwood (2010b, 2005, 2004b), describe expected student achievement and teacher pedagogical practices in increasing levels of sophistication from curriculum levels 1-8 for the Technological Practice strand components for technology in the NZC (Ministry of Education, 2007).

Section Three reviewed the origins of technological knowledge, providing insight into the debate that exists amongst technology educators as to its existence (Baird, 2002; Custer, 1995; Ihde, 1997; Johnson, 1997; Layton, 1987; McCormick, 2004; McGinn, 1990; Ropohl, 1997) and the ability to define its curricular elements (de Vries & Tamir, 1997; Herschbach, 1995; McCormick, 2004; Rowell, 2004). The Section introduced categories for knowledge proposed by philosophers and technology educators which included those presented by de Vries (2003a, 2003b), McCormick (1997), Ropohl's (1997), Rowell (2004) and Vincenti's (1990). These were reviewed as they informed the identification of the Technological Knowledge strand components for technology in the NZC (Ministry of Education, 2007). Section Three also reviewed concepts included in the Technological Knowledge component: *technological modelling* (Ministry of Education, 2007). These concepts include an understanding of how different forms of technological modelling enable technologists to 'test' the potential of a design as it evolves from a conceptual idea through to an implemented technological outcome (Compton & Compton, 2012). The forms of technological modelling include functional modelling and prototyping. This Section also introduced the Indicators of Progression for the

*technological modelling* component of technology in the NZC (Ministry of Education, 2007). These Indicators, developed from classroom based research undertaken by Compton and France (2006b) and Compton and Compton (2010b), describe expected student achievement and teacher pedagogical practices in increasing levels of sophistication from curriculum levels 1-8 for the *technological modelling* component for technology in the NZC (Ministry of Education, 2007). This section concluded by reviewing the Delphi research study titled *Concepts and Contexts in Engineering and Technology Education [CCETE Project, 2009]* that was conducted by a consensus of international expert technologists, technology educators and philosophers of technology to identify overarching, unifying concepts that are considered ‘foundational’ to engineering and technology education (Hacker, de Vries & Rossouw, 2009). It discussed the importance of clarifying overarching concepts for technology education (de Vries, 2012) and why the concepts of practical and functional reasoning were included in technology in the NZC (Ministry of Education, 2007).

Section Four of this chapter discussed decision making, the nature of decision problems and how these connect with technology education. It reviewed the literature surrounding the decision making process (Beyth-Marom, Fischhoff, Jacobs-Quadrel, & Furby, 1991; Bohanec, 2009; Hardy-Vallée, 2007; Milkman, Chugh & Bazerman, 2008; Stanovich & West, 2000), and how this breaks down into several activities or key stages to enable decision problems to be interrogated, alternatives considered, and decisions made (Bohanec, 2009). The means of classifying decision problems (Bohanec, 2009; Klein, 2008; Milkman, Chugh & Bazerman, 2008) was also discussed along with how reasoning is used to assess the probable success of considered alternatives (Carruthers, 2003; Harman, 2009; Pollock, 1998). This section concluded with a review of the two forms of reasoning, *functional* and *practical* reasoning, which are highlighted in the *technological modelling* component of technology in the NZC (Ministry of Education, 2007), and an examination of how these support consideration of both the technical aspects and social acceptance of a design solution, when the needs of a technological outcome are explored (Fisher, 2008; Ullman, 1992).

The research presented in this thesis sought to determine the influence of the component *technological modelling* on students' ability to make informed decisions when undertaking technological practice. To ascertain this influence, student achievement in the components of Technological Practice (*brief development, planning for practice, and outcome development and evaluation*) and their concepts in *technological modelling* were explored, along with the decision making type(s) and forms of reasoning they drew on when engaged in technological practice. While the literature presented in this chapter showed that technology in the NZC (Ministry of Education, 2007) has embraced students developing conceptual understandings about *technological modelling*, and practical and functional reasoning, there has been no specific research undertaken to date that identifies the influence that these understandings have on their decision making when developing technological outcomes. The literature reviewed in this chapter suggests that when student conceptual knowledge of technology is enhanced, this contributes to students developing technological outcomes that are fit for purpose in their broadest sense, and a technological literacy that is 'broad, deep and critical' in nature (Compton, 2010a; Compton and France, 2007a; Compton and France, 2007b). This research sets out to verify if this suggestion in the literature can be confirmed and how this might be linked to student decision making. Exploration of students' understandings about the components of Technological Practice, concepts of *technological modelling*, and the nature of their decision making and reasoning thus form the research questions for this thesis as detailed in Chapter One Section 1.4.

# CHAPTER THREE

## METHODOLOGY AND RESEARCH METHODS

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### 3.1 Overview of the Chapter

This chapter describes the methodology employed for this research. The chapter begins with a general discussion about educational research, and a description of educational research methods and methodological approaches. This is followed by an outline of methods used to collect data in educational settings. Section 3.3 describes and justifies the research design adopted for this research, the research tools used to gather student data and measures taken to ensure their trustworthiness. It also discusses the category labels used to analyse student data for the components: *brief development, planning for practice, outcome development and evaluation* and *technological modelling*; and for decision making and reasoning. An overview of the research participants and their schools is provided in Section 3.4. Section 3.5 explains how the research was conducted, along with a description of the measures taken to enhance the validity and reliability of the data gathered, and how relevant ethical considerations were addressed. Section 3.6 presents a summary of this chapter.

### 3.2 Educational Research

#### 3.2.1 Methodological approaches

Research in its broadest sense may take on a variety of meanings and be employed across a range of contexts. Mouly (1978) states that “research is best conceived as the process of arriving at dependable solutions to problems through the planned and systematic collection, analysis, and interpretation of data” (p.12). Research conducted within the domain of education (educational research), is primarily focused on the identification and clarification of issues and concepts concerned with teaching and learning within formal educational settings. As such, educational research predominantly centres on activities and undertakings aimed at developing

understandings of people and their actions within their social setting. It is concerned with identifying and understanding learning behaviours from both normative and/or interpretive perspectives (Cohen, Manion & Morrison, 2002). Educational research is therefore conducted in a systematic and scholarly manner, and is grounded within a research methodology.

Research methodology describes the process(es) that guides research rather than just the products of the research itself (Cohen, Manion & Morrison, 2002). Explicitly stating the methodology applied to research is important in defining the way a researcher goes about proving what they believe they know and/or identifying what they come to understand (Guba & Lincoln, 1989). By its very nature, research methodology is bound within a paradigm, or set of common beliefs and shared agreements. Davidson and Tolich (1999) describe these beliefs and shared agreements as “philosophical assumptions about what the world is made of and how it works” (p.26), which are bound within one’s perception of *reality* (ontology) and its relationship to *knowledge* (epistemology). Two major research paradigms have traditionally been identified in Western scientific research - *positivist* and *interpretivist*. Over the years, these two paradigms have largely been perceived as polar. For example, in certain disciplines interpretivists are labeled as being antipositivists (Galliers, 1991) and vice versa. In more recent years, *critical social science* has emerged as a third paradigm. *Critical social science* is often seen as being quasi-interpretive due to researchers operating within this paradigm also sharing an interpretive viewpoint of the world.

### ***Ontology and Epistemology of a Positivist Paradigm***

Positivists believe that human behaviour is fundamentally governed by a set of universal laws based on their knowledge of known facts, establishing scientific truths and observable objective phenomena (Horton & Hanes, 1993). Within a positivist paradigm, objective reality is considered to exist beyond the human mind (Weber, 2004) and therefore independent of anyone’s attitudes, perceptions or feelings. Positivist researchers therefore see reality as external in form, and objective or independent of their own perception or mental state. To achieve this they set out to maintain a separation between themselves and those that they observe. Their research is based on a grounded hypothesis concerned with



establishing the cause and effect on an empirical phenomenon through fragmenting and compartmentalising it until it is understood, predictable and controllable (Horton & Hanes, 1993; Cohen, Manion & Morrison, 2002). Within positivist research, subjectivity is therefore completely mitigated; with knowledge being derived solely from proof or deduction. Deduction in this case begins with a universal truth or a “connected view of a situation” (Dewey, 1910, p.82) and works backwards to isolate details of the empirical phenomena through tests, refutations, modifications and/or confirmations, with the intent of interpreting “isolated details into a unified experience” (*loc. cit.*) so that generalised concepts and theories can be derived.

Positivist paradigms are often associated with scientific inquiry, particularly in the natural and physical sciences where empirical phenomena concerning physical matter, biological entities and/or chemical elements afford repeatability and isolation when subjected to investigation. The nature of the phenomena, which characterise the physical and natural sciences, is attributable to the success of positivism in these sciences, rather than the ontological and epistemological underpinnings of a positivist paradigm itself. When an empirical phenomena that is socially focused attempts to uncover human behaviour, a positivist paradigm is usually less successful. This is due to a positivist paradigm not valuing processes such as intuition and insight (Cohen, Manion & Morrison, 2002), disregarding tacit knowledge, and not taking into account the value system and beliefs of the researcher. Moral, ethical, political, and economic implications are therefore often not taken into account, when a positivist paradigm is employed in human inquiry.

### ***Ontology and Epistemology of a Interpretive Paradigm***

An interpretive paradigm is characterised by its concern for the individual. It focuses on gaining an understanding of the “subjective world of human experience” (Cohen, Manion & Morrison, 2002, p.22) from within. To achieve this, an interpretive paradigm recognises ‘reality’ as intrinsically linked to an observer’s (researcher’s) feelings and mental state, and therefore determined by their experiences, culture and other sociological factors that shape them. The ontology of an interpretivist paradigm therefore, is based on a belief that the researcher and

reality are inseparable (Weber, 2004). This view of reality is therefore in direct contrast to that held by those who work within a positivist paradigm.

Knowledge in an interpretivist paradigm is considered to be socially constructed, and based on a subjective interpretation of everyday concepts and meanings (Sanghera, 2005b). As a result, interpretive researchers uphold that knowledge is “intentionally constituted through a person’s [researcher’s] lived experiences” (Weber, 2004, p.iv). According to Lincoln and Guba (1990) the challenge for interpretive researchers’ is to maintain objectivity and ensure that the research remains trustworthy. This has led to many positivists questioning the scientific essence of interpretivism. They claim that if the aim of scientific research is to advance knowledge, and hence derive generalised and objective knowledge, then general theories cannot be developed and consequently validated based on subjective interpretations. This concern however can be mitigated when interpretive researchers use a two-leveled process of interpretation - *understanding* and *interpretation* and ‘bracket’ their personal value theories to ensure that they do not introduce their own subjective practices into the research site (Berg, 2004; Cohen, Manion & Morrison, 2002).

In the first level process of interpretation, interpretive researchers seek to understand, through data collection, the empirical phenomena and to make sense of the world that the subject(s) under study lives in. Subjective interpretations made during this process are used to determine the belief systems and interpretations held by the subject(s), and to establish the objectified parameters for continued study. The second level process focuses on the interpretation of analysed data in order to identify patterns of human activity and action, and to determine theoretical explanations grounded in the research site (Berg, 2004). Shutz (1954) suggests that “scientific constructs formed on the second level, in accordance with the procedural rules valid for all empirical sciences, are objective ideal typical constructs and, as such, of a different kind from those developed on the first level of common-sense thinking which they have to supersede” (p.270). According to Shultz (1954) therefore, interpretations made during the second level process are a part of the scientific knowledge being investigated, and therefore can be scientifically validated through scientific induction. Scientific induction in this case is referring

to the method by which all processes are observed and data regulated to formulate explanatory ideas and theories (Dewey, 1933). As a part of this regulation, empirical data which is often fragmented and incoherent can be realised to describe coherent ideas or emergent theory by the gradual insertion of universal facts and their properties. Due to the nature of this process, multiple realities can often present themselves to researchers in an interpretive paradigm. In such cases it is a researcher's responsibility to emerge theories from these realities that explain the "purposes of those people who are their source" (Cohen, Manion & Morrison, 2002, p.23) through ascertaining and debating their truthfulness or fact.

### ***Ontology and Epistemology of a Critical Social Science Paradigm***

A critical social science paradigm is characterised by a belief that research should be conducted to "critique and transform social relations" (Neuman, 1997, p.74). Critical social science researchers therefore are often dissatisfied with the way things are, and undertake research in order to make dramatic improvements through uncovering myths and hidden 'truths' that exist within a situation (empirical phenomena) that is not overtly obvious (Cohen, Manion & Morrison, 2002; Neuman, 1997). Researchers within a critical social science paradigm understand that knowledge often possesses multiple realities within social, cultural, political and historical situations (Belbase, 2007). Consequently, to gain an understanding of knowledge, researchers need to reveal the underpinning constructs of the social relationship within the empirical phenomena. The epistemological stance of critical social science therefore, identifies knowledge as a form of self-reflection that requires both an understanding and a theoretical explanation in order to reduce or overcome entrapment in systems of domination or dependence. When an empirical phenomenon is understood and theoretically explained, critical social science researchers are then able to establish emancipative knowledge that is not bound to restrictions and oppression (Cohen, Manion & Morrison, 2002; Neuman, 1997). To gain understandings of the social relationship within empirical phenomenon, researchers who adopt a critical social science paradigm often need to ask the embarrassing questions which expose inequalities and hypocrisies within social settings (Cohen, Manion & Morrison, 2002).

The ontology adopted by critical social science shares much in common with an interpretivist paradigm, that is, “social reality is socially constructed” (Sanghera, 2005c, p.1) within a real world and therefore can only be understood within the limitations of its own constructs. What critical social science, however, also upholds is that this reality should be examined and empirically tested before suggesting change (Cohen, Manion & Morrison, 2002). Researchers who adopt a critical social science paradigm, cannot undertake objective observation due to the preconceived assumptions and interests that they bring to the research site, and their desire to initiate change. Such a desire for change means that researchers who work within a critical social science paradigm are often criticised for their involvement due to a perception that they influence the research process. Ensuring trustworthiness of research findings needs to therefore be an integral part of critical social science researcher practice as they gather and interact with data, and draw conclusions from it.

Guba (1979) points out that research paradigms are embodied by assumptions and therefore in selecting which paradigm to apply to a research site the researcher needs to answer the following question: “which set of assumptions is best met by the phenomena to be investigated” (p.4). In a similar vein Cohen, Manion and Morrison (2002) point out that some research paradigms are better suited to research purposes and questions than others. Therefore selection of a research paradigm needs to be done on the basis of a ‘best fit’ between the empirical phenomenon under examination and the questions that seek explanation. Likewise, the research methods or instruments that are used to gather data, and the guidelines by which data are interpreted and explained also need to be fit for their intended purpose (Cohen, Manion & Morrison, 2002).

### **3.2.2 Research methods**

Research methods are traditionally grouped into two distinct categories. These cover a wide range of approaches that are used to access data focused on the empirical phenomenon under investigation. The two categories are labelled *quantitative* and *qualitative* methods.

*Quantitative* research methods collect data in the form of numbers, to test theories or hypotheses that comprise variables about social or human problems (Creswell, 1994; Neuman, 1997). In quantitative research, data are analysed using statistical procedures in order to “determine whether predictive generalisations of the theory hold true” (Creswell, 1994, p.2). As such, quantitative methods are traditionally aligned to positivist research methodology and therefore uphold to an ontology where “reality is objective and singular” and “apart from the researcher” (Creswell, 1994, p.5). As a result, quantitative researchers can adopt an independent, valueless distance from the research site with their only influence being to “attempt to control for bias, select a systematic sample and be objective in assessing a situation” (Creswell, 1994, p.6). Many problems studied using quantitative research methods have previously either been selected for study, or have had component parts previously scrutinised. As a consequence of this, there is often a body of existing literature which can assist in determining variables and/or establishing hypotheses for examination of new quantitative study. Data collection methods most commonly used for quantitative research include experiments and surveys that comprise closed questions, which often demand a multiple-choice or rating scale response.

*Qualitative* research attempts to understand social or human problems within their natural setting, by building a ‘holistic picture’ that can be expressed by words which often incorporate research participant views (Creswell, 1994). In qualitative research, data are analysed using inductive logic to identify category labels that allow patterns or theories to be derived to explain empirical phenomena (Creswell, 1994; Neuman, 1997; Cohen, Manion & Morrison, 2002). Qualitative methods are traditionally aligned to interpretative research methodology and therefore uphold an ontology where “reality is subjective and multiple and seen by participants in the study” (Creswell, 1994, p.5). Qualitative researchers therefore, assume that the only reality that exists is that which is constructed within the research site. As a result they adopt an interactive, collaborative bond with research participants to minimise the distance between themselves and those being researched (Creswell, 1994). A consideration for qualitative researchers is the need to “acknowledge the value-laden nature” of their study, and accurately report their “values and biases, as well as the value nature of the information gathered” (Creswell, 1994, p.6).

Unlike quantitative research, most problems studied using qualitative research methods are usually exploratory studies, containing unknown variables that have little to no existing literature or theory base to draw on (Creswell, 1994). Data collection methods most commonly used for qualitative research include surveys that comprise open-ended questions that demand a written and/or pictorial response; observation and interviews (Neuman, 1997).

Where combinations of quantitative and qualitative methods are used within the same research, this is called a *mixed methods approach* to research. A *mixed methods approach* to a single research study can allow:

- data to be triangulated to determine if there is a convergence of results
- an overlapping or difference in the phenomenon under investigation to be identified
- findings from the first method to be used to inform the second method that follows
- the study to expand in order to add breadth and depth where needed
- contradictions found to be viewed through a fresh lens by use of an alternative method.

(Creswell, 1994)

Models for combining research methods include: a *two-phase design* where the researcher conducts a qualitative phase of the study and a separate quantitative phase; the *dominant-less dominant design* where one of the methods is more dominant in use within the study than the other; and the *mixed-methodology design* where both methods are mixed at all or many of the phases undertaken in the research (Neuman, 1997).

In light of the above discussion, details of the research methods used for this research are discussed in detail in Section 3.3.

### 3.3 Approaches used for this Research

#### 3.3.1 Methodological approach

As discussed in Chapter Two, the hypothesis underpinning this study is a hunch that students are more likely to be equipped to justify their developed technological outcomes as ‘fit for purpose’ if their knowledge of *technological modelling* is enhanced. This hunch, which is currently untested, was highlighted during the development of the *LAS* for technology (Ministry of Education, 2007) as needing explanation (Compton & France, 2006a).

In my previous role, as the contracted facilitator for the *Beacon Practice Technology Initiative*<sup>33</sup> and in my current role as the *National Technology Professional Development Manager*, I have had opportunity to work closely with two of the three teachers who indicated a willingness to offer students (student participants) as subjects for this study. Whilst having had previous close association with research participants (teachers and their students) may be seen as a disadvantage to the trustworthiness of the research findings (Lincoln & Gubba, 1990), it can also be beneficial. This is due to the opportunity that this association provided me, as a researcher, to make explicit any beliefs and concepts I brought to the site that may have influence on the research process (Neuman, 1997). Having a previous close working association with two of the participant teachers also allowed me to ask the ‘difficult’ questions that may not have otherwise been asked until well into the research, when a mutual trust between researcher and participants had been established.

Bassey (1995) identified three categories of research that are commonly applied in education: *theoretical* research, *evaluative* research and *action* research. These he describes as:

- *Theoretical* research: focused on describing, interpreting and explaining events without making any judgements about them

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<sup>33</sup> The *Beacon Practice Technology Initiative* was a resource development project that was conducted by the New Zealand Ministry of Education under the GIF Technology Initiative in 2004-2007.



- *Evaluative* research: focused on describing, interpreting and explaining events so that the researcher or others can make evaluative judgements about them
- *Action* research: focused on describing, interpreting and explaining events while all the time seeking to change them for the better.

With a desire to improve practices currently undertaken in the research sites around technological modelling to enable students to better justify their outcomes of technological practice as being fit for purpose, Bassey's (1995) description of action research, although somewhat instrumental, was considered a useful design for this research.

### 3.3.2 Action research design

There are many definitions of action research available. Carr and Kemmis (1986) describe action research as:

*Action research is simply a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of these practices, and the situations in which the practices are carried out. (p.162)*

While Carr and Kemmis (1986) definition captures the overall intent of action research, to bring about improvements through self-reflective enquiry, it does not acknowledge that improvements are often the result of systematic and deliberate actions informed by reflections on previous activity. Such improvements rely upon the scaffolding of deliberate cycles where planning, acting, reflecting and analysing are repeated over a period of time, so that action is followed by research which in turn is followed by further action. This cyclical framework allows the practice applied in action research to respond to situations uncovered within the research site, and for understandings to grow through the active involvement of all participants to the enquiry. Carr and Kemmis (1993) state that "action research helps practitioners to theorize their practice, to revise their theories self-critically in the light of practice, and to transform their practice into praxis (informed, committed action)" (p.23). Unlike other forms of scientific research, where theoretical beliefs are often formulated by the researcher independent of the research site, and then later applied at the site (Elliott, 1991), action research is reliant on there being a partnership between researcher and research participants, to

uncover and validate theoretical understandings through practice. Action research is therefore regarded as research in partnership *with*, rather than *on* participants. This participatory element of action research, Carr and Kemmis (1993) argue, "... extends beyond (a) mere presence in the exercise to collaborative involvement ... " and therefore requires "... all participants to be partners of communication on equal terms" (p. 238). For such equality in partnership to be attained, the researcher and the participants (in my case teachers and students) need to be on equal footing (Kyle and McCutcheon, 1984). This view of participation is argued by Greenwood, Whyte and Harkavy (1993) as being something which cannot be imposed on the research process but rather a desirable goal which should be aimed for. They state that:

*Participation is a process that must be generated. It begins with participatory intent and continues by building participatory processes into the activity with the limits set by the participants and the conditions. To view participation as something that can be imposed is both naïve and morally suspect.*

*(Greenwood, Whyte & Harkavy, 1993, p.176)*

Participation within action research can therefore be seen as being a continuum that ranges from "expert researcher to participatory action research" (Greenwood, Whyte & Harkavy, 1993, p.176). According to Greenwood et al (1993), action research which employs an expert researcher model, places the researcher in full control of the research process. However in a fully implemented participatory action research model "authority over and execution of the research is a collaborative process" (p.176) between the researcher and all participants associated with the enquiry under study. For a researcher to move towards full participatory action research, they need to continually evaluate the way their activities serve to allow participatory practices to be cultured in the research site. Such evaluation requires the researcher to interrogate their own personal values (ontological presumptions), the process they adopt to analyse such presumptions (epistemological analysis) and examine any discrepancies identified between these. They also need to be willing to change the way in which they conceptualise issues (Heikkinen, Huttunen, & Syrjala, 2007; Lomax, 1994). Action research therefore is bound by ethical enquiry and consequently needs to be undertaken within an agreed framework of ethics, to ensure that justification of the research itself along with any resulting findings, stand up to examination. Within the literature on action research,

a number of writers have identified a set of guiding principles to characterise action research and provide validity to this praxis of research (Cohen, Manion & Morrison, 2002). These guiding principles can be broadly categorised in to three headings; those concerned with the *natural setting*, *rigorous procedures*, and *effects* (Poskitt, 1994).

*Natural setting*: action research takes place within naturalistic settings and as such does not set out to control variables within the research site, but rather examine the realities of a site as it presents. Discoveries (findings) identified within the site are theorised and used to plan future directions through the application of deliberate actions, rather than being informed by perceptions theorised outside the research site (Cohen, Manion & Morrison, 2002; Poskitt, 1994). Although planned, deliberate actions need to be responsive to surprises and opportunities that present themselves in the research site. This ensures that each research cycle is able to build on the practice which has gone before. For this response to occur, all participants in the research site should be acknowledged as being researchers in their own right, and empowered to experiment freely and examine their own practices (Poskitt, 1994). Such an approach to research can result in tensions between a researchers' desire to impose and test theoretical ideas, and the need to for them to remain open and responsive to developing and evolving practices. These tensions can be minimised when all participants:

- have ownership of the problem or practices under investigation
- are committed to finding improvements
- are encouraged to be objective in their resolve to finding improvements.

*Rigorous procedures*: action research is reliant on critical reflection of empirical evidence; both in-action and on-action. To allow for this, researchers need to be disciplined in recording observational data, hunches and opinions (Poskitt, 1994), and in obtaining data that sheds insight into actions that instigate improvement. An essential part of this evidence is the recording of the deliberate actions that are embedded in the research site. Triangulating data from different sources, to confirm their validity, and enable theoretical conclusions to be derived and invoked into actions, helps to authenticate action research as a legitimate research methodology based on a scientific enquiry approach.

*Effects:* the intent of action research is to improve understandings, problem definition and practice within a social setting (Elliot, 1981; Poskitt, 1994). When data interpretations are a sense-making process, that conceptualise experiences through explaining research participant's unique knowledge base and their personal reflection (Dehler & Edmonds, 2006), then subsequent actions have an opportunity to effect improvement within the research site. The cyclic nature of action research allows the outcomes of 'sense making' to be reformed through repeated interpretations of cause and effect.

A criticism which has often been leveled at action research is that its findings are often presented in narratives which report on the evolving experiences of those who participated in the research. Heikkinen, Huttunen and Syrjala, (2007) argue however that where action research reports:

- acknowledge the past events that have shaped the present practices;
- are reflexive
- allow a story to be elaborated dialectically
- provide useable practices that can be regarded as useful, and
- evoke emotions and mental images

then such reports allow the 'quality' of the action research undertaken to be interpreted.

The research practices adopted by action researchers are often seen as different to those used by other research categories. This difference is due to the diverse range of contexts and fields where action research is applied, and also the varied philosophical and psychological beliefs held by action researchers (Reason & Bradbury, 2001). These differences have resulted in action research being openly debated by academics for its legitimacy as a form of 'scientific' research. When action research is undertaken within educational contexts this debate often centers on factors such as:

- the validity of having practitioners (teachers) involved in research for their own personal professional and/or for organisational improvement (McNiff, 2002)

- the ability of teachers to understand the complexities of doing research: “... research and teaching are significantly different roles which depend on different types of knowledge, skill and disposition. Expecting teachers to take over the task of doing educational research underestimates the difficulty of that task and the expertise it requires ...” (Foster, 1999, p.395)
- the apparent separation that exists between theory and practice (Levinson, 1972)
- the validity of the theoretical understandings elicited from research findings and their ability to be generalised beyond the research site (Githens, 2007)
- the loose use of the term ‘action research’ and how it is often misapplied to types of inquiry that are not really action research (Kemmis, 1988).

While there is not one coherent history of action research (Reason & Bradbury, 2001), most academics credit Kurt Lewin (1890-1947), a social psychologist, as the “father of action research” (Kemmis, 1993, p.1) for social psychology and education. Lewin’s research within social science was primarily centered on resolving social conflict. He believed that research should be used constructively to address problems of exploitation and poverty in minority groups. His interest was in “how people could, through self-education learn to enable themselves to improve their situation” (Kemmis, 1993, p.1). Since Lewin’s first introduced action research there have been “several waves of advocacy for educational research” that have resulted in a variety of educational action research approaches, each with their “own potential and limitations, and increasingly with its own literature” (Kemmis, 1993, p.1). Several writers (Grundy, 1988; Hart & Bond, 1994; Kemiss, 1993; Masters, 1995; McKernan, 1991) classify these approaches for action research in educational contexts into three main forms:

- Technical Action Research
- Practical Action Research
- Emancipatory or Critical Action Research.

### ***Technical Action Research***

This form of action research, first promoted by Lewin, uses a positivist, scientific frame of reference to solve perceived problems. Research projects conducted under a technical action research model, tend to be instigated and managed by an external

researcher who is positioned as being the ‘skilled expert’. Management of the project by an expert is perceived to enable efficient and productive research practices to be undertaken. Technical action research usually focuses on experimental action research (Hart & Bond, 1994) that leads to an accumulation of predictive knowledge that can be used, through deductive process, to refine existing theories. As such, technical action research is often structured around four distinct actions:

- a plan of action to improve what is already happening
- an act to implement the plan
- observations of the effect of the action in the context in which it occurs
- reflection on these effects to inform further planning and subsequent action through a succession of cycles.

(Kemmis & McTaggart, 1982)

The application of these actions needs to be flexible so that the researcher can respond to any unforeseen effects and unexpected constraints identified at the research site.

### ***Practical Action Research***

Practical action research takes a pragmatic approach to solving practical problems that often arise within professional practice. This form of action research may employ an expert researcher to collaborate with a person (or group of people) who ‘own’ the problem or situation to be investigated or the research can be undertaken by a professional to research their own practice. As such, practical action research allows practitioners to gain new insights into their actions, and promotes the development of autonomous and reflective practitioners. To ensure that practical action researchers are able to gain personal interpretive understandings about practical problems and draw valid theoretical understandings, a series of cycles of deliberately planned and reflective actions is essential (Elliot, 1987). Following an initial exploration of the research site to clarify the problem(s) to be studied, subsequent actions performed in each cycle need to be informed by the findings from the previous cycle. When practical action research is used to help improve professional practice, McNiff, Lomax, & Whitehead (1996) warn that emphasis must go on the praxis rather than just the practice in order to ensure that informed

and committed actions will “gives rise to knowledge rather than just successful action” (p.8 – cited in McNiff, 2002).

### ***Emancipatory or Critical Action Research***

Emancipatory action research often employs critical inquiry to address issues of social change and emancipation. This form of action research is reliant on participants working collaboratively together. Emancipative action research projects often have twin goals:

- to reduce the gap between the problems experienced by disadvantaged people in specific settings
- to develop local theoretical understandings which explain the situation.

The aim of emancipative action research is to enable and empower people to take strategic and effective action to improve their lives. Emancipative action research is highly participative and often informed by critical theory. This form of action research, the ‘Deakin’ model, promoted by Kemmis, Carr and McTaggart allows participants to develop interpretative meanings and organise collective action to overcome constraints (Poskitt, 1994). For participants to develop such meanings, and undertake collective action, they all need to be fully engaged in the research and communicate openly with one another. Within education, emancipative action research tends to focus on enabling “rational, just and democratic forms of education” (McKernan, 1991, p.27) rather than trying to address the “everyday practical concerns of practitioners” (Poskitt, 1994, p.65).

The research methods used to collect and analyse data do not differ for the three types of action research described above however, the purposes of the research, and the social and power relationships that exist between the participants and researcher(s) do. A continuum of participation exists across the three types, from the differentiated roles and recognition of the researcher as ‘expert’ in *technical action research*, to the highly participative and shared roles of empowering research captured by *emancipative action research*. Differences in these action research approaches stem from “cultural traditions, national and local situations, intellectual traditions in universities and schools, professional knowledge and practices, and also because action research can be emergent” (Hughes, Ndonko,



Ouedraogo, Ngum & Popp, 2004, p.2). When action research is owned by participants, they will often evolve their own means of doing research which is specific to their situation (Coughlan & Collins, 2001) and personal understandings. As a result, new models for conducting action research continue to emerge that reflect the diversity of the local character, where action research projects are undertaken.

### **3.3.3 Rationale for using Action Research for this study**

An emancipative action research design, underpinned by an interpretive paradigm, was adopted for this study for its empathy to research conducted in natural settings; focus on critical reflection; and intention of improving understandings and practice within social settings (Elliot, 1981; Poskitt, 1994). In an interpretivist paradigm knowledge is socially constructed and intentionally constituted through a researcher's lived experiences (Sanghera, 2005b; Weber, 2004). Adopting this research design therefore meant that the researcher and realities of the research site, in terms of researcher and teachers actions and resulting student outcomes, were inseparable (Weber, 2004). It also meant that an *open design* attitude to data analysis could be adopted to allow subsequent data collection and analysis to profit from everything learnt prior to that point (Guba, 1979). Within this design therefore, the researcher and teachers could observe both the "cause and effect" (Cohen, Manion & Morrison, 2002, p.181) of selected systematic actions used to develop student concepts of technological modelling. These actions, informed by understandings gained from data from the prior research cycles.

Lewin's cyclic model of action research, as seen in Figure 2, was used as a framework for the emancipatory action research adopted for this study. Four cycles were undertaken, as seen in Figure 3, to ensure that sufficient data were collected and interacted with, to enable research conclusions to be drawn.

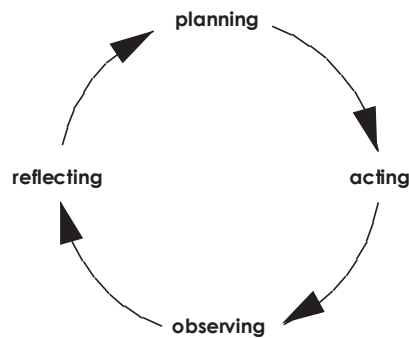


Figure 2: Lewin's scheme of action (cited in Cardino, 2003)

Each of these cycles required *planning* in which the researcher and the teacher participants devised a 'plan of action'. This 'plan of action' was based on an understanding of the research goals for that cycle of the research, and an understanding of the issue(s)/barrier(s) to improve student achievement in the component *technological modelling*. A part of the 'plan of action' was the identification of the specific knowledge that was to be taught during this cycle and pedagogical strategies to be used to do this. *Enacting* this plan involved teacher delivery of the unit and *observing* in order to evaluate changes in student conceptual understandings and any improvements in their ability to justify their developed technological outcomes as 'fit for purpose'. Through *reflecting* on any observed changes (or not) and implications of these changes, a reconsideration of the cycle's research goals was also able to be undertaken.

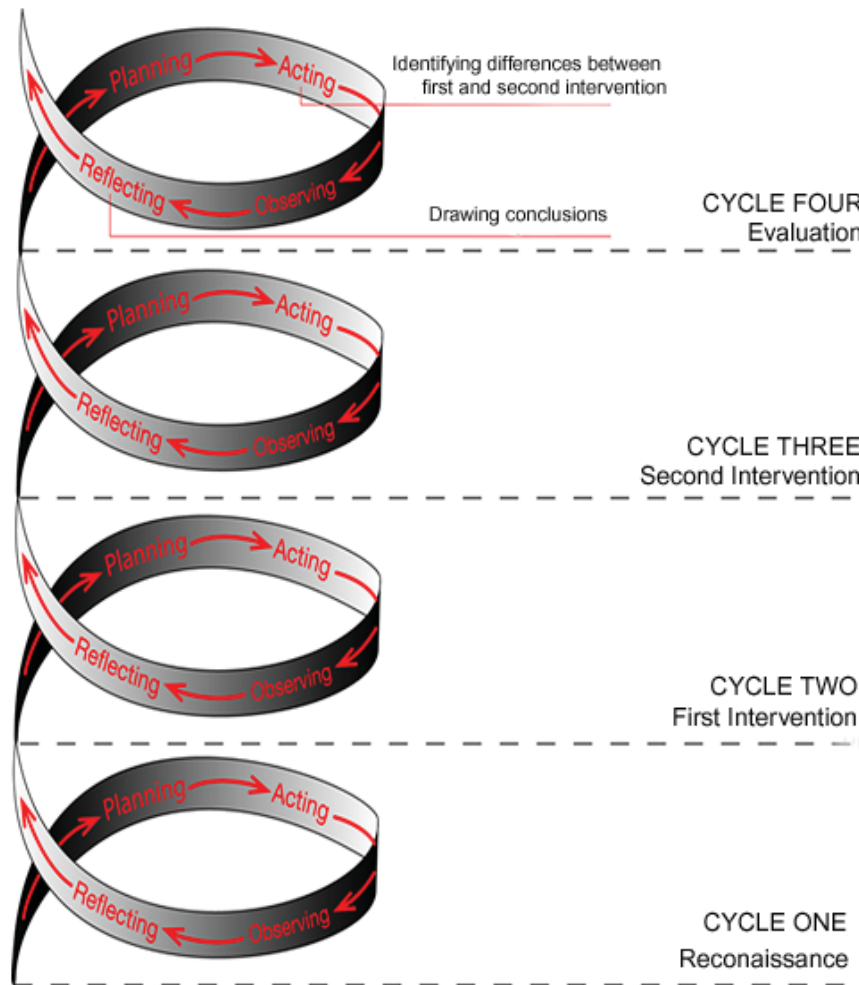


Figure 3: Cycles of the research

As illustrated in Figure 3, there were four cycles applied in this research. A description of each research cycle that includes: timeframes, actions undertaken and factors that influenced the cycles follows in Table 1.

Table 1 Research Cycles

Timeframe	Actions	Factors Influencing Cycle
<b>CYCLE ONE: Reconnaissance</b>		
April, 2008	Obtain ethics approval from Massey University Human Ethics Committee.	<p>Students confirmed as research participants were those most likely to study Technology in Years 12 and 13.</p> <p>Student portfolio evidence examined was developed by the research participant students in Year 11 and used for assessment against Level 1 NCEA internal and external Achievement Standards in 2007.</p> <p>No Year 11 technology programmes in the research schools had focused teaching activities/units on developing student conceptual understandings of technological modelling.</p>
	Explain project to teacher research participants (and principals) including expected outcomes and their required contribution to the research. Confirm student participants and obtain signed consent forms.	
May, 2008	Collect baseline data ( <i>Baseline Data</i> ). This data comprised observation, portfolio evidence and a technological modelling questionnaire, student/researcher conversations.	
June, 2008	<b>Initial analysis</b> of <i>Baseline Data</i> –identify implications for planned interventions for teaching units for <i>Cycle Two</i> and discuss with teachers.	
	Assist teachers to <b>plan</b> teaching units/activities for <i>Cycle Two</i> with learning <b>interventions</b> that <b>reflect understandings</b> gained from <i>Baseline Data</i> .	
end June, 2008	<b>Secondary analysis</b> of <i>Baseline Data</i> – identifying <b>emergent themes</b> to inform planning/teaching for <i>Cycle Two interventions</i> .	
<b>CYCLE TWO: First Intervention</b>		
June – Oct, 2008	Deliver <i>Cycle Two</i> units/teaching activities.	<p>Student portfolio evidence submitted for assessment against external Level Two Technology Achievement Standards could not be gathered from students until January 2009. A secondary analysis of Cycle Two data was undertaken in late Jan- Feb 2009.</p> <p>Researcher observations during classroom visits were used to ensure that activities delivered offered opportunity for student change.</p> <p>Where identified that students failed to engage with technological modelling concepts taught and/or respond positively, further <b>interventions</b> were introduced.</p> <p><i>Cycle Two</i> provided opportunity for the researcher to establish a working rapport with the student participants (and teachers).</p>
	Researcher classroom visits to <b>observe</b> and <b>interact</b> with participating students.	
	Collect student artefacts – portfolio evidence (documentation of technological practice, photographs of technological outcomes, mock-ups, records of researcher/student conversations). Redistribute technological modelling questionnaire for students to complete.	
Nov- Dec 2008	<b>Initial analysis</b> of available data from <i>Cycle Two</i> – <b>compare findings</b> from <i>Cycle One</i> data with initial findings from <i>Cycle Two</i> .	
Jan – Feb, 2009	<b>Secondary analysis</b> of all data from <i>Cycle Two</i> – compares <i>Cycle One</i> findings with those from <i>Cycle Two</i> and <b>emergent themes</b> to inform next <b>intervention</b> .	
April 2009	Assist teachers to plan teaching units/activities for <i>Cycle Three</i> with learning <b>interventions</b> that <b>reflect understandings</b> gained from <i>Baseline Data</i> .	

<i>Timeframe</i>	<i>Actions</i>	<b>Factors Influencing Cycle</b>
<b><i>CYCLE THREE: Second Intervention</i></b>		
Feb, 2009	Confirm students research participants for 2009.	<p>Student portfolio evidence submitted for assessment against external Level 3 Technology Achievement Standards could not be gathered from students until January 2010. A secondary analysis of Cycle Two data was undertaken in late Jan- Feb 2010.</p> <p>Researcher observations during classroom visits were used to ensure that activities delivered offered opportunity for student change. Where identified that students failed to engage with concepts taught and/or respond positively, further interventions were introduced.</p>
June – Sept, 2009	Deliver <i>Cycle Three</i> units/teaching activities.	
	<p>Researcher classroom visits to <b>observe</b> participating students.</p> <p>Collect student artefacts – portfolio evidence (documentation of technological practice, photographs of technological outcomes, mock-ups, records of researcher/student conversations).</p> <p>Redistribute technological modelling questionnaire for students to complete.</p>	
Oct, 2009	<b>Initial analysis</b> of available data from <i>Cycle Three</i> – <b>compare findings</b> from <i>Cycle One</i> and <i>Two</i> with those from <i>Cycle Three</i> .	
Nov, 2009	<b>Interview</b> research participant students to validate/clarify conceptual understandings identified from initial analysis of <i>Cycle Three</i> data.	
Jan – Feb, 2010	<b>Secondary analysis</b> of all data from <i>Cycle Three</i> – compares findings from <i>Cycle One</i> and <i>Two</i> data with findings from <i>Cycle Three</i> , and <b>emergent themes</b> .	
<b><i>CYCLE FOUR: Evaluation</i></b>		
March, 2011 – June, 2013	<p><b>Evaluation</b> of overall emerging themes to identify:</p> <ul style="list-style-type: none"> <li>– differences between student conceptual understanding of technological modelling from those identified in <i>Cycles One, Two</i> and <i>Three</i>.</li> <li>– ability of students to justify their outcomes, developed through undertaking technological practice, as ‘fit for purpose’.</li> </ul> <p><b>Conclusions drawn</b> and <b>theories developed</b> to explain links between student conceptual understandings about technological modelling, their decision making when undertaking technological practice and ability to justify their technological outcome as ‘fit for purpose’.</p>	

In order to triangulate data and determine the trustworthiness (Lincoln & Guba, 1990) of the student responses, different sources of data collection were used in all cycles of the research. These sources included use of data collection tools such as questionnaires, interviews and historical documents. The historical documents included:

- portfolios of student evidence of their undertaking technological practice to develop technological outcomes (Cycles One, Two and Three)
- teacher unit/activity plans that provided insight into the pedagogical strategies used to enhance student conceptual understandings of technological modelling (Cycles Two and Three).

### **3.3.4 Data collection tools**

#### **Questionnaires**

Questionnaires are used as instruments to structure the collection of survey information and enable their analysis to be comparatively straightforward (Cohen, Manion & Morrison, 2002). The design of questionnaires ranges from highly structured to unstructured; is dependent on the type of data they are seeking to obtain; and the way in which they are administered to research participants. When designing questionnaires, Cohen et al. (2002) suggest that: the larger the size of the sample being questioned, the more desirable it is for the questionnaire design to be well structured, offer closed questions and require numerical responses. Correspondingly when a small sample size is used, questionnaires may incorporate less structure and use more open-ended questions to allow greater word-based research participant responses (Cohen, Manion & Morrison, 2002).

When planning the design of a questionnaire Cohen, Manion & Morrison (2002) suggest that researchers need to:

- clarify the questionnaire’s central purpose (or set of purposes) in terms of its primary objective
- identify and itemise the subsidiary topics/issues that relate to the questionnaire’s central purpose
- identify the kinds of data measures that will be required to provide relevant evidence for each of the subsidiary topics/issues. These measures include such things as the sub-questions that need to be asked, the type of data that is best suited (i.e. numerical or word-based) and nature of the response modes (i.e. multi-choice questions, rating scales, open-ended questions, dichotomous questions).

Cohen, Manion & Morrison (2002) also point out the need for designers of questionnaires to consider the population that their questions will be used on, and the resources available to administer it. They warn that wording of questions and their layout can have a major influence on the validity and reliability of data collected. Pre-testing (piloting) questionnaires, prior to employing them as research instruments is therefore a critical step in their design (Cohen, Manion & Morrison, 2002) to ensure that the questionnaire respondents (research participants) can provide valid and reliable data. The resources available to administer a questionnaire within the research environment, including acknowledgement of any religious and/or cultural protocols, also needs to be considered.

The questionnaire employed for this research, was made-up of a range of inter-related open-ended questions. This allowed the researcher to compare research participant responses between questions – see Appendix B: *Student Questionnaire*. This format was chosen to make the questionnaire as ‘user-friendly’ as possible for the student participants, whilst simultaneously eliciting from them data that could inform the research. An advantage of using open-ended questions in the questionnaire is that they invite research participants to provide an “honest, personal comment” (Cohen, Manion & Morrison, 2002, p.255). Open-ended questions also firmly place the responsibility for, and ownership of, a response (data) in the hands of research participants and as such assist in eliciting data that otherwise may not have been captured (Cohen et al, 2002). The disadvantage of using open-ended questions however, is that they can make it difficult for the researcher to make comparisons between research participant responses, as there is often little in common to compare. To overcome this disadvantage, common or emerging themes (Neuman, 1997) were identified from this research across student participant responses. The questions were also framed in the questionnaire following consultation with the student participants’ teachers, and pre-testing of the questions themselves to ensure that students were able to commit their understandings and/or opinions to paper. Student participants were also encouraged to ask the researcher and/or teacher for clarification of the intent of any questions in the questionnaire. Discrepancies identified between responses to the open-ended questions were used as one of the triggers to determine the need for a follow-up interview (Patton, 1990).



### ***Interviews***

Interviews provide researchers with an insight into what is inside a person's head, and as such make it possible for them to gain an understanding about what a person knows (knowledge or information), what a person likes or dislikes (values and preferences), and what a person thinks (attitudes and beliefs) (Tuckerman, 1972). As such, interviews provide a means, within qualitative research, for a researcher to interpret the meaning of a person's experiences so that they may understand the world from their point of view.

A common characteristic of all interviews is the transactions that take place between those seeking information (the researcher or interviewer) and those supplying information (the research participant). Cannell and Kahn (1968 - cited in Cohen & Manion, 1994) defined research interviews as a "two-person conversation initiated by the interviewer for the specific purpose of obtaining research-relevant information, and focused by him (sic) on content specified by research objectives of systematic description, prediction, or explanation" (p.271). Kerlinger (1970) however notes that although the research objectives or purpose govern the content of the questions asked, sequence and wording are entirely in the hands of the interviewer. In order to make implicit the boundaries within which a researcher may vary the content, sequence and wording within an interview, Cohen and Manion (1994) defined four interview strategies – *structured interview*, *unstructured interview*, *non-directive interviews*, and *focused or semi-structured interviews*. In a *structured interview* the questions to be asked and the schedule of how they are presented at an interview are determined in advance, and the researcher is obliged to present them as planned. In contrast an *unstructured interview*, whilst still requiring careful advanced planning, to ensure that the research objectives are met, allows the researcher to vary the questions and procedures that are employed during the course of the interview. An unstructured interview therefore, provides flexibility for the researcher to pursue issues as they arise during the course of an interview. In *non-directive interviews* the interviewer guides the discussion, with a minimum of direction or control being exhibited in order to allow research participant(s) to freely express themselves. This strategy is most often used to collect subjective and spontaneous data from a research participant(s) or to uncover their attitude towards, or opinion on, a subject under

investigation. Questions for non-directive interviews therefore, are seldom developed in advance of the interview, but are usually developed during the course of the interview in response to research participant(s) comments. With a *focused or semi-structured interview* the interviewer undertakes prior research into the views or perspectives held by the research participant(s) in relation to the subject under investigation. This prior research allows the interviewer to develop questions or guidelines to structure an interview, which although not 'set in concrete' provide a focus (Cohen & Manion, 1994). A *focused or semi-structured interview* allows the interviewer to probe deep into the research participant's attitudes or opinions on specific aspects of the subject under investigation, in order to uncover that which was not disclosed from initial research undertaken prior to interview.

Interviews are heavily reliant upon social and interpersonal interactions occurring between the interviewer and interviewee (research participant). Interviewers therefore, "must be at pains to conduct the interview carefully and sensitively" and create an environment where the research participant(s) trusts the interviewer to the point that they "feel secure to talk freely" (Cohen, Manion & Morrison, 2002, p.279). Ethical considerations need to be clarified with research participants before an interview commences (Cohen, et al, 2002). These considerations include: gaining informed consent, guarantees of confidentiality, and consequence as a result of the interview such as what counts as data and what will remain as 'off the record' information, making transcripts/interview data available to research participants to alter or retract from further consideration. Another consideration a researcher needs to take into account includes how obtrusive their recording technique will be to gathering data. While the use of audio or video may appear to be uncomplicated techniques to record interview data, their very presence may constrain research participant responses due to suggestions of surveillance and/or interrogation (Cohen, et al, 2002). Use of such techniques therefore needs to be carefully elaborated upon, to ensure that they do not create an environment where the data collected is invalid and/or unreliable.

### 3.3.5 Coding and Categorising Data

A code is used in qualitative research as a means to record the essence of ‘language based’ or ‘visual’ data (Saldana, 2009). Codes are usually comprised of a word or short phrase that symbolise the portion of the data under analysis or that has been analysed. While data is often coded as an analytic strategy, Basit (2003) points out that “coding and analysis are not synonymous ... [rather] coding is a crucial aspect of analysis” (p.145) that provides the instruments to allow researchers to gain deeper understandings about captured data. While coding is important in handling data and allowing interpretations to be generated and refined, grouping data under category labels into those that ‘look alike’ and ‘feel alike’ enables researchers to explore relationships, and draw assumptions on the topic under investigation (Saldana, 2009; Lincoln & Guba, 1985).

Categorising coded data that shares common characteristics provides a means to rise above the reality of data and progress towards thematic, conceptual and/or theoretical understandings (Saldana, 2009). Richards and Morse (2007) explain this when they state “categorising is how we get ‘up’ from the diversity of the data to the shapes of the data” and evolve concepts that explain “higher-level, and more abstract constructs” (p.133). Being able to advance rich interpretive meanings or theories from categorised data enables researchers to “predict patterns of what may be observed and what may happen in similar present and future context” (Saldana, 2009, p.13) by projecting from the ‘particular’ to the ‘general’.

The Indicators of Progression matrices for the components of Technological Practice (Compton & Harwood, 2010b) and Technological Knowledge (Compton & Compton, 2010b) strands of technology in the NZC (Ministry of Education, 2007) provided the framework to enable data to be analysed, coded and categorised so that relationships could be explored to answer the sub questions:

1. What curriculum levels for *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation* do students exhibit in Cycle One?
2. What evidence of reasoning and decision making can be identified from Cycle One student data?

3. What impact did interventions in Cycles Two and Three have on student achievement in *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation*?
4. What impact did interventions in Cycles Two and Three have on student decision making when undertaking technological practice?
5. What is the relationship between student achievement in *technological modelling*, and their achievement in *brief development*, *planning for practice*, and *outcome development and evaluation*?
6. What is the relationship between student achievement in *technological modelling*, and their reasoning and decision making when undertaking technological practice?

Examples of the indicators for Indicators of Progression matrices for the components of Technological Practice: *brief development*, *planning for practice*, *outcome development and evaluation*; and *technological modelling* are presented and category labels explained in Section 3.3.6.

### **3.3.6 Indicators and Category Labels for Components of Technological Practice**

The indicators from the Indicators of Progression for the Technological Practice strand (Compton & Harwood, 2010b) were used to determine the curriculum level understandings students demonstrated for the components: *brief development*, *planning for practice*, and *outcome development and evaluation* – see Appendix D for a copy of the *Indicators of Progression for Technological Practice*. Each of the eight curriculum levels was given two sub-category labels (e.g. BD 1p; BD 1a). The letters BD referring to *brief development*; P4P - *planning for practice*; and ODE - *outcome development and evaluation*. The number referring to the curriculum level (Levels 1-8), and letter ‘p’ referred to a *partial* competency (i.e. a student that demonstrated *some* of the competencies expressed by the indicators for a level), and the letter ‘a’ referring to students who demonstrated *all* of the indicators at that level. Where students presented *no understanding* of a component, they were categorised as pre-Level 1 – demonstrating below Level 1

understandings. Examples of category labels in use that include illustrations of how student data were coded and categorised are presented in Tables 2, 3 and 4.

Table 2: Examples of Category Labels: brief development

LEVEL	INDICATOR <sup>34</sup>	Example of Student Data	Coding
Level 3	<p>Students can:</p> <ul style="list-style-type: none"> <li>describe the physical and functional nature of the outcome they are going to produce and explain how the outcome will have the ability to address the need or opportunity</li> <li>describe attributes for the outcome and identify those which are key for the development and evaluation of an outcome.</li> </ul>	<p><i>Develop a product for tourist to hang on the wall that captures memories of ..... that can be transported throughout the world.</i></p> <p><u>Attributes</u> - product needs to:</p> <ul style="list-style-type: none"> <li>Be original</li> <li>Portable and safe too travel</li> <li>Weight: not to heavy</li> <li>Aesthetics: memory easily identifiable.</li> </ul> <p>(extract Student 8B: Cycle 1)</p>	BD 3p
		<p><i>Brother living down in ..... – design something to remind him of ..... and our family.</i></p> <p><u>Attributes</u> - product must:</p> <ul style="list-style-type: none"> <li>Look nice and be original</li> <li>Celebrate mums travels to Holland by using kept Dutch coins and collected antique coins</li> <li>Last forever with no easily broken parts</li> <li>Fit into budget</li> <li>Take no longer than 3 weeks to make</li> <li>Be able to be worn.</li> </ul> <p>(extract Student 5B: Cycle 1)</p>	BD 3a
Level 5	<p>Students can:</p> <ul style="list-style-type: none"> <li>identify a need or opportunity from the given context and issue</li> <li>establish a conceptual statement that justifies the nature of the outcome and why such an outcome should be developed</li> <li>establish the specifications for an outcome based on the nature of the outcome required to address the need or opportunity, and informed by key stakeholder considerations</li> <li>communicate specifications that allow an outcome to be evaluated as fit for purpose.</li> </ul>	<p>The student used three key <u>stakeholders to test design ideas</u> including potential attributes and those being considered as key, initial brief and developing specifications. <u>Evidence of stakeholder feedback</u> being considered in developing brief.</p> <p><i>To develop an age appropriate quality garment for my younger sister (aged 6) to wear to my 16<sup>th</sup> birthday dinner at .... in .....</i></p> <p><u>Specifications</u></p> <ul style="list-style-type: none"> <li>Suitable for spring weather temperatures approx 20°C</li> <li>Age and occasion appropriate – age 6, winery, formal</li> <li>Comfortable and lose to move in, but fitting</li> <li>Crease resistant and durable – worn more than once</li> <li>Total cost under \$50.00</li> <li>Cotton fabric, not itchy or hash against skin</li> </ul> <p>(extracts from Student 7A: Cycle 2)</p>	BD 5p

<sup>34</sup> The indicators for *Brief Development* shown in Table 1 are those published by the New Zealand Ministry of Education (Compton & Harwood, 2010b). For an introduction to these see Chapter Two, Section 2.2.3.

Chapter 3  
Methodology and Research Methods

LEVEL	INDICATOR	Example of Student Data – cont.	Coding
Level 5 <i>cont.</i>	<p>Students can:</p> <ul style="list-style-type: none"> <li>• identify a need or opportunity from the given context and issue</li> <li>• establish a conceptual statement that justifies the nature of the outcome and why such an outcome should be developed</li> <li>• establish the specifications for an outcome based on the nature of the outcome required to address the need or opportunity, and informed by key stakeholder considerations</li> <li>• communicate specifications that allow an outcome to be evaluated as fit for purpose.</li> </ul>	<p>The student used two key stakeholders to test design ideas including potential attributes and those being considered as key, initial brief, <u>conceptual design ideas including material choice</u> and developing specifications. Stakeholder feedback being considered in developing brief.</p> <p><i>Context: garments and accessories often have to serve more than one purpose. Develop and implement a one-off solution with a dual personality.</i></p> <p><i>Conceptual Statement: To design and construct an outfit which can be worn as two different styles on two different occasions. Occasion One as a bridesmaid at my eldest sister's wedding and Occasion Two at the New Years Day (Horse) Races.</i></p> <p><i>Specifications - the outfit</i></p> <p><i>Function:</i></p> <ul style="list-style-type: none"> <li>– Must have two ways that it can be worn</li> <li>– Suitable for &lt;place name&gt; weather in August and January – temp range 7-28°C</li> <li>– Appropriate for indoor and outdoor wearing ..... include layers that can be added or taken off as required</li> <li>– Made from .....</li> </ul> <p><i>Aesthetics:</i></p> <ul style="list-style-type: none"> <li>– Be appropriate and fit in with two formal occasions – beachy wear for wedding/horse racing for New Years Day</li> <li>– Be a good fit which flatters my size 8 pear shaped figure ....</li> <li>– Include accessories which can be added/removed that change the aesthetic appearance of the outfit</li> </ul> <p><i>(extracts from Student 5A: Cycle 2)</i></p>	BD 5a
Level 7	<p>Students can:</p> <ul style="list-style-type: none"> <li>• explore the context to select an issue</li> <li>• identify a need or opportunity relevant to their selected issue</li> <li>• establish a conceptual statement that justifies the nature of the outcome and why such an outcome should be developed with reference to the issue it is addressing</li> </ul>	<p>The student <u>explored possible clients to establish a need</u> and developed a conceptual statement in consultation with key stakeholders (shop owner, identified customers of shop).</p> <p><i>Develop and construct a unique one-off solution for my sisters to wear at a piano recital at the end of the term. The recital will be performed in an auditorium at &lt;name&gt;. The garment needs to be formal and provide warmth due to minimal movement during recital.</i></p>	BD 7p



Chapter 3  
Methodology and Research Methods

LEVEL	INDICATOR	Example of Student Data – cont.	Coding
Level 7 <i>cont.</i>	<ul style="list-style-type: none"> <li>• establish the specifications for an outcome using stakeholder feedback, and based on the nature of the outcome required to address the need or opportunity, consideration of the environment in which the outcome will be situated, and resources available</li> <li>• communicate specifications that allow an outcome to be evaluated as fit for purpose</li> <li>• justify the specifications in terms of stakeholder feedback, and the nature of the outcome required to address the need or opportunity, consideration of the environment in which the outcome will be situated, and resources available.</li> </ul>	<p>In consultation with client (sister), mother and piano teacher, and through undertaking exploration of the environment (act of playing piano, location of recital) <u>identified desirable attributes tested</u> and developed in to <u>measurable specifications</u>.</p> <p><u>Specifications</u></p> <p><i>Aesthetics: the outfit needs to be formal with a contemporary look – incorporate straight lines, be fitting.....</i></p> <p><i>Function: the outfit needs fit my sister (size 10 with masculine figure), allow free movement of the arms, be comfortable to wear when seated in temperatures of 20-22<sup>o</sup>C , use non creasing fabrics that are easy care and machine washable.....</i></p> <p style="text-align: right;"><i>(extracts from Student 8A: Cycle 3)</i></p>	BD 7p <i>cont.</i>
		<p>The student <u>explored the context and selected an issue and an opportunity</u>.</p> <p><i>The current clothes worn by shop assistants at &lt;name of shop&gt; do not reflect the image portrayed by the name of the shop or the garments it sells. Opportunity to design an outfit based on a 1930 collection to be worn by shop attendants in &lt;named shop&gt; that is in keeping with the shops image.</i></p> <p>Developed a conceptual statement in consultation with key stakeholders (shop owner, identified customers of shop).</p> <p><i>Construct an outfit for &lt;shop name&gt; in consultation with &lt;shop manager&gt; for staff to wear while work.ing The outfit needs to be in keeping with the image of the shop and be based on a1930’s hunting/country theme. It needs to make a statement about the quality of the merchandise sold in the shop.</i></p> <p>In consultation with stakeholders desirable attributes were identified, tested and developed in to measurable specifications.</p> <p><u>Specifications</u></p> <p><i>Standard of fit – the overall aesthetics of the garment needs to fit a variety of women’s body shapes, individual tailoring to be undertake to tailor it to individual wearers.</i></p> <p><i>Materials used in outfit - need to be comfortable to wear in temperatures between 18-24<sup>o</sup>C, be easily care/machine washable and maintain their appearance Fabrics selected are: waist coat -merino wool, shorts - linen, shirt – linen .....</i></p> <p style="text-align: right;"><i>(extracts from Student 6A: Cycle 3)</i></p>	BD 7a



Table 3: Examples of Category Labels: planning for practice

LEVEL	INDICATOR <sup>35</sup>	Example of Student Data	Coding
Level 1	Students can: <ul style="list-style-type: none"> <li>identify what they will do next</li> <li>identify the particular materials, components and/or software they might use.</li> </ul>	<u>Planning</u> <ul style="list-style-type: none"> <li>Talk to stakeholders</li> <li>Make key decisions</li> <li>Read through initial brief</li> <li>Select my fabric .....</li> </ul> (extract Student 2A: Cycle 1)	P4P 1p
		<u>Planning</u> <ul style="list-style-type: none"> <li>Talk to stakeholders – Mrs ....., Mum ....</li> <li>Organise to get magazines to look for design ideas</li> <li>Get Burda pattern 2480 .....</li> </ul> (extract Student 3A: Cycle 1)	P4P 1a
Level 3	Students can: <ul style="list-style-type: none"> <li>identify key stages, and resources required, and record when each stage will need to be completed to make sure an outcome is completed</li> <li>explain progress to date in terms of meeting key stages and use of resources, and discuss implications for what they need to do next.</li> </ul>	The student <u>recorded on a Gantt Chart stages for her practice including start and expected completion date</u> to undertake each stage. Notes were written in a box at the bottom of pages in student’s portfolio of evidence of having undertaken technological practice indicating resources used. <u>No evidence presented</u> of considering ‘what to do next’. (extract Student 5A: Cycle 1)	P4P 3p
		The student <u>recorded on a Gantt Chart stages for her practice including start and expected completion date</u> to undertake each stage. Notes were written in a box at the bottom of pages in student’s portfolio of evidence of having undertaken technological practice. These notes explained what she had completed, resources she had used and what she would do next. Headings used were: <i>What I have achieved</i> <i>Resources used</i> <i>What I need to do next.</i> (extract Student 4A: Cycle 1)	P4P 3a
Level 5	Students can: <ul style="list-style-type: none"> <li>analyse own and others use of planning tools to inform the selection of tools best suited for their use to plan and monitor progress and record key decisions</li> <li>use planning tools to identify and record key stages, and manage time</li> </ul>	The student <u>analysed two technologist’s planning practices and identified the tools</u> they used and what they did with them. She selected a Gantt Chart to <u>record identified key stages for her practices and time required</u> to undertake each stage. <u>Planning decisions</u> during practice were recorded on a template with headings: <i>Key decisions made</i> <i>What I plan to do next</i> <i>Resources used/people considered.</i> (extracts from Student 2A: Cycle 3)	P4P 5p

<sup>35</sup> The indicators for *Planning for Practice* shown in Table 2 are those published by the New Zealand Ministry of Education (Compton and Harwood, 2010). For an introduction to these see Chapter Two, Section 2.2.3.

	<p>and resources (including stakeholder interactions) to ensure completion of an outcome</p> <ul style="list-style-type: none"> <li>• use planning tools to record key planning decisions regarding the management of time, resources and stakeholder interactions.</li> </ul>	<p>The student analysed two technologist’s <u>planning practices</u> and identified the tools they used and <u>what they did with them</u>. She used a Gantt Chart to record identified key stages for her practices and time required to undertake each stage.</p> <p><u>Reflections on planning</u> recorded</p> <p><i>I felt that my planning throughout the last unit was not adequate. I did not ...</i></p> <p><u>Planning intentions</u> for practice were recorded on a template with headings:</p> <p><i>Tasks to complete – e.g. review Zambesi fashion video to identify key planning stages</i> <i>Resources - Zambesi video.</i></p> <p><u>Planning decisions</u> recorded on a template with headings</p> <p><i>Decisions from previous stage</i> <i>Key decisions were made; why</i> <i>Planning for this stage</i> <i>People I have contacted</i> <i>Predicted time taken/actual time taken</i> <i>Resources.</i></p> <p><i>(extracts from Student 8A: Cycle 2)</i></p>	P4P 5a
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Table 4: Examples of Category Labels: outcome development and evaluation

LEVEL	INDICATOR <sup>36</sup>	Example of Student Data	Coding
Level 3	<p>Students can:</p> <ul style="list-style-type: none"> <li>• describe potential outcomes, through drawing, models and/or verbally</li> <li>• evaluate potential outcomes in terms of identified attributes to select the outcome to produce</li> <li>• produce an outcome in keeping with the brief</li> <li>• evaluate the final outcome in terms of how successfully it addresses the brief.</li> </ul>	<p>Student used <u>images sourced from magazines and internet, and drawing with notes that described potential designs</u> e.g.</p> <p><i>Towel that folds into a drawstring bag with straps – can be brightly coloured, soft.</i> <i>Fitted towel with hood and hole for head – soft, is able to get wet...</i></p> <p>Stakeholder feedback used to evaluate design ideas/concepts. Evaluation <u>however not against stated attributes</u>.</p> <p>Outcome produced and evaluated by student and stakeholders – <u>evaluation not against the brief</u>.</p> <p><i>(extracts from Student 5A: Cycle 1)</i></p>	ODE 2p
		<p>Student used images sourced from magazines and internet, and drawing with <u>notes that described design features</u> e.g.</p> <p><i>Overalls a good design idea but could be a factor when &lt;name of child&gt; wants to go to the toilet</i> <i>Elastic topped pants great for easy access</i> <i>v-neck top – good for putting on taking off.</i> <i>Fitted towel with hood and hole for head –</i></p>	ODE 2a

<sup>36</sup> The indicators for *Outcome Development and Evaluation* shown in Table 3 are those published by the New Zealand Ministry of Education (Compton and Harwood, 2010). For an introduction to these see Chapter Two, Section 2.2.3.

Chapter 3  
Methodology and Research Methods

		<p><i>soft, is able to get wet...</i></p> <p>Questions focused on identified <u>attributes</u> used to <u>gather stakeholder feedback in order to evaluate design ideas/concepts.</u></p> <p>Outcome produced and <u>evaluated by student and stakeholders against the brief.</u></p> <p><i>(extracts from Student 2A: Cycle 1)</i></p>	
Level 3	<p>Students can:</p> <ul style="list-style-type: none"> <li>• describe design ideas (either through drawing, models and/or verbally) for potential outcomes</li> <li>• evaluate design ideas in terms of key attributes to develop a conceptual design for the outcome</li> <li>• select materials/components, based on their performance properties, for use in the production of the outcome</li> <li>• produce an outcome that addresses the brief</li> <li>• evaluate the final outcome against the key attributes to determine how well it met the need or opportunity.</li> </ul>	<p>Student made a collage of images sourced from magazines and internet, and drawing with <u>notes that described design features</u> e.g.</p> <p><i>Change colour to pink; neckline vertical with thick stripes ...</i></p> <p>Evaluated design ideas against brief attributes to develop a range conceptual designs. Attributes focused on included: <i>shape, colour, neck style, warmth.</i></p> <p>Selected a commercial pattern to suit the style of the final design concept to be used for the child's garment. Materials selected for use in the garment – <u>no consideration of their material properties.</u></p> <p>Childs garment produced using commercial pattern – sizes adjusted to suit the child.</p> <p>Final outcome tested on the child and evaluated against the brief attributes.</p> <p><i>extracts from Student 7A: Cycle 1)</i></p>	ODE 3p
Level 5	<p>Students can:</p> <ul style="list-style-type: none"> <li>• generate design ideas that are informed by research and analysis of existing outcomes</li> <li>• undertake functional modelling to develop design ideas into a conceptual design that addresses the specifications</li> <li>• evaluate suitability of materials/components, based on their performance properties, to select those appropriate for use in the production of a feasible outcome</li> <li>• produce and trial a prototype of the outcome</li> </ul>	<p>Student <u>analysed images of existing garments and accessories</u> found in magazines and on the internet, using <u>notes to describe design features</u> e.g.</p> <p><i>Shape of dress looks flattering – well fitted, fitting body curves. Lace material at the hem adds more detail.</i></p> <p><i>Waist gathering helps flair the skirt ...</i></p> <p><u>Developed design ideas into concept designs.</u></p> <p><u>Functional modelling used</u> included testing design ideas with stakeholders; mock-ups to test material loss when pleating. Stakeholder feedback gather using a questionnaire however <u>questions not aligned to identified attributes/specifications,</u> rather it focused on seeking stakeholder likes/dislikes.</p> <p>Material selection <u>justified against known material performance properties.</u></p> <p>Prototype produced, trialled and <u>evaluated as 'fit for purpose' by student and key stakeholder against the brief.</u></p> <p><i>(extracts from Student 5A: Cycle 2)</i></p>	ODE 5p

Chapter 3  
Methodology and Research Methods

LEVEL	INDICATOR	Example of Student Data – cont.	Coding
Level 5 <i>cont.</i>	<ul style="list-style-type: none"> <li>• evaluate the fitness for purpose of the final outcome against the specifications.</li> </ul>	<p>Student analysed images of existing garments found in magazines and on the internet, using <u>notes to describe design features</u> e.g.</p> <p><i>Gathering at waist to accentuate the waist, using silk makes the dress fall/flow, use of a belt to change shape of dress and lower waistline onto hip ....</i></p> <p>Developed design ideas into concept designs use of <u>notes to describe design features</u>.</p> <p>Functional modelling used included testing design ideas with stakeholders; mock-ups to test material fit (toile) and adapt pattern pieces. Stakeholder feedback <u>aligned to identified attributes/brief specifications</u>.</p> <p><u>Evaluated a range of materials</u> against known material performance properties to select those suitable for use.</p> <p>Prototype produced, and trialled and evaluated as ‘fit for purpose’ by student and key stakeholder against the brief.</p> <p style="text-align: right;"><i>(extracts from Student 2A: Cycle 2)</i></p>	ODE 5a
Level 7	<p>Students can:</p> <ul style="list-style-type: none"> <li>• generate design ideas that are informed by research and critical analysis of existing outcomes</li> <li>• develop design ideas for outcomes that are justified as feasible with evidence gained through functional modelling</li> <li>• critically analyse evaluative practices used when functional modelling to inform own functional modelling</li> <li>• undertake functional modelling to evaluate design ideas and develop and test a conceptual design to provide evidence of the proposed outcome’s ability to be fit for purpose</li> <li>• evaluate suitability of materials/components, based on their performance properties,</li> </ul>	<p><u>Student critically analysed</u> a range of existing solutions (period wedding dresses) e.g.</p> <p><i>Use of boned corset to draw in and stabilise waist ; separate bodice and skirt – very tight fitting bodice used to hide waist band of skirt and flair over hips to create length</i></p> <p>.....</p> <p>Developed design ideas into concept designs use of <u>functional modelling</u> (stakeholder feedback, mock-ups, toile’s) with <u>notes that described design features</u> e.g.</p> <p><i>The thinnest part was fitting too far down therefore stopping it from sitting properly because she is shorter than the average person.</i></p> <p><i>I need to adjust the bottom flare as it is not sitting right – will mock it up again to check adjustments...</i></p> <p><u>Evaluated a range of materials against known material performance properties</u> to select those suitable for use for specific parts of the garment – bodice, skirt.</p> <p>Prototype produced, and trialled and evaluated as ‘fit for purpose’ by student and key stakeholder <u>against the brief</u>. <u>Use of photographs with notes and stakeholder feedback that justified suitability of outfit in use (being worn at the wedding)</u> as being fit for purpose.</p> <p style="text-align: right;"><i>(extracts from Student 4C: Cycle 3)</i></p>	ODE 7p

Chapter 3  
Methodology and Research Methods

LEVEL	INDICATOR	Example of Student Data – cont.	Coding
	<ul style="list-style-type: none"> <li>• to select those appropriate for use in the production of a feasible outcome</li> <li>• undertake prototyping to gain specific evidence of an outcomes fitness for purpose and use this to justify any decisions to refine, modify and/or accept the outcome as final</li> <li>• use stakeholder feedback and an understanding of the physical and social requirements of where the outcome will be situated to support and justify key design decisions and evaluations of fitness for purpose.</li> </ul>	<p>Student critically analysed a range of existing solutions e.g. when analysing a shirt the student comments included:</p> <p><i>Seams over-locked to ensure neat finishing and sharp edges. Point of difference for shirt is the contrasting materials used in the cuff that can be pinned back with a button. Heavy use of stiffening to produce sharp crisp edges .....</i></p> <p>Developed design ideas into concept designs use of functional modelling (stakeholder feedback, mock-ups, toile’s) and <u>notes that justified design features as being feasible</u> e.g.</p> <p><i>All seams over-locked to ensure neat finishing; increase height and width of waist band to ensure comfort when sitting .....</i></p> <p><u>Notes also critically analysed practices used and questioned</u> it they were giving the information sought e.g.</p> <p><i>This mock-up didn’t show me if the material for the shorts would drape as we needed it to do – I will need to do another mock-up in the linen that I am thinking we will use.</i></p> <p>Evaluated a range of materials against known material performance properties to select those suitable for use.</p> <p>Prototype produced, trialled and evaluated as ‘fit for purpose’ by student and key stakeholder against the brief. Use of photographs to demonstrate suitability of outfit in use (standing, sitting, playing the piano) and comments recorded that justify the outcome as being fit for purpose e.g.</p> <p><i>Standing and walking around the shorts allowed for stretch between legs., also seams allowed materials to stretch comfortably when moving into position and sitting on piano stool - there was no restriction evident on legs that stopped the piano pedals being used or uncomfortableness when extending use the full length of the key board....</i></p> <p style="text-align: right;"><i>(extracts from Student 8A: Cycle 3)</i></p>	ODE 7a

The indicators from the Indicators of Progression for the component *technological modelling* (Compton & Compton, 2010b) from the Technological Knowledge strand of technology in the NZC (Ministry of Education, 2007), were used to determine the curriculum level understandings students demonstrated for *technological modelling* – see Appendix E: *Indicators of Progression for Technological Modelling*. Again each of the eight curriculum levels was given two

sub-category labels (e.g. TM 1p; TM 1a). The letters TM referring to *technological modelling*; the number to the curriculum level (Levels 1-8); letter ‘p’ referred to a *partial* understanding; the letter ‘a’ referring to students who demonstrated *all* of the indicators at that level. Where students presented *no understanding* of *technological modelling* they were categorised at pre-Level 1 – demonstrating below Level 1 understandings. Examples of category labels in use that include illustrations of how student data were coded and categorised are presented in Tables 5.

*Table 5: Examples of Category Labels: technological modelling*

LEVEL	INDICATOR <sup>37</sup>	Example of Student Data	Coding
Level 1	Students can: <ul style="list-style-type: none"> <li>• describe what a functional model is</li> <li>• identify the purpose of functional modelling</li> <li>• describe what a prototype is</li> <li>• identify the purpose of prototyping.</li> </ul>	A functional model “lets you know what to do.” A prototype “is a final product made once that can be used to make many.” The purpose of a prototype is “to see if it works.” <p style="text-align: center;">(extracts from Student 2B: Cycle 1)</p>	TM 1p
Level 3	Students can: <ul style="list-style-type: none"> <li>• discuss examples to identify the different forms of functional models that were used to gather specific information about the suitability of design concepts</li> <li>• identify the benefits and limitations of functional modelling undertaken in particular examples</li> <li>• describe examples of particular prototypes that did not meet specifications</li> </ul>	<u>Different forms of functional models</u> “I have used mock-ups, stakeholder questionnaires, showing stakeholders my design concept drawings.” <u>Benefits of functional modelling</u> “when I showed my design ideas to my stakeholders they knew what I was thinking of making and gave me feedback.” <u>Limitations of functional modelling</u> “I don’t know, I guess sometimes they (stakeholders) don’t understand what the drawings (design ideas) are about.” <u>Examples of prototypes</u> “my finished outfit, when I first made it I needed to alter the size of the top as it didn’t fit me... I put in two seams in the back that pulled it in without altering the shape too much, it then fitted really well.” <p style="text-align: center;">(extracts from Student 2B: Cycle 2)</p>	TM 3p

<sup>37</sup> The indicators for *technological modelling* shown in Table 5 are those published by Compton and Compton (2010b). For an introduction to these see Chapter Two, Section 2.4.3.



Chapter 3  
Methodology and Research Methods

LEVEL	INDICATOR	Example of Student Data	Coding
<p>Level 3 <i>cont.</i></p>	<ul style="list-style-type: none"> <li>explain why functional modelling and prototyping are both needed to support decision making when developing an outcome.</li> </ul>	<p><u>Different forms of functional models</u></p> <p><i>“I have used toile’s, surveys, concept screening with stakeholders, getting feedback from experts as to it they think what I am thinking of doing will work, mock-ups of parts of my outfit in calico to check pattern sizes .....</i>”</p> <p><u>Benefits of functional modelling</u></p> <p><i>“it lets you test your ideas with stakeholders to see if they like what you are thinking of making, gives you confidence that what you are going to make will work – when I made a mock up of the bodice of my dress to see if the pattern size was okay and if not where it needed to be changed.”</i></p> <p><u>Limitations of functional modelling</u></p> <p><i>“It takes time to do but it is worth it – you need to know what you are trying to test before making the model otherwise you can waste a lot of time. When I made a mock up of my bodice out of calico it only told me is the sizing was right – I couldn’t tell if the material I was thinking of using would sit right so I had made another one (mock-up) out of a similar material to what I finally selected..”</i></p> <p><i>“If your stakeholders don’t really know what it is you are wanting to make then they can give you a lot of feedback that is not much good to you.”</i></p> <p><u>Examples of prototypes</u></p> <p><i>“it’s the final thing that is made – my outfit”</i>  <i>Prototypes that do not meet specifications do not meet the brief specifications when they are evaluated .One-off products that fail don’t meet brief specifications, for example a leaky home. My last project that was a memory catcher failed – when two of my stakeholders evaluated my product (prototype) they couldn’t tell what the memory was that it had captured without me telling them.”</i></p> <p><u>Why functional modelling and prototyping are both needed</u></p> <p><i>“they test different things - a functional models test your ideas when you are designing the outfit (product) and the prototype test the final design of your outfit being worn. The functional model tells you if you need to make design changes and the prototype tell you if your solution is fit for purpose.”</i></p> <p style="text-align: right;"><i>(extracts from Student 5B: Cycle 2)</i></p>	<p>TM 3a</p>



Chapter 3  
Methodology and Research Methods

LEVEL	INDICATOR	Example of Student Data	Coding
Level 5	Students can: <ul style="list-style-type: none"> <li>• identify examples of functional and practical reasoning within design decision making</li> <li>• explain how evidence gained from functional modelling was used to justify design decisions</li> <li>• identify examples of functional and practical reasoning underpinning prototype evaluations and the establishment of maintenance requirements</li> <li>• explain how evidence gained from prototyping was used to justify outcome evaluation as fit for purpose or in need of further development.</li> </ul>	<p>Student explained where she had used functional and practical reasoning in her technological practice to inform design decisions and examples of how this reasoning had influenced her designs e.g. <i>“I had to think about my friends and if they would like to be with me when I was wearing it; if my parents would want me to be wearing this outfit (practical reasoning); what materials I would make it out of and the properties they had, how I would test the materials to see if they did what I wanted them to do (functional reasoning).”</i></p> <p>Tested materials using functional models to determine if they were suitable (e.g. <i>rub and wear tests, colour fastness</i>) and what the maintenance requirement might be if used.</p> <p>Consulted with her mother to see if she liked the final outcome (prototype), if it functioned as expected – <i>fitted my body shape, kept me dry and warm, tested the prototype in a shower [water] to see how long it took for the water to soak through.</i></p> <p style="text-align: right;"><i>(extracts from Student 6B: Cycle 3)</i></p>	TM 5p
		<p>Student explained where she had used functional and practical reasoning in her technological practice to inform design decisions and examples of how this reasoning had influenced her designs e.g. <i>“who I needed to consult with to make my camou (camouflage) outfit for hunting, need to find out safety laws in case they need to be considered in my design so they are fit for purpose (practical reasoning); what colour camou material I should use to hunt deer and pigs, find out how long the material will last when used in a hunting environment , how can I design it so that it is useful for hunting but I still look like a female (functional reasoning)”</i>.</p> <p>Used modelling to test design ideas e.g. <i>“I used functional models to test the durability of materials (rub test) and to see if they would wash clean when soaked with blood; I got my father and his hunting mates (stakeholders) to evaluate my design ideas to see if they thought it would be fit for purpose.”</i></p> <p><i>“To test her prototype the student did a field test on a hunting trip. She used feedback from father and his hunting mates to test and justify its fitness for purpose against brief specifications. Tests done included determining if the outfit allowed for quiet movement in the bush, could be easily seen by humans but not deer and pigs, that it was not too hot to wear.</i></p> <p style="text-align: right;"><i>(extracts from Student 2B: Cycle 3)</i></p>	TM 5a

Chapter 3  
Methodology and Research Methods

LEVEL	INDICATOR	Example of Student Data	Coding
Level 7	<p>Students can:</p> <ul style="list-style-type: none"> <li>• discuss examples to illustrate why the status of evidence gained from technological modelling might change across contexts</li> <li>• explain why different people accept different types of evidence as valid and how this impacts on technological modelling</li> <li>• explain the role of technological modelling in ascertaining and mitigating risk</li> <li>• describe examples to illustrate the strengths and weaknesses of technological modelling for risk mitigation.</li> </ul>	<p>Student explained she had to use different technological models to test design ideas with her client (music teacher) than she did her teacher as they had different understandings about how things go together and will look. <i>“For my client I had to make physical mockups so that they could see my idea in 3D that I was thinking of doing. My teacher got what I was talking about from my sketch and an explanation – she had more knowledge of how to construct a garment (jacket) than my client.”</i></p> <p><u>Role of technological modelling in ascertaining and mitigating risk</u> – <i>“I used technological modelling to test my designs with my client ... so that she knew what I was going to making her ... she was paying for the materials so I didn’t want to get the jacket wrong, it not fit her ... not allow her to move freely when playing the piano.”</i></p> <p><u>Strengths and weaknesses of technological modelling</u> <i>“When I tested the size of the jacket using a calico toile [mock-up] the size was okay but we couldn’t tell if it allowed enough movement to play the piano ... so I made up a second mock-up using a similar material to the one I was thinking we would use in the final jacket ... it had the same properties ... this allowed me to test movement as well as fit.”</i></p> <p><i>“If I had just used drawings to explain my design ideas to my client while she said she liked them, I really didn’t know if she really understood them, that is why I used the physical models because she could touch and feel them.”</i></p> <p style="text-align: right;"><i>(extracts from Student 1A: Cycle 3)</i></p>	TM 7p

To enable reasoning underpinning decision making within student’s Technological Practice to be analysed, category labels informed by the literature presented in Chapter 2, Section 2.5, were identified. These are presented in Section 3.3.7.

### 3.3.7 Indicators and Category Labels for evaluating student reasoning and decision making within technological practice

To allow data to be analysed, and the research sub questions focused on student decision making to be answered, category labels were identified to describe the *types of reasoning underpinning decision making*. The labels signify potential links between student reasoning and decisions about alternatives, and what they do next when undertaking technological practice.

Literature presented in Chapter 2, Section 2.5.1 discussed *intuitive, analytical, routine* and *non-routine decisions*, and *single* and *multiple criteria* as different ways to categorise decision making. These however were not considered useful as category labels for analysing student decision making within technological practice for this study for the following reasons:

Determining if student's tacit knowledge was used *intuitively* or *analysed* was identified as problematic. The reason for this was that tacit knowledge when made explicit, either through student/researcher interview and/or by asking students to produce observable evidence of their decision making, necessitates a degree of student analysis. Accepting non-evidenced alternatives as being a result of *intuitive* or *analytical* decision making was also identified as being unreliable, due to the difficulty of the researcher determining if a student had undertaken 'in the head' unobservable analysis, when making a decision or if the alternative intuitively materialised.

Identifying if student decision making was *routine* (i.e. addressing problems they encounter frequently) or *non-routine* (i.e. addressing unfamiliar problems with unknown consequences) was also recognised as problematic when categorising student decision making in technological practice. Variations in students' past experiences, and the nature of teacher instruction provided, were seen to have a strong influence on the mix of *routine* or *non-routine* decision making students used when undertaking technological practice. Using these category labels, of *routine* or *non-routine* decision making was therefore determined to be unreliable.

Student participants undertaking technological practice to address decision problems that contained *single-criteria* were identified as unlikely, given that most of the problems they seek to solve when developing technological outcomes contain multiple dimensions. This is due to the nature of the technological practice students undertake and the focus placed on *technological modelling* at Level 6 (Ministry of Education, 2007). Rather, more common are decision problems that contain *multiple criteria*, which require relationships between criteria to be considered in order to determine the ‘best’ or most ‘favoured’ alternative. For example, decision problems such as: deciding which material provided the functional and/or aesthetic qualities sought in a technological outcome; determining who the key and wider community stakeholders are to an outcome being developed; and/or determining those technological outcome specifications considered imperative and those better categorised as desirable, all require students to consider multiple criteria. An initial analysis of student data showed that when students encountered a *single criteria* decision problem requiring consideration, when undertaking technological practice and modelling, their decision making centred on determining a yes/no or go/no-go type alternative. For example: deciding to consult with stakeholders or not; identifying if a material can be sourced or not; if a material fits within the cost allowance or not. Such decision problems however, when viewed within students’ overall technological practice, were connected to broader decisions problems and therefore were subsets of *multi criteria* decision problems. For example: deciding to consult with stakeholders or not is also linked to criteria such as: what needs to be determined through consultation; and who are the ‘best’ stakeholders to consult with at this stage of the technological practice/modelling; and what is the ‘best’ way to communicate information to stakeholder to gain their informed feedback.

The category labels identified from the Literature, reviewed in Chapter 2, Section 2.5, selected to analyse student reasoning underpinning their decision making were grouped into those focused on the *Nature of Reasoning* and those aligned to the *Nature of the Practice Sought*:

*Nature of Reasoning*

- practical reasoning
- functional reasoning
- integrated reasoning

*Nature of the Practice Sought*

- completed outcome
- best outcome
- best technological practice.

These labels are explained in Table 6.

*Table 6: Category of reasoning and drivers underpinning decision making*

<i>Category</i>	<i>Description</i>	<i>Category Label</i>
<i>Nature of Reasoning</i>		
No evidence of reasoning	<b>No</b> evidence of practical and/or functional reasoning	NE
Practical Reasoning	Reasoning <b>centred</b> on selecting a <b>socially accepted</b> technological outcome; consideration of moral, cultural and/or ethical concerns apparent (Compton, 2010; Compton & France, 2006b).	P
Functional Reasoning	Reasoning <b>centred</b> on determining the ‘ <b>technical feasibility</b> ’ of a technological outcome (Chakrabarti & Bligh, 2001; Compton, 2010).	F
Outcome focused Integrated Reasoning	Reasoning that provides justification that <b>a developed technological outcome</b> is socially acceptable and technical feasible.	IRo
Practice focused Integrated Reasoning	Reasoning that provides justification that <b>both the practice undertaken to develop a technological outcome and the outcome itself</b> are socially acceptable and technical feasible.	IRp
<i>Nature of the Practice Sought</i>		
Completed outcome	Decision making focused on <b>completing</b> an alternative, i.e. a technological outcome which is <b>good enough</b> (e.g. it works).	CO
Best outcome	Decision making focused on finding and implementing the ‘ <b>best</b> ’ alternative, i.e. a technological outcome that is ‘ <b>fit for purpose</b> ’.	BO
Best technological practice	Decision making focused on ensuring that <b>both the technological practice</b> undertaken and <b>selected alternative</b> is the ‘ <b>best</b> ’ available. Resulting technological outcome is considered to be ‘ <b>fit for purpose</b> ’ in its broadest sense.	BT

To enable differences within categories to be distinguished for *practical* and *functional reasoning*, two sub category descriptions were identified – *superficial (s)* and *robust (r)*. Student evidence classified as *superficial* mentioned reasoning in passing but did not use it as a ‘driver’ for future decision making. Evidence classified as *robust* consistently reasoned out alternatives to determine their contribution in future decision making. For example:

SUPERFICIAL (s)	Reasoning mentioned in passing that did not become a ‘driver’ of future decision making.  <i>Determining a material’s suitability for use in a product based on its colour, when colour was not later identified as priority specification for a technological outcome.</i>
ROBUST (r)	Consistently reasoned out alternatives to determine their contribution in future decision making.  <i>Considered, throughout their technological practice, a range of potential materials including their properties, to determine their overall suitability for use in a technological outcome.</i>

As a consequence of these sub category descriptions, category labels were defined by two letters. For example: ‘Ps’ denotes student data where their *practical reasoning* was predominantly *superficial*; ‘Pr’ indicates student data where *practical reasoning* was predominantly *robust*.

The categories of *completed outcome*, *best outcome* and *best technological practice* required no further categorisation as they, by their very nature, depict a hierarchy of decision making from one category to the next. For example, students either presented data that predominantly focused decision making on a *completed outcome* or their decision making focused on realising a *best outcome*. The student(s) whose decision making focused on realising a *best outcome* displayed more advanced decision making than those whose aim was to *complete an outcome*.

The identified category labels for *reasoning* and *decision making* will be used in Chapters Four and Five to analyse research student participant data to answer the research sub questions:

2. What evidence of reasoning and decision making can be identified from Cycle One student data?

4. What impact did interventions in Cycles Two and Three have on student decision making when undertaking technological practice?
6. What is the relationship between student achievement in *technological modelling*, and their reasoning and decision making when undertaking technological practice?

Measures were undertaken to ensure that these and the other research questions could be empirically measured, using data that was coded against the category labels, and that the findings drawn were both valid and reliable.

### 3.3.8 Validity and reliability

Validity and reliability are a central concern for all researchers. For those involved in social research they become ‘ideals’ that should be strived for, rather than an ‘absolute’, due to constructs in social theory which “are often ambiguous, diffuse, and not directly observable” (Neuman, 1997, p.138).

#### *Validity*

Validity refers to the “extent to which a (research) question or variable accurately reflects the concept the researcher is actually looking for” (Davidson & Tolich, 1999, p.32). The intent of research is to move the research question(s) from being an abstract theoretical concept to something which is concrete and can be empirically measured. Validity therefore asks whether the empirical measures used to capture the data, realistically measure the concept or research question(s) being asked (Davidson & Tolich, 1999).

There are several kinds of validity (Cohen, Manion & Morrison, 2002; Davidson & Tolich, 1999; Neuman, 1997). Davidson and Tolich (1999) grouped them into two categories, *empirical validation* and *theoretical* (or conceptual) *validity*, as they believe they each reflect different aspects of the same fundamental question.

*Empirical validation* refers to the extent to which there is some evidence to support the choice of measure (a research instrument). Examples of empirical validity include: *criterion* validity, where the data collected from a research instrument are compared to a known standard ‘criterion’ that has previously been



shown to accurately indicate a particular concept; *concurrent* validity, where the data obtained from a research instrument are supported by existing evidence; or *predictive* validity, where data collected from an instrument are compared to the findings that appear later.

*Theoretical* (or conceptual) *validity* – is used where data collected by a research instrument(s) (e.g. a questionnaire) complies with the theoretical principles of a discipline, but where there is no pre-existing evidence to support its use as a research measure. Examples of theoretical validity include: *face validity*, where an instrument appears to measure what is expected (valid on the ‘face of it’); *content validity*, where validity is achieved through coverage of all possible aspects of the research topic; *construct validity*, is achieved when the research instrument is repeatedly used and behaves in a consistent way; *convergent validity*, where multiple measures of the same thing operate in the same way and *divergent validity*, where opposing constructs are negatively associated (Davidson & Tolich, 1999).

The question of research validity can also be both external and internal (Davidson & Tolich, 1999). *External* validity refers to the generalisability of research findings beyond the site in which the research was conducted while *internal* validity is focused on the extent to which findings accurately describe the reality of the site.

### ***Reliability***

Reliability is concerned with the research instrument(s) ability to produce consistent data. For a research instrument to be considered reliable it must provide the same information (data) from a similar group of respondents each time it is used, irrespective of when or where it is used or who the researcher is that uses it (Davidson & Tolich, 1999; Neuman, 1997). There are three principal types of reliability: *stability*, *representative* and *equivalence* reliability.

*Stability* reliability refers to trustworthiness across time, i.e. the research instrument used today will illicit similar data (the same information) if used one month or a year later with the same or a similar group of respondents.

*Representative* reliability refers to trustworthiness across different groups of respondents, i.e. the extent to which the research instrument will provide consistent data when used across different people.

*Equivalence* reliability applies when different research instruments and/or indicators within a research instrument (e.g. different questions within a questionnaire) are used to measure the same concept. To be considered reliable, all instruments or indicators that focus on measuring the same concept need to provide similar data (Davidson & Tolich, 1999; Neuman, 1997).

While research instruments may be considered to be reliable, this does not guarantee their validity (Neuman, 1997). For example even though an instrument consistently produces the same or similar data over multiple measures, the instrument itself may not be valid, due to the data it produces not matching a known definition(s) of the construct under investigation. An example of this is a set of scales used to weigh an item - while multiple measures of the same item on the scales provide a consistent reading, the scales themselves if not calibrated to known weights, will not provide readings that accurately describe the weight in terms of an agreed measure. For a research instrument to be considered to have validity it must first be shown to be reliable (Davidson & Tolich, 1999; Neuman, 1997). Known definitions (i.e. agreed measures) that describe expected student competencies at each curriculum level in technology in the *NZC* (Ministry of Education, 2007) have been identified through classroom research. These definitions, labelled 'indicators', presented in the Indicators of Progression matrices, support teachers to: interpret the levelled Achievement Objectives for each strand of technology in the *NZC* (Ministry of Education, 2007); provide guidance on how to support student learning at each level; and explain what students should know or be able to do at each level.

The indicators from the Indicators of Progression matrices for the components of Technological Practice: *brief development*, *planning for practice*, and *outcome development and evaluation*; along with the component *technological modelling* from the Technological Knowledge strand of technology in the *NZC* (Ministry of Education, 2007) will be used to code and analyse data, and categorise it in order to identify the level of student competency displayed in this research. These indicators, developed from research undertaken inside New Zealand classrooms,

have been demonstrated to be reliable and valid in enabling student understandings to be determined against the technology in the *NZC* (Ministry of Education, 2007) achievement objectives, levels 1-8 (Compton & Compton, 2010b; Compton & France, 2006b; Compton & Harwood, 2010b, 2005, 2004b).

*Measures taken to ensure the trustworthiness of this research*

To address validity and ensure that the research questions could be empirically measured, data were collected over three research cycles using the same measures (research instruments). These instruments included student portfolio evidence of their undertaking technological practice and applying concepts underpinning technological modelling, student questionnaire, and student interview.

Data were analysed against the components *brief development, planning for practice, outcome development and evaluation* and *technological modelling*, and matched against the known indicators (criterion validity) described in the Indicators of Progression for Technological Practice (Compton & Harwood, 2010b) and *technological modelling* (Compton & Compton, 2010b). To ensure that the research instruments used to collect data for student reasoning types and decision making was empirically valid (Davidson & Tolich, 1999) data were compared to findings in later cycles (predictive validity).

To support consistent qualitative judgements on data to be made, the coding of data from earlier cycles were compared to those identified in a subsequent cycle. This enabled the reliability of the data gathering instruments to be tested (Davidson & Tolich, 1999), and also allowed a check to be taken to ensure that similar data were coded consistently. Findings from each research cycle were also shared with participant teachers to ensure that conclusions drawn accurately described the reality of student understandings and decision making. The sharing of research findings with participant teachers provided a measure of the internal validity of the research sites (Davidson & Tolich, 1999), and enabled the teachers and researcher to co-construct the next teaching activity, focused on enhancing students understanding of concepts underpinning *technological modelling*.

## 3.4 Research Participants

This research was centred in three New Zealand schools. It drew on data gathered over two-years from senior secondary students in year 12 in 2008 and year 13 in 2009 (aged 17-18 years). The schools chosen to participate in this research were state co-educational schools that offered technology programmes in their senior school. These schools were geographically located in large urban centres in the North and South Island of New Zealand. Each school offered technology courses that used technology achievement standards and provided students' access to the *National Certificate of Educational Achievement* (NCEA) at Levels 2 and 3.

### 3.4.1 Profile of schools and participants

#### School A

School A was a state co-educational secondary school that provided education for year nine to thirteen students. This school was decile 9<sup>38</sup> and had a roll of approximately 990 students. Technology was taught as a compulsory subject in years 9 -10 and as an option in years 11-13. In year 9 students were provided opportunity to study three 10 week options of technology and at year 10 two half year modules of technology. At senior secondary, years 11, 12 and 13, students were able to undertake a full year of study in technology. Ten students identified themselves as willing to be research participants from School A. In 2008, all of these students were in year 12 and female, coded A1 – A9.

During the research, students participated in a technology programme which had a material focus<sup>39</sup> predominantly centred on the use of textiles and garment construction.

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<sup>38</sup> *Decile* ratings are a numerical measure used in New Zealand to quantify aspects of a school's community. It is calculated using different data sets on a school community. This includes data on household income, the occupation of parents and the educational qualifications of parents. Using these as a measure, schools are divided into ten groups (ten deciles), with each group containing ten percent of the schools in New Zealand with *Decile One* schools scoring the lowest and *Decile Ten* the highest.

<sup>39</sup> In a *materials* focused technology programme students design and develop technological outcomes (products and/or systems) that resolve a need or opportunity using a variety of materials (e.g. wood, metal, plastics, textiles, glass, ceramics).

### **School B**

School B was a state co-educational secondary school that provided education for year nine to thirteen students. This school was decile 6 and had a roll of approximately 1440 students. In year 9 and 10 technology was taught in options as a part of compulsory curriculum and as an optional subject in years 11-13. In year 9 students were provided opportunity to study two 16 week options of technology, in year 10 two 20 week options, and in years 11, 12 and 13 a full year of study in technology. Fourteen students identified themselves as willing to be research participants from School B. In 2008, all of these students were in year 12, coded B1 – B13. With the exception of B5 who was male all other students were female.

During the research, students participated in a technology programme that had a material focus which was predominantly centred on textiles.

### **School C**

School C was a state integrated co-educational catholic secondary school that provided education for year nine to thirteen students. This school was decile 8 and had a roll of approximately 896 students. Technology was taught as a compulsory subject in years 9 -10 and as an option in years 11-13. In years 9-10 students were provided opportunity to study two 10 week options of technology at each year level and in years 11, 12 and 13 a full year of study. Five students identified themselves as willing to be research participants from School C. In 2008, all of these students were in year 12 and male, coded C1 – C5.

During the research, students participated in a technology programme that had a material focus which was predominantly centred on the creation of wood and metal products.

### **3.5 Ethics**

Ethical issues for educational and social researchers are focused on concerns, dilemmas, and conflicts that arise over the proper way to conduct their research. As such, “ethics define what it is or is not legitimate to do, or what moral research procedure is (Neuman, 1997, p.443). For the researcher, there are no ethical absolutes as most issues involve trade-offs between competing values and depend on the specific situation that is under investigation. In saying this however, there are a set of agreed upon principles that govern the way that educational and social researchers should follow when engaged in research. These principles are primarily focused on ensuring that a balance remains between “the pursuit of scientific knowledge and the rights of research participants or of others in society” (Neuman, 1997, p.443). Researchers therefore, need to ensure that the rights of research participants to be protected from potential harm, including loss of privacy, dignity, self-esteem and/or democratic freedom is weighed up against the potential benefits that can be gained from the research. These benefits may include advancing society’s understandings about social life, improvements for future decision making and/or helping the research participant(s) themselves. Strategies used in educational and social research to minimise potential harm to research participants include: seeking of informed consent; the use of pseudonyms and the right of participants to withdraw from the research at any stage during its undertaking (Berg, 2004; Punch, 2000).

In keeping with the guiding principles outlined above, with the desire to minimise potential harm to research participants whilst maximising opportunity to pursue scientific knowledge, the Board of Trustees [BoT] of schools who had potential teacher and student research participants, were first approached and invited to participate in the research. A letter was sent to the Chairperson of the BoT that explained this research project, and the voluntary nature of having students from their school participate in the study along with a consent form for them to sign. The researcher was available to answer any questions that the chairperson had concerning the nature of the research project and their schools potential involvement. For further explanation see Appendix A.

Once invited school BoT and teacher participants agreed to take part in the research, potential student participants were sent an information letter and a consent form. The letter explained the research project and the voluntary nature of their participation. The letter also outlined how confidentiality and anonymity would be addressed and the likely benefits to themselves and the wider technology education community, which their participation in the research project offered. For further explanation see Appendix A. This letter to student research participants also made them aware that they had the opportunity to ask questions of the researcher and informed them of their right to withdraw from the study at any stage prior to any data gathered being analysed.

This research was undertaken within the guidelines and procedures as outlined by the Massey University Human Ethics Committee for Ethical Conduct for Research, Teaching and Evaluations involving Human Participants. Ethical approval was gained from this committee for this research to be undertaken.

### **3.6 Summary**

Chapter Three discussed the differences between the research paradigms *positivist* and *interpretivist* and the quasi-interpretivist approach of a *critical social science* paradigm. It also discussed the differences between using *qualitative* and *quantitative* approaches for accessing data. The chapter discussed different methodological approaches to research and explained why emancipative action research, underpinned by an interpretivist paradigm, was selected as appropriate for this study. It contended that such a design allowed the researcher (and teachers) to observe both the “cause and effect” (Cohen, Manion & Morrison, 2002, p.181) of the teaching strategies (interventions) used to develop student concepts of technological modelling, and the impact these had on enhancing their understandings. It also argued that this adopted research design had empathy for research conducted in educational classroom settings, due to its focus on critical reflection and its support of an open design attitude to data analysis. This attitude allowed subsequent cycle interventions to be informed from everything learnt prior to that point, with the intent on improving the understandings and practice of all participants (researcher, teachers and students) in the research site.



This chapter also contended that semi-structured interviews, along with questionnaires, that used open-ended questions, allowed the researcher within an interpretivist paradigm, to gain an insight into the concepts of *technological modelling* held by the student research participants.

The category labels and Indicators of Progression for the components of Technological Practice and *technological modelling* were presented, along with examples of how student data were coded against the indicators for these components.

A discussion then followed to explain the selection of the labels used to analyse student reasoning and decision making, and enable the sub research questions to be answered. Concepts of validity and reliability of research data, and measures undertaken to ensure the trustworthiness of this research were then presented, along with an explanation of how data were gathered from student research participants.

The Chapter concluded by presenting a discussion on ethics and how it was applied within this research. It also presented an outline of the research participants and the opportunities that they have had to experience technology education at secondary school.

In Chapter Four, the findings from the Cycle One data are presented and discussed.

# CHAPTER FOUR

## RESEARCH FINDINGS: CYCLE ONE

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### 4.1 Overview of the Chapter

This chapter focuses on the Cycle One data (baseline data) that were collected to determine the influence of the Technological Knowledge component *technological modelling* on students' ability to make informed decisions, as they undertake technological practice. Data were gathered from 27 students in Year 11 in the three schools that participated in the project. This chapter presents initial findings that support the answering of the research question:

What is the relationship between student conceptual understanding of technological modelling, their achievement in the components of Technological Practice, and their reasoning and decision making when undertaking technological practice?

Section 4.2 presents the individual findings of the 27 students who participated in the research. Section 4.3 presents the findings on a school by school basis. Section 4.4 discusses combined school data and Section 4.5 provides a summary of the findings and answers the sub research questions:

1. What curriculum levels for *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation* do students exhibit in Cycle One?
2. What evidence of reasoning and decision making can be identified from Cycle One student data?

It also presents an initial discussion that focuses on sub research questions:

5. What is the relationship between student achievement in *technological modelling*, and their achievement in *brief development, planning for practice*, and *outcome development and evaluation*?
6. What is the relationship between student achievement in *technological modelling*, and their reasoning and decision making when undertaking technological practice?

## 4.2 Findings by Individual Students

Initial data were collated in Cycle One from the structured questionnaire (see Appendix B: Student Questionnaire) to identify student conceptual understandings of the technology curriculum component *technological modelling*; and from portfolio evidence of their undertaking *brief development, planning for practice*, and *outcome development and evaluation*. A qualitative analysis, to identify the ‘core’ concepts and achievements exhibited by students in these four components of technology, was undertaken using the Indicators of Progression and category labels introduced in Chapter Three, Section 3.3.5. Based on the researcher’s interpretation of ‘core’ concepts understood and achievements exhibited by students, data were coded against these category labels for each component as presented in Chapter Three, Section 3.3.6.

Student portfolio evidence was also analysed to identify the nature of student’s reasoning and decision making when undertaking technological practice. These data were categorised against the category labels for *reasoning* and *decision making* within technological practice presented in Chapter Three, Section 3.3.7.

The results of these analyses are presented in Section 4.2.1 and 4.2.2.

### 4.2.1 Cycle One: Students' achievement in technological modelling, and the components of Technological Practice

Data collected from the 27 student research participants, analysed qualitatively and coded against the category labels for *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation* are presented in Table 7. These students, according to the NZC (Ministry of Education, 2007, p.45), would typically be expected to be working at Levels 5 for each component.

For illustrative examples of how data were coded and categorised, see Chapter 3 Section 3.3.6.

*Table 7: Individual student level of achievement in technological modelling; brief development, planning for practice, and outcome development and evaluation*

Students N=27	Technological modelling	Brief development	Planning for practice	Outcome development and evaluation
1A	2p	4p	2a	2a
2A	1p	4a	1p	2a
3A	1p	4p	2a	2p
4A	pre 1	4a	3a	2a
5A	1p	5p	3p	2p
6A	pre 1	5p	3a	3p
7A	pre 1	5p	3a	3p
8A	pre 1	5p	3a	3p
9A	1P	4a	2a	2a
1B	1p	4a	1a	2p
2B	1p	4a	1a	1a
3B	2p	3a	1a	2p
4B	1p	4a	1a	1p
5B	1p	3a	2p	2a
6B	2p	3a	1a	2p
7B	pre 1	3p	2p	3p
8B	1p	3p	1a	2p
9B	1p	3p	1p	3p
10B	1p	3p	1a	2p
11B	2p	4a	1a	3p
12B	1p	4p	1a	3p
13B	1p	4p	1a	3p
1C	2p	4a	2p	4a
2C	1p	4a	2p	2p
3C	pre 1	2p	2p	2p
4C	1p	2p	2a	2p
5C	1p	2p	2p	1a

Student achievement in *technological modelling* was consistently low across all students, with six students (22.2%) showing pre-level 1 understanding, sixteen students (59.3%) demonstrating partial Level 1 understanding and five students (18.5%) partial Level 2 understanding.

The majority of students (92.6%) demonstrated a higher level of achievement in *brief development* than in the other components. Student achievement in: *brief development* ranged from partial Level 2 (2p) achievement, to partial Level 5 (5p); *planning for practice* from partial Level 1 (1p) achievement, to demonstrating all indicators at Level 3 (3a); and *outcome development and evaluation* from partial Level 1 (1p) achievement, to all indicators at Level 4 (4a).

Further discussion on findings of student concepts in *technological modelling*, and their achievement in *brief development*, *planning for practice* and *outcome development and evaluation* in Cycle One will be presented in Section 4.3.

#### **4.2.2 Cycle One: Students' reasoning and decision making**

Coded findings for the 27 student research participants representing the nature of their reasoning and drivers that underpinned their *decision making* when undertaking technological practice is presented in Table 8. For an explanation of the codes used to record student data for decision making and reasoning see: Chapter Three, Section 3.3.7.

Table 8: Individual student reasoning and decision making

Students N=27	Reasoning									Decision Making		
	Practical Reasoning			Functional Reasoning			Integrated Reasoning			Completed Outcome	Best Outcome	Best Technological Practice
	NE	Ps	Pr	NE	Fs	Fr	NE	IRo	IRp	CO	BO	BT
1A		X			X			X			X	
2A		X			X			X			X	
3A		X			X			X			X	
4A		X			X			X			X	
5A		X			X			X			X	
6A		X			X			X			X	
7A		X			X			X			X	
8A		X			X			X		X		
9A		X			X		X			X		
1B		X			X			X			X	
2B		X			X		X			X		
3B		X			X		X			X		
4B	X			X			X			X		
5B		X		X			X			X		
6B	X				X		X			X		
7B	X			X			X			X		
8B	X			X			X			X		
9B		X		X			X			X		
10B		X			X		X			X		
11B		X			X		X			X		
12B	X			X			X			X		
13B	X				X		X			X		
1C	X					X	X				X	
2C	X			X			X			X		
3C	X			X			X			X		
4C	X			X			X			X		
5C	X			X			X			X		

In Cycle One, 11 students (40.7%) presented no evidence of undertaking *practical reasoning* and 10 students (37.0%) no evidence of *functional reasoning*. Eight students (29.6%) demonstrated no evidence of undertaking *practical reasoning* and *functional reasoning*.

Sixteen students (59.3%) presented evidence of undertaking *superficial practical reasoning* and 16 students (59.3%) demonstrated evidence of *superficial functional reasoning*. Of these students, 14 students (87.5%) presented both *superficial practical reasoning* and *superficial functional reasoning*. The remaining two

students (12.5%) presented no evidence of undertaking *practical reasoning*. No students demonstrated *robust practical reasoning* and one student (3.7%) *robust functional reasoning*.

Eighteen students (66.7%) demonstrated no evidence of undertaking any form of *integrated reasoning (outcome or practice focused)* and nine students (33.3%) *outcome focused integrated reasoning*.

Eighteen students (66.7%) focused their decision making on *completing an outcome* and nine students (33.3%) on a *best outcome*. No students presented evidence of focusing their decision making on *best technological practice*. Further discussion on findings of student reasoning and decision making will be provided following further analysis of Cycle One data - see Section 4.3.5.

### **4.3 Cycle One Findings**

Due to the number of student research participants in individual schools being low (ranging from n=5 to n=13) the data were analysed as one aggregated set, where n = 27, to enable trends (or not) emerging from the research data to be identified.

The findings from the combined student responses to the *technological modelling* questionnaire and evidence of *brief development, planning for practice, and outcome development and evaluation* when students develop a technological outcome in response to a given issue are presented in Sections 4.3.1, 4.3.2, 4.3.3 and 4.3.4.

#### **4.3.1 Cycle One: Student Level of Achievement in technological modelling**

The level of student achievement coded against the category labels for *technological modelling* is presented in Table 9.

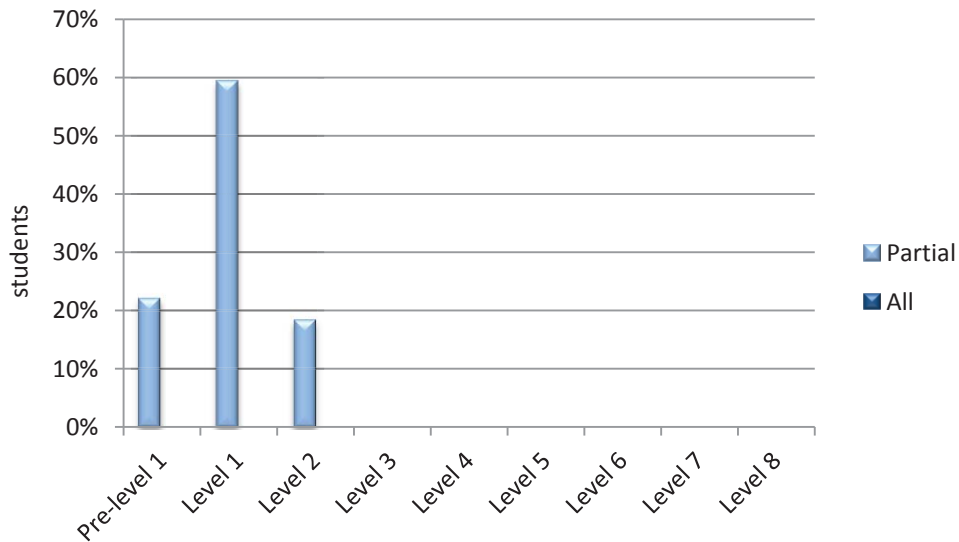


Table 9: Combined student participant data Cycle One: technological modelling

<i>n</i> = 27	Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Technological Modelling (Cycle 1)	6	16		5							Level of achievement expected for year group						
%	22.2	59.3		18.5													

Students held concepts of *technological modelling* that ranged from pre-level 1 understanding to partial Level 2 understandings. Six students (22.2%) were categorised at pre-level 1, sixteen students (59.3%) demonstrated partial Level 1 conceptual understandings and five students (18.5%) demonstrated partial understanding at Level 2. The majority of students (81.5%) demonstrated Level 1 understanding. Figure 4 presents these data graphically.

Figure 4: Combined student participant data Cycle One: student understandings of technological modelling



### 4.3.2 Cycle One: Student Level of Achievement in brief development

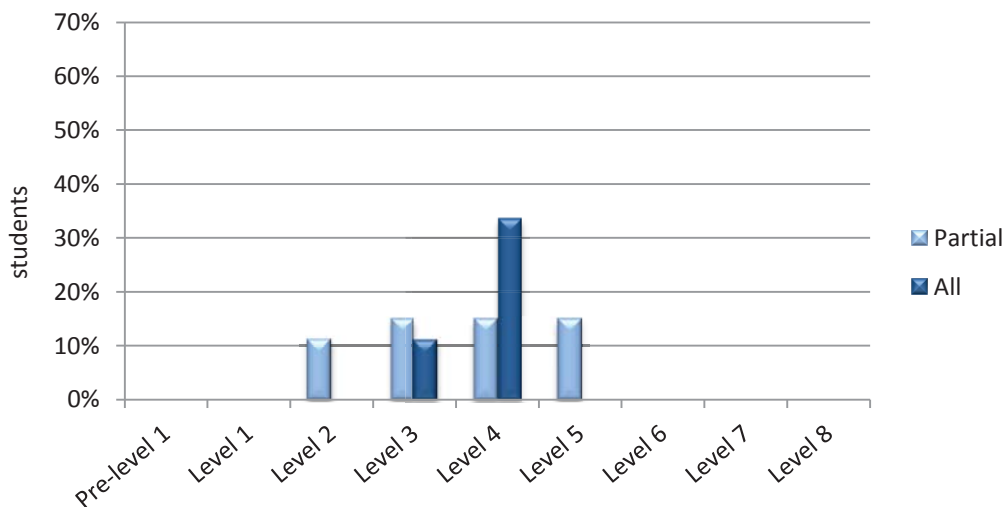
The level of student achievement coded against the category labels for *brief development* is presented in Table 10.

Table 10: Combined student participant data Cycle One: brief development

n = 27	Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Brief Development (Cycle 1)				3		4	3	4	9	4	Level of achievement expected for year group						
%				11.1		14.8	11.1	14.8	33.4	14.8							

Student achievement of *brief development* ranged from partial Level 2 achievement to partial achievement at Level 5. Three students (11.1%) demonstrated partial Level 2 achievement, four students (14.8%) partial Level 3 achievement and three students (11.1%) demonstrated achievement of all indicators at Level 3. Four students (14.8%) demonstrated partial Level 4 achievement, nine students (33.4%) achievement of all indicators at Level 4 and four students (14.8%) partial Level 5 achievement. No single curriculum level showed a majority of student achievement - the highest percentage of students (48.2%) demonstrating Level 4 achievement. Figure 5 presents these data graphically.

Figure 5: Combined student participant data Cycle One: student achievement in brief development



### 4.3.3 Cycle One: Student Level of Achievement in planning for practice

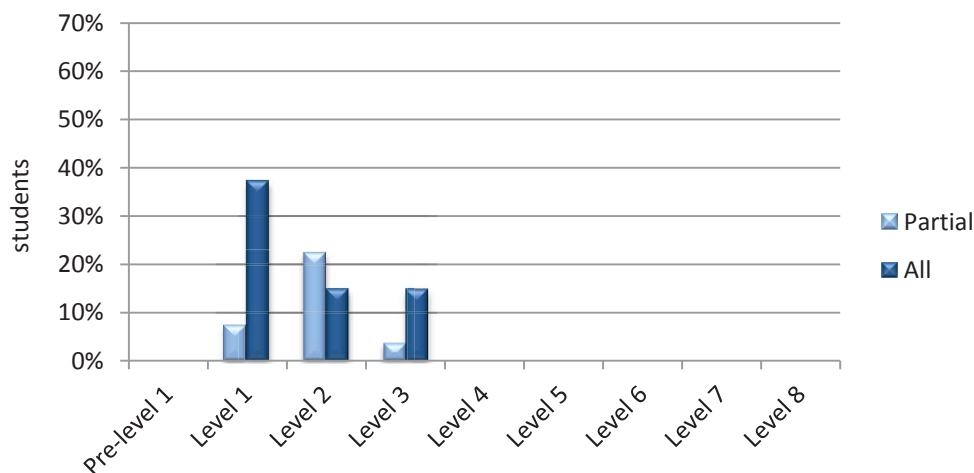
The level of student achievement coded against the category labels for *planning for practice* is presented in Table 11.

Table 11: Combined student participant data Cycle One: planning for practice

<i>n</i> = 27	Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Planning for Practice (Cycle 1)		2	10	6	4	1	4				Level of achievement expected for year group						
%		7.4	37.0	22.2	14.8	3.7	14.8										

Student achievement of *planning for practice* ranged from partial Level 1 achievement, to achievement of all indicators at Level 3. Two students (7.4%) demonstrated partial Level 1 achievement, ten students (37.0%) achievement of all indicators at Level 1 and six students (22.2%) partial Level 2 achievement. Four students (14.8%) demonstrated achievement of all indicators at Level 2, one student (3.7%) demonstrated partial Level 3 achievement and four students (14.8%) achievement of all indicators at Level 3. No single curriculum level showed a majority of student achievement - the highest percentage of students (44.4%) demonstrating Level 1 achievement. Figure 6 presents these data graphically.

Figure 6: Combined student participant data Cycle One: student achievement in planning for practice



### 4.3.4 Cycle One: Student Level of Achievement in outcome development and evaluation

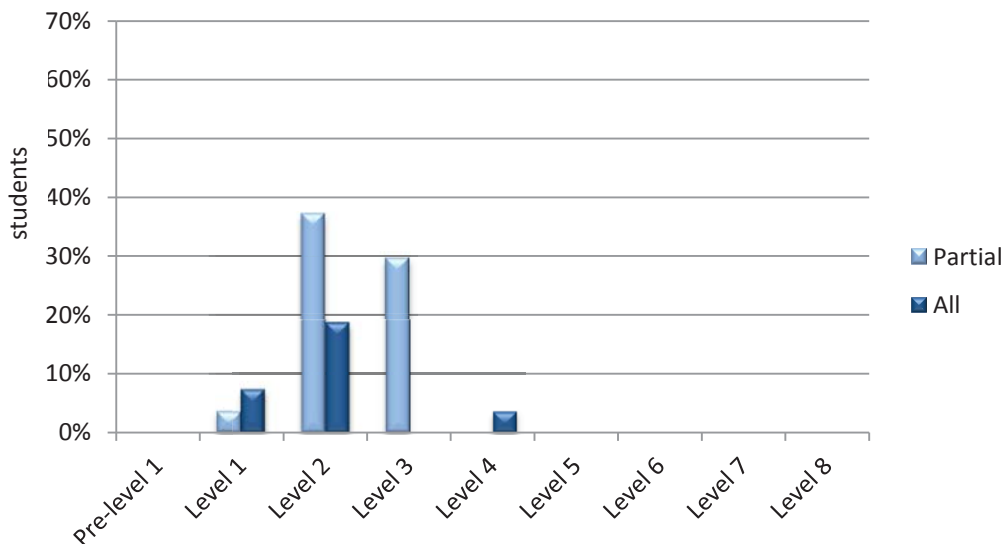
The level of student achievement coded against the category labels for *outcome development and evaluation* is presented in Table 12.

Table 12: Combined student participant data Cycle One: outcome development and evaluation

<i>n</i> = 27	Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Outcome Development and Evaluation (Cycle 1)		1	2	10	5	8			1		Level of achievement expected for year group						
%		3.7	7.4	37.1	18.5	29.6			3.7								

Student achievement of *outcome development and evaluation* ranged from partial Level 1 achievement, to achievement of all indicators at Level 4. One student (3.7%) demonstrated partial Level 1 achievement, two students (7.4%) achievement of all indicators at Level 1 and ten students (37.1%) partial Level 2 achievement. Five students (18.5%) demonstrated achievement of all indicators at Level 2, eight students (29.6%) partial Level 3 achievement and one student (3.7%) achievement of all indicators at Level 4. The majority of student’s (55.6%) demonstrated Level 2 achievement. Figure 7 presents these data graphically.

Figure 7: Combined student participant data Cycle One: student achievement in outcome development and evaluation



The findings representing the nature of student reasoning and drivers that underpinned their decision making when students develop a technological outcome in response to a given issue, are presented in Section 4.3.5.

### 4.3.5 Cycle One: Student Level of Achievement in reasoning and decision making

The combined student participant data coded against the category labels for reasoning and decision making is presented in Table 13.

*Table 13: Combined student participant data Cycle One: reasoning and decision making*

<i>n</i> = 27	Reasoning									Decision Making		
	Practical Reasoning			Functional Reasoning			Integrated Reasoning			Completed Outcome	Best Outcome	Best Technological Practice
	NE	Ps	Pr	NE	Fs	Fr	NE	IRo	IRp	CO	BO	BT
Decision making and reasoning in technological practice (Cycle 1)	11	16		10	16	1	18	9		18	9	
%	40.7	59.3		37.0	59.3	3.7	66.7	33.3		66.7	33.3	

Eleven students (40.7%) presented no evidence of undertaking *practical reasoning* and sixteen students (59.3%) demonstrated *superficial practical reasoning*; ten students (37.0%) presented no evidence of undertaking *functional reasoning* and sixteen students (59.3%) demonstrated *superficial functional reasoning*, and one student (3.7%) *robust functional reasoning*.

Eighteen students (66.7%) presented no evidence of *integrated reasoning* (outcome or practice focused), and nine students (33.3%) presented evidence of *outcome focused integrated reasoning*.

Eighteen students (66.7%) focused their decision making on a *completed outcome* and nine students (33.3%) on realising a *best outcome*. No students focused their decision making on *best technological practice*.

Of the eighteen students (66.7%) who focused their decision making on a *completed outcome*:

- eight students (44.5%) presented no evidence of *practical* and *functional reasoning*
- two students (11.1%) presented *superficial evidence* of *practical reasoning* and no evidence of *functional reasoning*
- two students (11.1%) presented no evidence of *practical reasoning* and evidence of *superficial functional reasoning*
- six students (33.3%) presented evidence of *superficial practical reasoning* and *functional reasoning*. Of these students, three students (50%) presented no evidence of *integrated reasoning* and three (50.0%) *outcome focused integrated reasoning*.

Of the nine students (33.3%) who focused their decision making on a *best outcome*:

- eight students (88.9%) presented *superficial evidence* of *practical reasoning* and *functional reasoning*. All eight of these students (100.0%) also demonstrated *outcome focused integrated reasoning*
- one student (11.1%) presented no evidence of *practical reasoning* and *robust functional reasoning*. This student also presented no evidence of *integrated reasoning*.

The relationship between student participant understandings of *technological modelling* and their understandings of the components of *technology practice* is presented in Section 4.4.

#### **4.4 Relationship between Student Understanding of Technological Modelling and their Achievement in the Components of Technology Practice**

The findings from exploring relationships of combined student participant evidence, of their understanding of *technological modelling* against achievement in the components *brief development*, *planning for practice* and *outcome development and evaluation* when developing a technological outcome are presented in Sections 4.4.1, 4.4.2 and 4.4.3.

#### 4.4.1 Cycle One: Relationship between student understanding of technological modelling and their achievement in undertaking brief development

The findings for Cycle One of combined student participant understandings of *technological modelling*, and their achievement in *brief development*, are presented in Table 14.

Table 14: Cycle One: student understandings of technological modelling and their achievement in undertaking brief development

n =27		Technological Modelling																
		Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Brief development	Pre-level 1																	
	Level 1	p																
		a																
	Level 2	p	1	2														
		a																
	Level 3	p	1	3														
		a		1		2												
	Level 4	p		3		1												
		a	1	6		2												
	Level 5	p	3	1														
		a																
	Level 6	p																
		a																
	Level 7	p																
		a																
	Level 8	p																
		a																

Six students demonstrated a pre-level 1 understanding of *technological modelling*. These students demonstrated achievement in *brief development* that ranged from partial achievement at Level 2, to partial Level 5 achievement.

Sixteen students demonstrated partial Level 1 understanding in *technological modelling*. These students demonstrated achievement in *brief development* that ranged from partial achievement at Level 2, to partial Level 5 achievement.

Five students demonstrated partial Level 2 understandings of *technological modelling*. These students demonstrated achievement in *brief development* that ranged from achievement of all indicators at Level 3, to achievement of all indicators at Level 4.

Student understandings of *technological modelling* and achievement in *brief development* were below the expected curriculum level (Ministry of Education,



2007). Further exploration will be undertaken in Chapter Five, following explicit teaching of concepts underpinning *technological modelling* during Cycles Two and Three.

#### 4.4.2 Cycle One: Relationship between student understanding of technological modelling and their achievement in undertaking planning for practice

The findings for Cycle One, from combined student participant understandings of *technological modelling*, and their achievement in *planning for practice*, are presented in Table 15.

Table 15: Cycle One: student understandings of technological modelling and their achievement in undertaking planning for practice

n =27		Technological Modelling																
		Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Planning for Practice	Pre-level 1																	
	Level 1	p	2															
		a	7		3													
	Level 2	p	2	3	1													
		a	3		1													
	Level 3	p	1															
		a	4															
	Level 4	p																
		a																
	Level 5	p																
		a																
	Level 6	p																
		a																
	Level 7	p																
		a																
	Level 8	p																
		a																

Six students demonstrated a pre-level 1 understanding of *technological modelling*. These students demonstrated achievement in *planning for practice* that ranged from partial achievement at Level 2, to demonstrating achievement of all indicators at Level 3.

Sixteen students demonstrated a partial Level 1 understanding of *technological modelling*. These students demonstrated achievement in *planning for practice* that ranged from achievement at partial Level 1, to partial Level 3 achievement.

Five students demonstrated a partial Level 2 understanding of *technological modelling*. These students demonstrated achievement in *planning for practice* that ranged from achievement of all indicators at Level 1, to achievement of all indicators at Level 2.

Student understandings of *technological modelling* and achievement in *planning for practice* were also below the expected curriculum level (Ministry of Education, 2007). Further exploration will be undertaken in Chapter Five, following explicit teaching of concepts underpinning *technological modelling* during Cycles Two and Three.

#### 4.4.3 Cycle One: Relationship between student understanding of technological modelling and their achievement in undertaking outcome development and evaluation

The findings for Cycle One, from the combined student participant understandings of *technological modelling*, and their achievement in *outcome development and evaluation* are presented in Table 16.

Table 16: Cycle One: student understandings of technological modelling and their achievement in undertaking outcome development and evaluation

n =27		Technological Modelling																
		Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Outcome Development and Evaluation	Pre-level 1																	
	Level 1	p		1														
		a		2														
	Level 2	p	1	7		2												
		a	1	3		1												
	Level 3	p	4	3		1												
		a																
	Level 4	p																
		a				1												
	Level 5	p																
		a																
	Level 6	p																
		a																
	Level 7	p																
		a																
	Level 8	p																
		a																

Six students demonstrated pre-level 1 understanding of *technological modelling*. These students demonstrated achievement in *outcome development and evaluation* that ranged from partial achievement at Level 2, to partial Level 3 achievement.

Sixteen students demonstrated partial Level 1 understanding of *technological modelling*. These students demonstrated achievement in *outcome development and evaluation* that ranged from partial achievement at Level 1, to partial Level 3 achievement.

Five students demonstrated a partial Level 2 understanding of *technological modelling*. These students demonstrated achievement in *outcome development and evaluation* that ranged from partial achievement at Level 2, to achievement of all indicators at Level 4.

Student understanding in *technological modelling* and their achievement of *outcome development and evaluation* were also below the expected curriculum level (Ministry of Education, 2007). Further exploration will be undertaken in Chapter Five, following explicit teaching of concepts underpinning *technological modelling* during Cycles Two and Three.

The relationship between student participant understandings of *technological modelling* and their reasoning and decision making is presented in Section 4.5.

## 4.5 Relationship between Understanding of Technological Modelling and Reasoning and Decision Making

Student participant understanding of *technological modelling* and their *decision making and reasoning* is presented in Table 17.

Table 17: Cycle One: student understandings of technological modelling and their decision making and reasoning

<i>n</i> =27			Technological Modelling																	
			Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a	
Reasoning	Practical Reasoning	NE	2	7		2														
		s	4	9		3														
		r																		
	Functional Reasoning	NE	2	8																
		s	4	8		4														
		r				1														
	No Evidence of Integrated Reasoning		2	12		4														
Outcome focused Integrated Reasoning		4	4		1															
Practice focused Integrated Reasoning																				
Decision making	Completed Outcome		3	12		3														
	Best Outcome		3	4		2														
	Best Technological Practice																			

Six students (22.2%) presented a pre-level 1 achievement of *technological modelling*. Of these:

- two students (33.3%) demonstrated no evidence of *practical reasoning* and four students (66.7%) *superficial practical reasoning*
- two students (33.3%) demonstrated no evidence of *functional reasoning* and four students (66.7%) *superficial functional reasoning*
- two students (33.3%) demonstrated no evidence of *integrated reasoning* and four students (66.7%) demonstrated *outcome focused integrated reasoning*.

Of the six students (22.2%) who presented pre-level 1 achievement in *technological modelling*, three students (50.0%) focused on a *completed outcome* and three students (50.0%) placed an emphasis on completing a *best outcome*.

Sixteen students (59.3%) demonstrated partial Level 1 achievement for *technological modelling*. Of these students:

- seven students (43.7%) demonstrated no evidence of *practical reasoning* and nine students (56.3%) *superficial practical reasoning*
- eight students (50.0%) demonstrated no evidence of *functional reasoning* and eight students (50.0%) *superficial functional reasoning*
- twelve students (75.0%) demonstrated no evidence of *integrated reasoning* and four students (25.0%) demonstrated *outcome focused integrated reasoning*.

Of the sixteen students who demonstrated partial Level 1 achievement in *technological modelling*, twelve students (75.0%) demonstrated evidence focused on a *completed outcome* and four students (25.0%) placed an emphasis on completing a *best outcome*.

Five students (18.5%) demonstrated partial Level 2 achievement for *technological modelling*. Of these students:

- two of these students (40.0%) demonstrated no evidence of *practical reasoning* and three students (60.0%) *superficial practical reasoning*
- four students (80.0%) demonstrated *superficial functional reasoning* and one student (20%) *robust functional reasoning*
- four students (80%) demonstrated no evidence of *integrated reasoning* and one student (20.0%) demonstrated evidence of *outcome focused integrated reasoning*.

Of the five students who demonstrated partial Level 2 achievement in *technological modelling*, three students (60.0%) demonstrated evidence focused on a *completed outcome* and two students (40.0%) placed emphasis on completing a *best outcome*.

There are no obvious trends in Cycle One emerging from data when student conceptual understandings of *technological modelling*, and their *reasoning* and *decision making* are compared. This relationship will be further examined to identify if trends emerge following explicit teaching of concepts underpinning *technological modelling* during Cycles Two and Three. A summary of the findings, with discussion, is presented in Section 4.6.

## 4.6 Summary of Findings

This chapter presented findings from Cycle One data (base line data). These findings contribute to answering the research sub questions:

1. What curriculum levels for *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation* do students exhibit in Cycle One?
2. What evidence of reasoning and decision making can be identified from Cycle One student data?

Findings were presented that also enabled initial discussion on data that contribute to answering sub questions:

5. What is the relationship between student achievement in *technological modelling*, and their achievement in *brief development*, *planning for practice*, and *outcome development and evaluation*?
6. What is the relationship between student achievement in *technological modelling*, and their reasoning and decision making when undertaking technological practice?

Answers to each sub question are presented in the following Sections.

### 4.6.1 In Cycle One: what curriculum levels for *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation* do students exhibit?

The Cycle One data used to analyse student achievement against the Technological Practice components: *brief development*, *planning for practice*, *outcome development and evaluation* came from portfolio evidence of students undertaking technological practice to develop a technological outcome to address an issue. Student held concepts of *technological modelling* were identified in their responses to the structured questionnaire. Student achievement levels identified from these data was as follows:

- *technological modelling* ranged from pre-level 1 to partial understandings at Level 2, with the majority of students (59.3%) presenting Level 1 understandings
- *brief development* ranged from partial achievement at Level 2 to partial achievement at Level 5, with the highest percentage of students (48.2%) demonstrating Level 4 achievement
- *planning for practice* ranged from partial achievement at Level 1 to achievement of all indicators at Level 3, the highest percentage of students (44.4%) demonstrating Level 1 achievement
- *outcome development and evaluation* ranged from partial achievement at Level 1 to achievement of all indicators at Level 4, with the majority of students (55.6%) demonstrating Level 2 achievement.

The levels of achievement presented by students across all three components of Technological Practice were lower than the expected curriculum level attainment for students completing Year 11 (Ministry of Education, 2007). A reason for this may have been that this was the first time each of the components of Technological Practice had been interrogated in isolation. Previous teacher assessment had focused on identifying student learning outcomes against all three components of Technological Practice as they worked together to support students to develop technological outcomes.

The low levels of student conceptual understandings in *technological modelling* presented in Cycle One aligned with findings from previous studies (Compton & France, 2006; Compton, Harwood & Compton, 2007; Compton & Compton, 2009). A reason for low levels of conceptual understandings is that prior to collecting these data, students had received no formal instruction on *technological modelling*. The understandings exhibited by students were therefore likely gained from sources such as informal interactions with teachers and technologists; and their exposure to the general use of the term ‘modelling’ in everyday usage.



#### 4.6.2 In Cycle One: what evidence of reasoning and decision making can be identified from student data?

Evidence of student reasoning and decision making when undertaking technological practice was determined from an analysis of student Cycle One data (see Chapter Four: Section 4.2.2) against the *Nature of Reasoning* and *Nature of Practice Sought* category labels identified from the literature (see Chapter 3: Section 3.3.7). This analysis identified students who demonstrated:

- no evidence of undertaking *practical reasoning* and *functional reasoning* focused their decision making on realising a *completed outcome*
- no evidence of undertaking *practical reasoning*, but evidence of *functional reasoning (superficial or robust)* focused their decision making on realising a *completed outcome*.
- no evidence of undertaking *functional reasoning*, but evidence of *practical reasoning (superficial)* also focused their decision making on realising a *completed outcome*.

The nine students (33.3%) who demonstrated *superficial practical reasoning* and *superficial functional reasoning* undertook *outcome focused integrated reasoning*. Their decision making with the exception of one student (11.1%) was found to focus on determining a '*best*' *outcome*; the one student who did not, focused on a *completed outcome*. Those students (18.5%) who demonstrated *superficial practical reasoning* and *superficial functional reasoning* but then did not undertake any form of *integrated reasoning* (outcome or practice focused) also directed their decision making on a *completed outcome*.

From this initial data (Cycle One) there is some support to suggest that there is a relationship between:

- evidence of *practical reasoning* and *functional reasoning* resulting in a higher likelihood of undertaking *outcome focused integrated reasoning*
- no evidence of *outcome focused integrated reasoning* resulting in a higher likelihood of decision making focused on realising a *completed outcome*
- evidence of *outcome focused integrated reasoning* resulting in a higher likelihood of decision making focused on realising a '*best*' *outcome*.

**4.6.3 In Cycle One: what is the relationship between student achievement in *technological modelling*, and their achievement in *brief development*, *planning for practice*, and *outcome development and evaluation*?**

Cycle One data showed that students who presented a pre-level 1 understanding of *technological modelling* still demonstrated achievement in the components of Technological Practice: *brief development*, *planning for practice*, and *outcome development and evaluation*. Their achievements however, as explained above, were at curriculum levels below those that would be typically expected for students completing Year 11 (Ministry of Education, 2007).

In Cycle One there was:

- no identifiable trend in the data that would signal a relationship between student conceptual understandings of *technological modelling* and their achievement in *brief development*.
- no obvious relationship identified between student conceptual understandings of *technological modelling* and their achievement of *planning for practice*. The evidence indicated that those students demonstrating the highest achievement of practices associated with *planning for practice* displayed the lowest conceptual understandings of *technological modelling*.
- no obvious relationship identified between student conceptual understandings of *technological modelling* and their achievement of *outcome development and evaluation*.

Further exploration into these relationships will be undertaken in Chapter Five following explicit teaching of concepts underpinning technological modelling in Cycles Two and Three.

#### **4.6.4 In Cycle One: what is the relationship between student achievement in technological modelling, and their reasoning and decision making when undertaking technological practice**

Cycle One data showed that there were no obvious trends emerging when initial findings on student decision making (including their reasoning) and conceptual understandings of *technological modelling* were compared. An explanation for this may be the low level of understanding of *technological modelling* students demonstrated in Cycle One. In Cycle One, six students (22.2%) demonstrated an understanding of *technological modelling* 5 levels below that which would be expected of students completing Year 11 (Ministry of Education, 2007); eleven students (59.3%) demonstrated understanding 4 levels below that expected; and five students (18.5%) 3 levels below the expected understanding. These initial findings will be reviewed following interventions focused on raising student achievement in *technological modelling* in Cycles Two and Three (see Chapter 5).

In Chapter Five, the findings from the Cycle Two and Three data are presented and discussed.

# CHAPTER FIVE

## RESEARCH FINDINGS: CYCLE TWO AND THREE

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### 5.1 Overview of the Chapter

The Technological Modelling questionnaire was re-administered to the 27 research participant students, to collect Cycle Two data at the end of their Year 12 school year (2008) and Cycle Three data at the end of their Year 13 school year (2009). These data were gathered during Cycles Two and Three, and followed teachers delivering explicit teaching activities, within technology units, focused on enhancing student understandings of concepts underpinning *technological modelling*. Where ongoing teacher observations and interactions with students, within a Cycle, indicated little change in their conceptual understandings of *technological modelling*, further instructions and/or activities were introduced into the unit(s) to allow maximum opportunity for student understandings to progress. An analysis of learning outcomes, following students' completion of the units, enabled the researcher and participant teachers to identify themes in conceptual understanding about technological modelling, held by students.

This chapter presents findings from Cycles Two and Three. It focuses on establishing answers for the sub questions:

3. What impact did interventions in Cycles Two and Three have on student achievement in *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation*?
4. What impact did interventions in Cycles Two and Three have on student reasoning and decision making when undertaking technological practice?
5. What is the relationship between student achievement in *technological modelling*, and their achievement in *brief development*, *planning for practice*, and *outcome development and evaluation*?

6. What is the relationship between student achievement in *technological modelling*, and their reasoning and decision making when undertaking technological practice?

Section 5.2 provides a brief description of the interventions (activities) used by teachers, focused on enhancing student concepts of *technological modelling* in Cycle Two and Three. Where further instructions and/or activities were introduced into the units, these are also described.

Section 5.3 presents the findings for the 27 students who participated in the research from the Cycle Two and Three data and provides a comparison of these findings with those found in Cycle One.

Section 5.4 uses findings presented in Section 5.3 to answer research sub questions 3-6.

## **5.2 Cycle Two and Three: Interventions Focused on Enhancing Student Concepts of Technological Modelling**

Interventions aimed at enhancing student conceptual understandings of *technological modelling* in Cycles Two and Three are briefly described for each school. These interventions, informed by individual student/school findings and emergent themes from the preceding cycle, were targeted at raising student conceptual understandings of the concepts underpinning *technological modelling*. The interventions, presented to students as planned activity(ies) that incorporated explicit teaching, also supported students to undertake technological practice to resolve an identified problem or opportunity and thereby incorporate, as appropriate, learnt *technological modelling* concepts into the Technological Practice components: *brief development*, *planning for practice* and *outcome development and evaluation*. Where it was identified, during the delivery of the planned activity, that students failed to engage with the *technological modelling* concepts being taught and/or respond positively to them, further interventions were introduced. Although the concepts of *technological modelling* introduced to

students were similar in each school, how teachers chose to teach these varied across schools in response to individual student learning needs, their interests and/or the context of the technology unit(s) presented to students. The interventions applied in each school for Cycle Two and Three are presented in Section 5.2.1.

### 5.2.1 Cycle Two and Three: description of interventions

#### School A

Cycle One findings identified students in School A possessed understandings of concepts underpinning technological modelling ranging from pre-Level 1 - 2p. To address this low level of conceptual understanding the teacher in School A chose, as an intervention in Cycle Two, to enhance student understandings by engaging students in class discussion. Her focus was on getting students to understand the purpose of technological modelling, the different forms of technological modelling, and how reasoning is used when modelling to inform next steps and minimise risk. To do this the teacher introduced students to an Australian *Beyond 2000*<sup>40</sup> television series documentary on the development of the Adidas Predator Soccer Boot. This documentary highlighted how technological modelling (functional models and prototypes) were used to inform the development of the soccer boot, from first concepts through to prototype trialling. Students were asked to identify the different forms of technological modelling used in the soccer boot's development, and discuss how these were used to determine what 'could' and 'should' be developed. Examples of practical and functional reasoning applied in the product's development were identified and discussed along with the differences between functional modelling and prototyping. How technological modelling was used to ascertain and mitigate risk, and how the status of evidence gained from technological modelling can change across contexts, were also discussed.

Informed by findings and emergent themes from Cycle Two, the teacher developed her Cycle Three interventions to augment student understandings on concepts

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<sup>40</sup> Beyond 2000:

<http://colsearch.nfsa.afc.gov.au/nfsa/search/summary/summary.w3p;adv=yes;group=;groupequals=;page=0;parentid=;query=Number%3A138027%20%20Number%3A439840%20%20Number%3A439803%20%20Number%3A665131%20%20Number%3A407066;querytype=;resCount=10>

underpinning *technological modelling*, particularly around different forms of reasoning and their use, how technological modelling supports technologists to minimise risk and the status of evidence obtained from technological modelling. These interventions, drawing on case studies of two technologists practice<sup>41</sup> included a structured activity that required students to identify where technologists had applied practical and functional reasoning to inform their design decisions.

Students were also encouraged to identify how:

- practical and functional reasoning contributed to the overall development of the technologist's technological outcomes
- prototyping had been used to minimise risk, obtain optimal performance and determine maintenance requirements for technological outcomes prior to them being released as a marketable product.

Drawing on examples in the two case studies, the students discussed as a class how the type and status of evidence gained from technological modelling, differed within and across the different case study contexts - corporate uniform and classroom furniture. These discussions were aimed at supporting students to gain an understanding of how the status of evidence obtained from technological modelling can change across contexts. As the students were undertaking their own technological practice the teacher identified from formative assessment, that a number had still not grasped the differences between practical and functional reasoning during the initial Cycle Three intervention. To address this, the teacher held a class discussion where students explained the reasoning they were applying at different stages of their own practice, and what this enabled them to explore and clarify in terms of their own design decisions.

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<sup>41</sup> These case studies used were: Zambesi Style - see: <http://technology.tki.org.nz/Resources/Case-studies/Technologists-practice-case-studies/Resistant-materials-textiles/Zambesi-style> and Custom Classroom Furniture – see: <http://technology.tki.org.nz/Resources/Case-studies/Technologists-practice-case-studies/Resistant-materials-hard/Custom-Classroom-Furniture>



## School B

Cycle One findings identified students in School B possessed understandings of concepts underpinning *technological modelling* ranging from pre-Level 1 - 2p. To address this low level of conceptual understanding the teacher in School B chose, in Cycle Two, to enhance student understandings in Cycle Two through a mix of focused discussion and specific activities. Like the teacher in School A, the focus of planned intervention in School B was on enhancing student understandings of the purpose of technological modelling, forms of technological modelling and the importance of practical and functional reasoning within technological modelling. To do this the teacher drew from the findings of Compton and Compton<sup>42</sup> (2010) on students' misconceptions related to *technological modelling*. She introduced students to multiple examples of technological modelling used across a range of technology contexts and engaged students in discussion about the design idea or outcome being tested, and how these tests informed decision making. The teacher highlighted for students how the term 'model' has different meanings across different contexts. For example a model in the fashion industry can be a person who displays merchandise (products), such as clothing or cosmetics; or a three dimensional form used to communicate a design idea. She was very conscious of using the term 'technological modelling' as opposed to 'model' or 'technological model' to ensure students clearly identified when she was referring to the 'process' of modelling used to a test design idea(s) or to an outcome(s) – technological model. Discussion also focused on ensuring students understood differences between functional models and prototypes.

The teacher introduced students to concepts of practical and functional reasoning and engaged students in discussion, drawing off examples, about how these forms of reasoning inform a products' development. How technological modelling is used to ascertain and mitigate risk, and how the status of evidence gained from

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<sup>42</sup> These were made available in research presentations and were later published in Compton, V, J. and Compton, A (2010). *Technological Knowledge and the Nature of Technology: Implications for Teaching and Learning*, see: <http://technology.tki.org.nz/Curriculum-support/Implications-for-Teaching-and-Learning>

technological modelling can change across contexts were also discussed. To reinforce understandings gained from the intervention, the teacher encouraged students to later identify, within their own technological practice, when they were undertaking practical and functional reasoning, and to use the terminology *functional model* and *prototype* in their portfolio explanations/justifications of the practice they undertook. This allowed her to make formative assessment judgements on student understandings of these concepts - practical and functional reasoning, and functional model and prototype. Where it was found that a student(s) had not understood the differences, the teacher addressed this through one-on-one interactions with a student and/or through small group discussions with students.

To address student misconceptions identified within Cycle Two findings, particularly concerning the importance of reasoning types when technological modelling, and to introduce students to concepts of how risk can be minimised, including the types and status of evidence, the teacher in Cycle Three presented case studies of technologist practice<sup>43</sup> to students. She asked the students to identify where functional and practical reasoning was used to inform design decisions, how these forms of reasoning contributed to the overall development of the technological outcome, how risk was mitigated and how optimal performance and maintenance requirements were determined during the product development stages. Students also discussed as a class, how the type and status of evidence gained from technological modelling differed within and across the two case study contexts - corporate uniform and food product.

### **School C**

Similar to students in Schools A and B, Cycle One findings identified students in School C as possessing understandings of concepts underpinning technological modelling ranging from pre-Level 1 - 2p. To address this low level of conceptual understanding the planned teaching activity in Cycle Two required students to

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<sup>43</sup> These case studies used were: Zambesi Style - see <http://technology.tki.org.nz/Resources/Case-studies/Technologists-practice-case-studies/Resistant-materials-textiles/Zambesi-style> and Sealords Group Ltd: – Developing a seafood product <http://technology.tki.org.nz/Resources/Case-studies/Technologists-practice-case-studies/Food-and-biotechnology/Sealord-Group-Ltd-Developing-a-seafood-product>

analyse case study examples of technologists and student practice published on the Techlink website<sup>44</sup> - *Craft Knives*<sup>45</sup> and *Kitchen Contours*<sup>46</sup>. This intervention was focused on supporting students to develop understandings about different types of technological modelling; their contribution to the overall development of a technological outcome; how technological modelling enables risk to be ascertained and mitigated; and why particular technological model types were better suited for testing ideas/concepts in specific contexts than others. Students were taught about practical and functional reasoning and asked to identify where in the case studies technologist(s) had applied or may have applied these, and how this influenced the development of the product and/or the technological practice analysed. As a means of formatively assessing student understandings of these forms of reasoning (practical and functional), students were later encouraged to identify when they were using practical and/or functional reasoning in their own technological practice.

To progress understandings students demonstrated in Cycle Two, the teacher in Cycle Three organised for Futureintech ambassadors<sup>47</sup> to act as mentors to students developing technological outcomes. Each ambassador explained to the class how they used different forms of technological modelling to support them to develop ‘fit for purpose’ technological outcomes; identify and mitigate risk; obtain optimal performance and determine maintenance requirements for their outcomes. Students, as a class, discussed differences identified in how the ambassadors used technological modelling and the reasons for this. Students consulted with their mentor ambassadors when developing their own technological outcomes, particularly about which form(s) of technological model they should use to test their design ideas and developing concepts, in order to mitigate risk and to ensure that their developed technological outcome was ‘fit for purpose’.

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<sup>44</sup> The resources once housed on the *Techlink* website are now located on the *Technology Online* website - see: <http://technology.tki.org.nz>

<sup>45</sup> *Craft Knives* see: <http://technology.tki.org.nz/Resources/Case-studies/Classroom-practice-case-studies/Resistant-materials-hard/Product-Development-craft-knives>

<sup>46</sup> *Kitchen Contours* see: <http://technology.tki.org.nz/Resources/Case-studies/Technologists-practice-case-studies/Resistant-materials-hard/Kitchen-Contours>

<sup>47</sup> Futureintech ambassadors are practicing technologists who promote careers in technology, engineering and science through providing students real-life examples of work and job specific roles. Futureintech is an initiative of the *Institution of Professional Engineers New Zealand* (IPENZ) and is funded by *New Zealand Trade and Enterprise*.

Teachers in all three schools were encouraged and supported by the researcher to leave space within their technology programmes to respond to students who had not grasped the concepts of *technological modelling* that had been introduced to them. This space meant that when student understanding of concepts underpinning *technological modelling* were identified through formative assessments to have not progressed, or that students held misconceptions about a concept, teachers were able to introduce additional focused teaching activities to address this. Teachers were also encouraged to question students when they undertook technological practice about ‘why’ they were doing the things they were doing, and ‘what’ they were attempting to achieve. Observations of the nature of the technological practice students undertook, particularly focusing on the types of reasoning students employed and the purpose or intent behind their modelling in practice were also used formatively to gauge student understandings of concepts underpinning *technological modelling*.

Following Cycles Two and Three, data were collected using the structured technological modelling questionnaire (see Appendix B: Student Questionnaire) to capture student conceptual understandings of *technological modelling*; and portfolio evidence gathered to determine their understanding of *brief development*, *planning for practice*, and *outcome development and evaluation*. A qualitative analysis of these data for these four components of technology, at Cycles Two and Three was undertaken against the Indicators introduced in Chapter Three, Section 3.3.6. The outcomes of this analysis are presented as findings in Section 5.2.2 and individual student shifts discussed.

Student portfolio evidence (data) from Cycles Two and Three was also analysed to establish findings and emerge themes on the nature of student’s *reasoning* and *decision making* when undertaking technological practice. These data were categorised against the Category Labels for *reasoning* and *decision making* within technological practice introduced in Chapter Three, Section 3.3.7. The findings from Cycle Two and Three data are presented in Section 5.2.3 and individual student shifts discussed.

Teachers in all three schools encouraged their students to use their understandings of *technological modelling* when undertaking their own technological practice to inform their developing outcomes (including conceptual ideas and realised technological outcome/s), and to test their potential fitness for purpose.

### 5.2.2 Cycle Two and Three: Students' achievement in technological modelling and the components of Technological Practice

Data from the 27 student research participants was analysed qualitatively and coded against the category labels for *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation* in keeping with the practice used in the Cycle One data analysis, and outlined in Chapter 3, Section 3.3.6. Findings from this analysis are presented in Table 18.

*Table 18: Individual student level of achievement in technological modelling; brief development, planning for practice, and outcome development and evaluation*

Students N=27	Technological modelling			Brief development			Planning for practice			Outcome development and evaluation		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
1A	2p	4a	7p	4p	5p	8p	2a	6p	6a	2a	6a	7a
2A	1p	3p	6p	4a	5p	7a	1p	4p	5p	2a	5a	6a
3A	1p	3a	6p	4p	6p	7p	2a	4a	6p	2p	6a	7p
4A	Pre 1	3a	6p	4a	5a	7p	3a	4a	5p	2a	6p	7p
5A	1p	3a	6p	5p	5a	7p	3p	4a	5p	2p	5p	6a
6A	Pre 1	4p	6a	5p	6a	7a	3a	6p	6a	3p	6a	7a
7A	Pre 1	3a	6p	5p	5a	7p	3a	5a	6p	3p	6a	7p
8A	Pre 1	3a	6p	5p	6p	7p	3a	5a	6p	3p	6a	7p
9A	1P	3a	6p	4a	5a	7p	2a	5p	5a	2a	4p	6a
1B	1p	3p	5a	4a	5p	6a	1a	4p	5p	2p	5p	6a
2B	1p	3p	5a	4a	5p	6a	1a	4p	5p	1a	4a	6a
3B	2p	4p	6p	3a	4a	7p	1a	4a	5p	2p	5p	6a
4B	1p	3p	6a	4a	5a	7a	1a	4a	5a	1p	5p	7p
5B	1p	3p	5a	3a	5a	6a	2p	4a	5p	2a	5p	6a
6B	2p	3a	5p	3a	5a	6a	1a	4a	5p	2p	5p	6p
7B	Pre 1	3p	5a	3p	4p	5a	2p	4p	4a	3p	4a	6a
8B	1p	3a	6p	3p	5p	6a	1a	4a	5p	2p	5p	6a
9B	1p	4p	5a	3p	4a	6a	1p	4a	5p	3p	5p	6a

*Chapter 5*  
*Research Findings: Cycle Two and Three*

Students N=27	Technological modelling (cont.)			Brief development (cont.)			Planning for practice (cont.)			Outcome development and evaluation (cont.)		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
<b>10B</b>	1p	3a	5a	3p	5p	6a	1a	4a	5p	2p	5p	6p
<b>11B</b>	2p	4a	6a	4a	5p	7p	1a	4a	5p	3p	6p	7p
<b>12B</b>	1p	3p	6a	4p	5a	7p	1a	4a	5p	3p	5a	7p
<b>13B</b>	1p	3p	6a	4p	5a	7a	1a	4a	5p	3p	6p	7p
<b>1C</b>	2p	4p	7p	4a	6a	8p	2p	6p	6a	4a	6a	8p
<b>2C</b>	1p	3a	5p	4a	5a	6p	2p	4a	5a	2p	5p	6p
<b>3C</b>	Pre 1	3p	5p	2p	5p	5p	2p	4a	5p	2p	5p	5p
<b>4C</b>	1p	3a	5p	2p	5p	6p	2a	4p	4p	2p	5p	5p
<b>5C</b>	1p	3a	5p	2p	5p	5p	2p	4p	4p	1a	5p	5p

All students (100.0%) demonstrated a shift in achievement in Cycle Two in the components, *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation* from that demonstrated in Cycle One. In Cycle Three, three students in School C (3C, 4C and 5C) demonstrated no shift in achievement for the component *outcome development and evaluation*. They however demonstrated a shift in their understanding in the component *technological modelling* – shifting from Level 3 (understanding *partial* or *all* indicators) in Cycle Two to 5p in Cycle Three. These students’ also made little or no shift in *brief development* and *planning for practice* between Cycles Two and Three. The remaining 24 students (88.9%) demonstrated a shift in achievement across all four curriculum components.

When students 3C, 4C and 5C were questioned about their lack of shifts in *brief development*, *planning for practice*, and *outcome development and evaluation* from that demonstrated in Cycle Two, they explained that they did not intend to pursue a career or tertiary study in technology. After a discussion with their teacher, these students, along with student 2C, had opted to focus their efforts on ‘making products’ rather than undertaking technological practice to ‘develop products’. This change of purpose for studying technology is explained by student 4C when he states:

*I want to go to University next year to study economics and accounting, technology is therefore not important to me..... I do like making things so that's why I am still doing it [technology] this year, however I just want to make things, not design them.*

*(Student 4C)*

The greatest student shift in achievement in *technological modelling* between Cycle One and Two was four curriculum levels – student 6A shifting from demonstrating pre level 1 in Cycle One to demonstrate a Level 4p understanding in Cycle Two. Student 1A demonstrated the highest understanding of *technological modelling* in Cycle Two – a Level 4a understanding. In Cycle Three the greatest shift in understanding was three levels, achieved by thirteen students. The highest understanding was demonstrated by student 1A and 1C – a Level 7p understanding.

The greatest student shift in achievement between Cycles One and Two for *brief development* was three curriculum levels - students 3C, 4C and 5C shifting from demonstrating Level 2p in Cycle One to Level 5p in Cycle Two. Student 6A demonstrated the highest achievement in *brief development* in Cycle Two – a Level 6a achievement. In Cycle Three the greatest shift in achievement was three levels demonstrated by student 1A – shifting from demonstrating Level 5p to 8p. The highest achievement in Cycle Three was demonstrated by student 1A – a Level 8p achievement.

The greatest student shift in achievement between Cycles One and Two for *planning for practice* was four curriculum levels - student 1A shifting from demonstrating Level 2a in Cycle One to Level 6p in Cycle Two, and student 1C from Level 2p to Level 6p. Students 1A, 6A and 1C demonstrated the highest achievement in *planning for practice* in Cycle Two – a Level 6p achievement. In Cycle Three the greatest shift in achievement was two levels demonstrated by student 3A – from Levels 4a to Level 6p. The highest achievement in Cycle Three was demonstrated by student 1A, 6A and 1C – a Level 6a achievement.

The greatest shift in curriculum level achievement between Cycles One and Two for *outcome development and evaluation* demonstrated by students (1A, 3A, 4A & 4B) was four curriculum levels - student 1A demonstrated a shift in achievement



from Level 2a to Level 6a, student 3A from Level 2p to Level 6a, student 4A from Level 2a to 6p and student 4B from Level 1p to Level 5p. The highest level of achievement demonstrated by students in Cycle Two was Level 6a. Five of the students that demonstrated this achievement were in School A (1A, 3A, 6A, 7A & 8A) and one student was from School C (1C). In Cycle Three the greatest shift in achievement was two levels, demonstrated by students 9A, 2B, 7B, 12B and 1C. Student 9A shifted from Level 4p to Level 6a, students 2B and 7B from Level 4a to Level 6a, student 12B from Level 5a to Level 7p and student 1C from Level 6a to Level 8p. The highest achievement in Cycle Three was demonstrated by student 1C - a Level 8p achievement.

Although at the end of Cycle Two all students demonstrated a shift in achievement for the components *technological modelling*, *brief development*, *planning for practice* and *outcome development and evaluation*, their achievement was still below expectations for students completing Year 12 - that being at curriculum Level 7 (Ministry of Education, 2007). Similarly, while most students demonstrated a shift at the end of Cycle Three, the majority were again below expectations for students completing Year 13 – that is at curriculum Level 8 (Ministry of Education, 2007).

In *technological modelling* following Cycle Two, six students (22.2%) demonstrated achievement three levels below curriculum expectation and twenty-one students (77.8%) four levels below curriculum expectations. Following Cycle Three, two students (7.4%) demonstrated achievement one level below curriculum expectation, fourteen students (51.9%) two levels below curriculum expectation and eleven students (40.7%) three levels below curriculum expectation.

For *brief development* following Cycle Two, four students (14.8%) demonstrated achievement one level below curriculum expectation, twenty students (74.1%) two levels below curriculum expectation, and three students (11.1%) three level below curriculum expectation. Following Cycle Three, two students (7.4%) demonstrated achievement in *brief development* at year level curriculum expectation, thirteen students (48.2%) one level below curriculum expectation, nine students (33.3%) two levels below curriculum expectation and three students (11.1%) three levels below curriculum expectation.

In *planning for practice* following Cycle Two, three students (11.1%) demonstrated achievement one level below curriculum expectation, three students (11.1%) two levels below curriculum expectation, and twenty-one students (77.8%) two levels below curriculum expectations. Following Cycle Three, six students (22.2%) demonstrated achievement two levels below curriculum expectation, eighteen students (66.7%) three levels below curriculum expectation and three students (11.1%) four levels below curriculum expectation.

In *outcome development and evaluation* following Cycle Two, nine students (33.3%) demonstrated achievement one level below curriculum expectation, fifteen students (55.6%) two levels below curriculum expectation and three students (11.1%) achievement three levels below curriculum expectation. Following Cycle Three, one student (3.7%) demonstrated achievement at curriculum expectation, ten students (37.0%) one level below curriculum expectation, thirteen students (48.2%) two levels below curriculum expectation and three students (11.1%) three levels below curriculum expectation.

Further discussion on findings of student attainment in *technological modelling, brief development, planning for practice* and *outcome development and evaluation* in Cycle Two and Three will be provided following further analysis in Section 5.2.4, 5.2.5, 5.2.6 and 5.2.7.

### **5.2.3 Cycle Two and Three: students' reasoning and decision making**

Coded findings for the 27 student research participants representing the nature of their *reasoning* and drivers that underpinned their *decision making* when undertaking technological practice in Cycles Two and Three is presented in Table 19. These data were categorised against the category labels for *reasoning* and *decision making* introduced in Chapter Three, Section 3.3.7.

Chapter 5  
Research Findings: Cycle Two and Three

Table 19: Individual student reasoning and decision making

Students N=27	Cycle	Reasoning									Decision Making		
		Practical Reasoning			Functional Reasoning			Integrated Reasoning			Completed Outcome	Best Outcome	Best Technological Practice
		NE	Ps	Pr	NE	Fs	Fr	NE	IRo	IRp	CO	BO	BT
1A	1		X			X			X			X	
	2			X		X			X			X	
	3			X			X			X			X
2A	1		X			X			X			X	
	2		X			X			X			X	
	3			X		X			X			X	
3A	1		X			X			X			X	
	2		X				X		X			X	
	3			X			X			X			X
4A	1		X			X			X			X	
	2			X		X			X			X	
	3			X			X		X			X	
5A	1		X			X			X			X	
	2		X			X			X			X	
	3			X		X			X			X	
6A	1		X			X			X			X	
	2			X		X			X			X	
	3			X			X			X		X	
7A	1		X			X			X			X	
	2			X		X			X			X	
	3			X			X			X			X
8A	1		X			X			X		X		
	2			X			X		X			X	
	3			X			X			X			X
9A	1		X			X		X			X		
	2		X			X			X			X	
	3			X		X			X			X	
1B	1		X			X			X			X	
	2		X			X			X			X	
	3		X				X		X			X	
2B	1		X			X		X			X		
	2		X			X			X			X	
	3		X				X		X			X	
3B	1		X			X		X			X		
	2		X				X		X			X	
	3		X				X		X			X	
4B	1	X			X			X			X		
	2		X			X			X			X	
	3		X				X		X			X	

*Chapter 5*  
*Research Findings: Cycle Two and Three*

Students (cont.)	Cycle	Reasoning (cont.)									Decision Making (cont.)		
		Practical Reasoning			Functional Reasoning			Integrated Reasoning			Completed Outcome	Best Outcome	Best Technological Practice
		NE	Ps	Pr	NE	Fs	Fr	NE	IRo	IRp	CO	BO	BT
5B	1		X		X			X			X		
	2		X			X			X			X	
	3		X			X			X			X	
6B	1	X				X		X			X		
	2		X			X			X			X	
	3		X			X			X			X	
7B	1	X			X			X			X		
	2		X			X			X			X	
	3		X			X			X			X	
8B	1	X			X			X			X		
	2		X			X			X			X	
	3		X			X			X			X	
9B	1		X		X			X			X		
	2		X			X			X			X	
	3		X			X			X			X	
10B	1		X			X		X			X		
	2		X			X			X			X	
	3		X			X			X			X	
11B	1		X			X		X			X		
	2		X				X		X			X	
	3		X				X		X			X	
12B	1	X			X			X			X		
	2		X			X			X			X	
	3		X			X			X			X	
13B	1	X				X		X			X		
	2		X			X			X			X	
	3		X			X			X			X	
1C	1	X					X	X				X	
	2		X				X		X			X	
	3		X				X		X			X	
2C	1	X			X			X			X		
	2		X			X		X			X		
	3		X			X			X		X		
3C	1	X			X			X			X		
	2		X			X			X		X		
	3		X			X			X		X		
4C	1	X			X			X			X		
	2	X			X			X			X		
	3		X			X		X			X		
5C	1	X			X			X			X		
	2		X			X		X			X		
	3		X			X		X			X		

Cycle Two data shows that:

- one student (4C) presented no evidence of undertaking *practical reasoning*. This same student also presented no evidence of *functional reasoning*. Twenty-one students (77.8%) demonstrated *superficial practical reasoning* and five students (18.5%) *robust practical reasoning*
- one student (4C) presented no evidence of undertaking *functional reasoning* twenty-one students (77.8%) demonstrated *superficial functional reasoning* and five students (18.5%) *robust functional reasoning*
- three students (11.1%) demonstrated no evidence of undertaking any form of *integrated reasoning* and twenty-four students (88.9%) *outcome focused integrated reasoning*. As in Cycle One, no students demonstrated *practice focused integrated reasoning*
- four students (14.8%) focused their decision making on a *completed outcome*. The remaining twenty-three students (85.2%) focused their decision making on a *best outcome*. As in Cycle One, no students presented evidence of *best technological practice* in Cycle Two.

Cycle Three data shows that:

- eighteen students (66.67%) demonstrated *superficial practical reasoning* and nine students (33.3%) *robust practical reasoning*. These nine students all came from School A
- fifteen students (55.6%) demonstrated *superficial functional reasoning* and the remaining twelve students (44.4%) *robust functional reasoning*. Of these twelve students, six students (50%) were in School A, five students (41.67%) in School B and one student (8.33%) in School C
- two students (7.4%) demonstrated *no evidence* of *integrated reasoning*, twenty students (74.1%) *outcome focused integrated reasoning* and five students (18.5%) *practice focused integrated reasoning*. These five students all came from School A
- four students (2C, 3C, 4C & 5C) (14.8%) focused their decision making on a *completed outcome*. These students all came from School C and were those who, as explained in Section 5.2.2, opted to focus their efforts on ‘making products’ rather than undertaking technological practice to

‘develop products’. Nineteen students (70.4%) focused their decision making on a *best outcome* and four students (14.8%) presented evidence of *best technological practice*.

#### 5.2.4 Cycle Two and Three: student level of achievement in technological modelling

The findings in Cycle Two and Three from the combined student participant evidence of *technological modelling* are presented in Table 20 alongside the Cycle One findings.

Table 20: Combined student participant data Cycle One, Two and Three: technological modelling

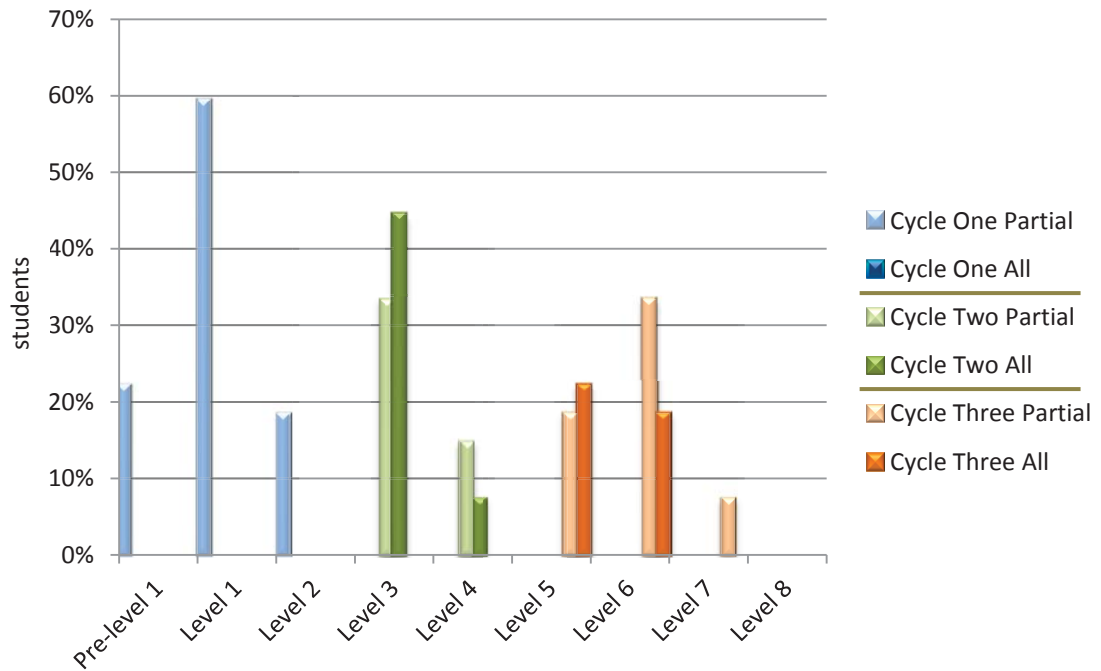
<b>n = 27</b>	Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Technological Modelling (Cycle 1)	6	16		5													
%	22.2	59.3		18.5													
Technological Modelling (Cycle 2)						9	12	4	2								
%						33.3	44.5	14.8	7.4								
Technological Modelling (Cycle 3)										5	6	9	5	2			
%										18.5	22.2	33.4	18.5	7.4			

In Cycle Two students held concepts of *technological modelling* that ranged from partial understandings at Level 3, to understanding of all indicators at Level 4. Nine students (33.3%) demonstrated partial understandings at Level 3, twelve students (44.5%) demonstrated that they understood all indicators at Level 3, four students (14.8%) partial understandings at Level 4, and two students (7.4%) all indicators at Level 4. The majority of students in Cycle Two (77.8%) demonstrated Level 3 achievement.

In Cycle Three, students held concepts of *technological modelling* that ranged from partial understandings at Level 5, to partial Level 7 understandings. Five students (18.5%) demonstrated partial understandings at Level 5, six students (22.2%) demonstrated that they understood all indicators at Level 5, nine students (33.4%) partial understandings at Level 6, five students (18.5%) understood all indicators at Level 6 and two students (7.4%) partial Level 7 understandings. The majority of

students in Cycle Three (51.9%) demonstrated Level 6 achievement. Figure 8 presents these data graphically.

Figure 8: Combined student participant data Cycle One, Two and Three: understandings of technological modelling



### 5.2.5 Cycle Two and Three: student level of achievement in brief development

The findings for *brief development* in Cycles Two and Three from the combined student participant evidence are presented in Table 21 alongside the Cycle One findings.



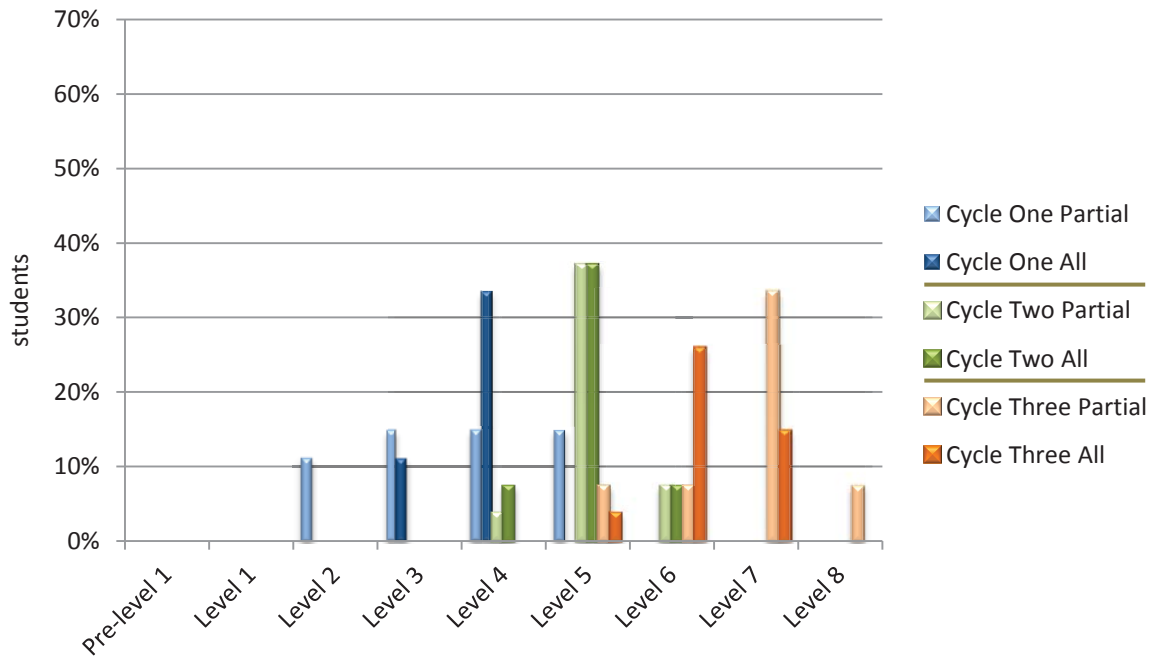
Table 21: Combined student participant data Cycle One, Two and Three: brief development

<b>n = 27</b>	Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Brief Development (Cycle 1)				3		4	3	4	9	4							
%				11.1		14.8	11.1	14.8	33.4	14.8							
Brief Development (Cycle 2)								1	2	10	10	2	2				
%								3.7	7.4	37.0	37.0	7.4	7.4				
Brief Development (Cycle 3)										2	1	2	7	9	4	2	
%										7.4	3.7	7.4	25.8	33.4	14.8	7.4	

In Cycle Two student achievement in *brief development* ranged from partial achievement at Level 4 to achievement of all indicators at Level 6. One student (3.7%) demonstrated partial achievement at Level 4, two students (7.4%) achievement of all indicators at Level 4, ten students (37.0%) partial achievement at Level 5, and ten students (37.0%) achievement of all indicators at Level 5. Two students (7.4%) demonstrated partial achievement at Level 6, and two students (7.4%) achievement of all indicators at Level 6. The majority of students in Cycle Two (74.0 %) demonstrated Level 5 achievement.

In Cycle Three, student achievement in *brief development* ranged from partial achievement at Level 5 to partial Level 8 achievement. Two students (7.4%) demonstrated partial achievement at Level 5, one student (3.7%) achievement of all indicators at Level 5, two students (7.4%) partial achievement at Level 6, seven students (25.9%) achievement of all indicators at Level 6, and nine students (33.4%) partial achievement at Level 7. Four students (14.8%) demonstrated achievement of all indicators at Level 7 and two students (7.8%) partial achievement at Level 8. No single curriculum level showed a majority of students, the highest percentage of students (48.2%) demonstrated Level 7 achievement. Figure 9 presents these data graphically.

Figure 9: Combined student participant data Cycle One, Two and Three: brief development



### 5.2.6 Cycle Two and Three: student level of achievement in planning for practice

The findings for *planning for practice* in Cycle Two and Three from the combined student participant evidence are presented in Table 22 alongside the Cycle One findings.

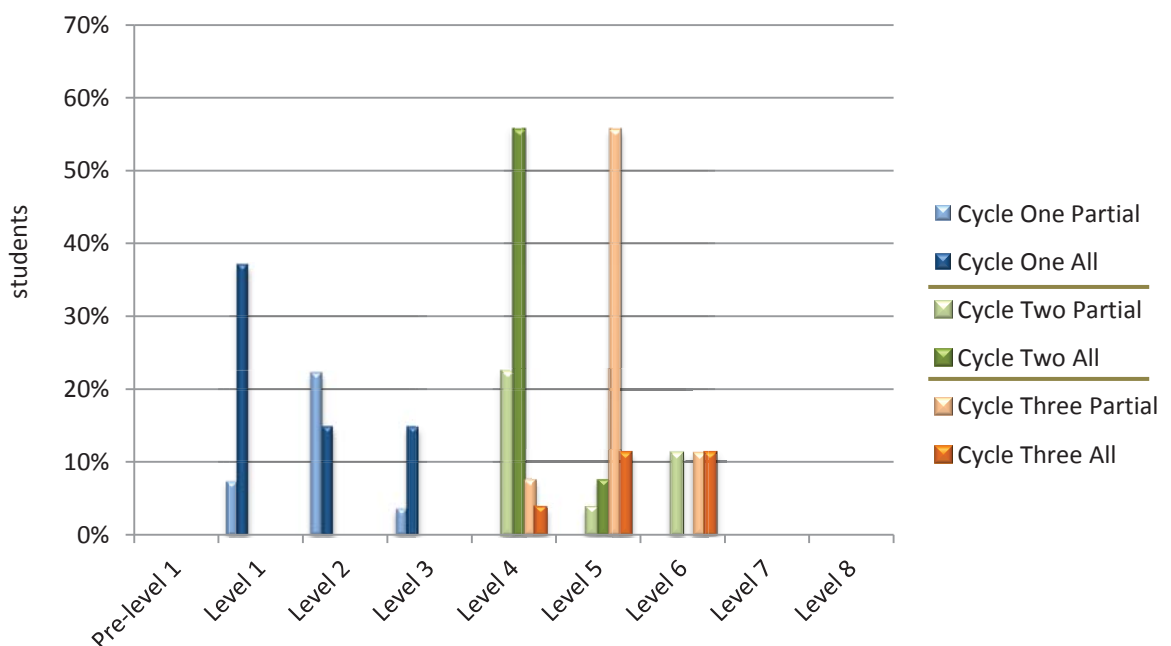
Table 22: Combined student participant data Cycle One, Two and Three: *planning for practice*

<i>n</i> = 27	Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Planning for Practice (Cycle 1)		2	10	6	4	1	4										
%		7.4	37.0	22.2	14.8	3.7	14.8										
Planning for Practice (Cycle 2)								6	15	1	2	3					
%								22.2	55.6	3.7	7.4	11.1					
Planning for Practice (Cycle 3)								2	1	15	3	3	3				
%								7.4	3.7	55.6	11.1	11.1	11.1				

In Cycle Two student achievement in *planning for practice* ranged from partial achievement at Level 4 to partial achievement at Level 6. Six students (22.2%) demonstrated partial achievement at Level 4, fifteen students (55.6%) achievement of all indicators at Level 4, one student (3.7%) partial achievement at Level 5, two students (7.4%) achievement of all indicators at Level 5, and three students (11.1%) partial achievement at Level 6. The majority of students in Cycle Two (77.8%) demonstrated Level 4 achievement.

Student achievement of *planning for practice* in Cycle Three ranged from partial Level 4 achievement to demonstrating achievement of all indicators at Level 6. Two students (7.4%) demonstrated partial Level 4 achievement; one student (3.7%) achievement of all indicators at Level 4, and fifteen students (55.6%) partial Level 5 achievement. Three students (11.1%) demonstrated achievement of all indicators at Level 5, three students (11.1%) partial achievement at Level 6 and three students (11.1%) achievement of all indicators at Level 6. The majority of students in Cycle Three (66.7%) demonstrated Level 5 achievement. Figure 10 presents these data graphically.

Figure 10: Combined student participant data Cycle One, Two and Three: *planning for practice*



### 5.2.7 Cycle Two and Three: student level of achievement in outcome development and evaluation

The findings for *outcome development and evaluation* in Cycle Two and Three from the combined student participant evidence are presented in Table 23 alongside the Cycle One findings.

*Table 23: Combined student participant data Cycle One, Two and Three: outcome development and evaluation*

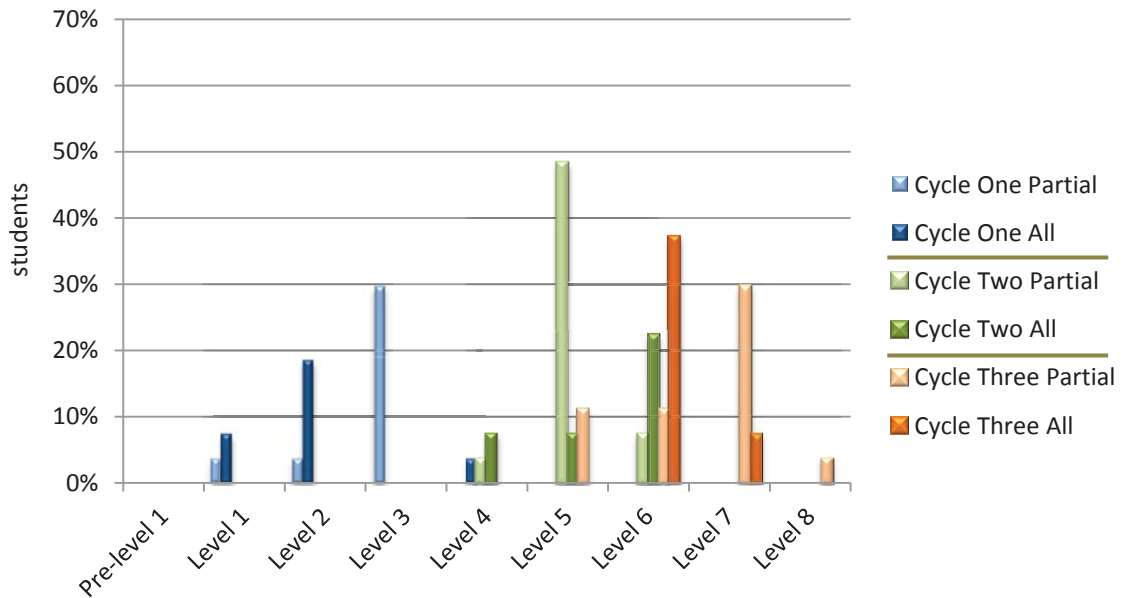
<b>n = 27</b>	Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Outcome Development and Evaluation (Cycle 1)		1	2	10	5	8			1								
%		3.7	7.4	37.1	18.5	29.6			3.7								
Outcome Development and Evaluation (Cycle 2)								1	2	13	2	3	6				
%								3.7	7.4	48.2	7.4	7.4	22.2				
Outcome Development and Evaluation (Cycle 3)										3		3	10	8	2	1	
%										11.1		11.1	37.1	29.6	7.4	3.7	

In Cycle Two student achievement in *outcome development and evaluation* ranged from partial achievement at Level 4, to demonstrating achievement of all indicators at Level 6. One student (3.7%) demonstrated partial achievement at Level 4, two students (7.4%) achievement of all indicators at Level 4, thirteen students (48.2%) partial achievement at Level 5, two students (7.4%) achievement of all indicators at Level 5, three students (11.1%) partial achievement at Level 6 and six students (22.2%) achievement of all indicators at Level 6. The majority of students in Cycle Two (55.6%) demonstrated achievement at Level 5.

Student achievement in *outcome development and evaluation* in Cycle Three ranged from partial achievement at Level 5 to partial Level 8 achievement. Three students (11.1%) demonstrated partial achievement at Level 5, three students (11.1%) partial Level 6 achievement and ten students (37.1%) achievement of all indicators at Level 6. Eight students (29.6%) demonstrated partial Level 7 achievement, two students (7.4%) achievement of all indicators at Level 7 and one student (3.7%) partial Level 8 achievement. No single curriculum level showed a

majority of student achievement - the highest percentage of students (48.2%) demonstrating Level 6 achievement. Figure 11 presents these data graphically.

Figure 11: Combined student participant data Cycle One, Two and Three: outcome development and evaluation



### 5.2.8 Student Level of Achievement in reasoning and decision making

The findings for *reasoning and decision making* in Cycle Three from the combined student participant evidence are presented in Table 24 alongside the Cycle One and Two findings.

Table 24: Combined student participant data Cycle One, Two and Three: reasoning and decision making

n = 27	Practical Reasoning			Functional Reasoning			Integrated Reasoning			Completed Outcome	Best Outcome	Best Technological Practice
	NE	Ps	Pr	NE	Fs	Fr	NE	IRo	IRp	CO	BO	BT
Decision making and reasoning in technological practice (Cycle 1)	11	16		10	16	1	18	9		18	9	
%	40.7	59.3		37.0	59.3	3.7	66.7	33.3		66.7	33.3	
Decision making and reasoning in technological practice (Cycle 2)	1	21	5	1	21	5	3	24		4	23	
%	3.7	77.8	15.5	3.7	77.8	15.5	11.1	88.9		14.8	85.2	
Decision making and reasoning in technological practice (Cycle 3)		18	9		15	12	2	20	5	4	19	4
%		66.7	33.3		55.6	44.4	7.4	74.1	18.5	14.8	70.4	14.8

In Cycle Two:

- one student (3.7%) demonstrated no evidence of *practical reasoning*, twenty-one students (77.8%) demonstrated *superficial practical reasoning* and five students (18.5%) demonstrated *robust practical reasoning*. The majority of students (77.8%) demonstrated *superficial practical reasoning*.
- one student (3.7%) demonstrated no evidence of *functional reasoning*, twenty-one students (77.8%) demonstrated *superficial functional reasoning* and five students (18.5%) demonstrated *robust functional reasoning*. The majority of students (77.8%) demonstrated *superficial functional reasoning*.
- three students (11.1%) presented no evidence of *integrated reasoning*, and twenty-four students (88.9%) presented evidence of *outcome focused integrated reasoning*. No students presented evidence of *practice focused integrated reasoning*. The majority of students (88.9%) demonstrated *outcome focused integrated reasoning*.
- four students (14.8%) focused their decision making on a *completed outcome*, and twenty-three students (85.2%) on realising a *best outcome*. No students focused their decision making on *best technological practice*. The majority of students (85.2%) demonstrated *best outcome*.

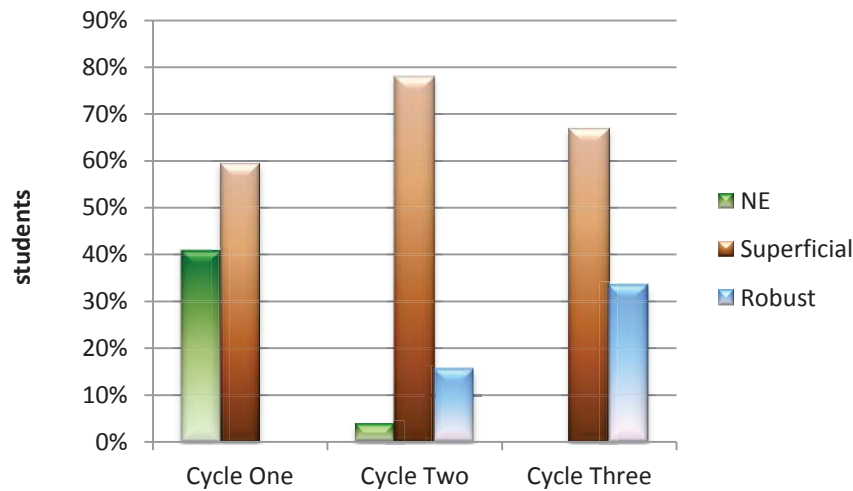
In Cycle Three:

- no students demonstrated *no evidence* of *practical reasoning* and eighteen students (66.7%) demonstrated *superficial practical reasoning* - a decrease of 11.1%. Nine students (33.3%) demonstrated *robust practical reasoning* - an increase of 17.8%. The majority of students (66.7%) in Cycle Three however still demonstrated *superficial functional reasoning*.
- no students demonstrated *no evidence* of *functional reasoning* and fifteen students (55.6%) demonstrated *superficial functional reasoning* - decrease of 22.2%. Twelve students demonstrated *robust functional reasoning* - an increase of 28.9%). The majority of students (55.6%) in Cycle Three however still demonstrated *superficial functional reasoning*.
- two students (7.4%) presented *no evidence* of *integrated reasoning*, and twenty students (74.1%) presented evidence of *outcome focused integrated reasoning* - a decrease of 14.8%. Unlike in Cycle Two where no students presented evidence of *practice focused integrated reasoning*, five students (18.5%) in Cycle Three presented evidence of *practice focused integrated reasoning*. The majority of students (74.1%) in Cycle Three demonstrated *outcome focused integrated reasoning*.
- four students (14.8%) focused their decision making on a *completed outcome*, and nineteen students (70.4%) on realising a *best outcome* - a decrease of 14.8%. Unlike in Cycle Two where no students presented evidence of *best technological practice*, four students (14.8%) in Cycle Three focused their decision making on *best technological practice*. The majority of students (70.4%) in Cycle Three demonstrated *best outcome*.

Between Cycles One and Two, student shifts in the application of *practical reasoning* shifted from 40.7% demonstrating no evidence and 59.3% *superficial* evidence to 3.7% of students presenting no evidence of *practical reasoning*, 77.8% *superficial practical reasoning* and 15.5% *robust practical reasoning*. In Cycle Three this shift was furthered with all students presenting evidence of undertaking *practical reasoning* - students demonstrating *superficial practical reasoning* decreased (reducing from 77.8% to 66.7%) and students demonstrating *robust*

*practical reasoning* (33.3%) increased (rising from 15.5% to 44.4%). Figure 12 presents these data graphically.

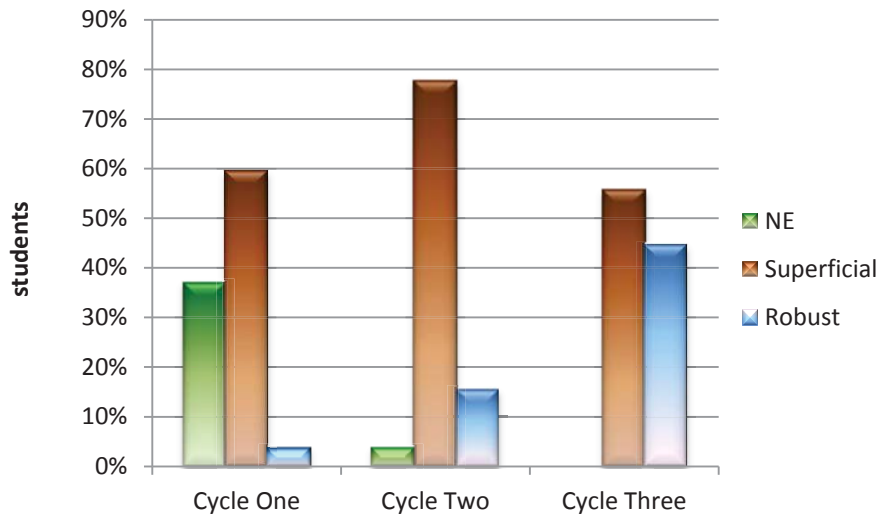
Figure 12: Cycle One, Two and Three: practical reasoning



Shifts in student *functional reasoning* between Cycles One and Two moved from 37.0% demonstrating *no evidence*, 59.3% *superficial functional reasoning*, and one student (3.7%) demonstrating *robust functional reasoning*, to one student (3.7%) demonstrating *no evidence of functional reasoning* and an increased number of students demonstrating *superficial* (77.8%) and *robust functional reasoning* (15.5%). In Cycle Three, this shift was furthered by all students presenting evidence of undertaking *functional reasoning* - students demonstrating *superficial functional reasoning* decreased (reducing from 77.8% in Cycle Two to 55.6% in Cycle Three), and students demonstrating *robust functional reasoning* increased (rising from 15.5% in Cycle Two to 44.4% in Cycle Three). Figure 13 presents these data graphically.

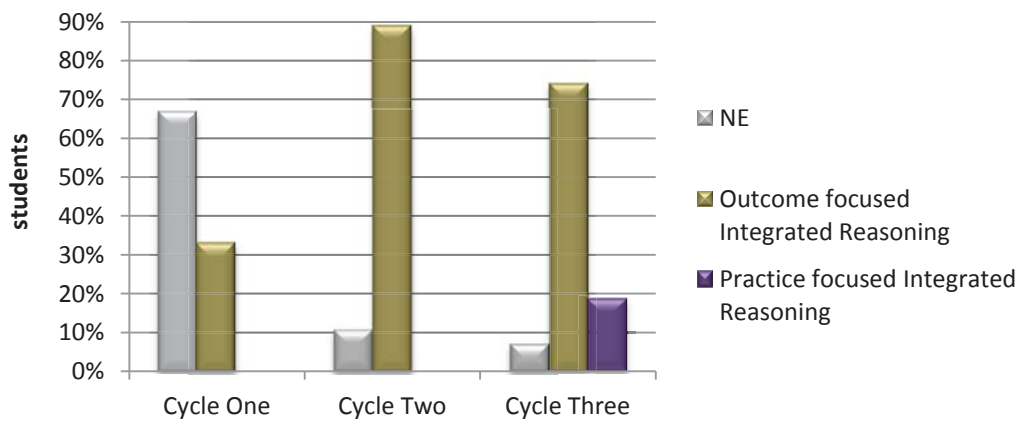


Figure 13: Cycle One, Two and Three: functional reasoning



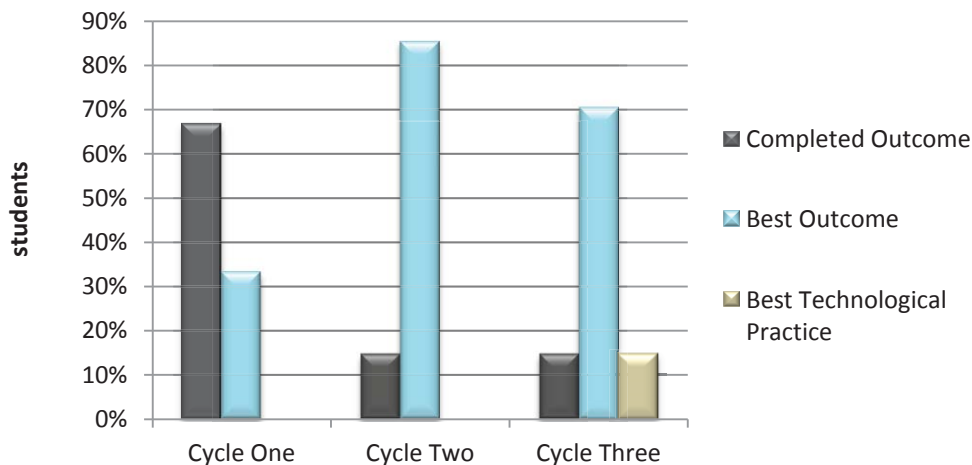
Student *integrated reasoning* between Cycles One and Two shifted from 66.7% of students demonstrating no evidence of *integrated reasoning* and 33.3% demonstrating *outcome focused integrated reasoning* to 11.1% of students demonstrating no evidence of *integrated reasoning* and 88.9% demonstrating *outcome focused integrated reasoning*. In Cycle Three, this shift was furthered by all students presenting evidence of undertaking *integrated reasoning* - students demonstrating *outcome focused integrated reasoning* decreased (reducing from 88.9% to 74.1%), and students demonstrating *practice focused integrated reasoning* increased (rising from no students in Cycle Two to 18.5%). Figure 14 presents these data graphically.

Figure 14: Cycle One, Two and Three: integrated reasoning



Student decision making between Cycles One and Two shifted from 66.7% of students focusing on a *completed outcome* and 33.3% of students on *best outcome*, to 14.8% of students focusing on a *completed outcome* and 85.2% focusing on developing a *best outcome*. In Cycle Three, this shift was furthered by the number of students demonstrating *best outcome* decreasing (reducing from 85.2% to 70.4%), and students demonstrating *best technological practice* increasing (rising from no students in Cycle Two to 14.8%). The same four students (14.8%) in Cycle Two who, from an informed choice (as discussed in Section 5.2.2), focused their decision making on a *completed outcome* applied the same decision making when undertaking technological practice to ‘develop products’ in Cycle Three. As a consequence their decision making in Cycle Three continued to centre on a *completed outcome*. Figure 15 presents these data graphically.

Figure 15: Cycle One, Two and Three: decision making



### 5.2.9 Relationship between student understanding of technological modelling and their achievement of the components of technology practice

The findings for Cycle One, Two and Three combined student participant understandings of *technological modelling*, and their achievement in *brief development*, are presented in Table 25.

Table 25: Cycle One, Two and Three: student understandings of technological modelling and their achievement in undertaking brief development

n =27		Technological Modelling																
		Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Brief development	Pre-level 1	Cycle 1																
		Cycle 2																
		Cycle 3																
	Level 1	Cycle 1	p															
			a															
		Cycle 2	p															
			a															
		Cycle 3	p															
			a															
	Level 2	Cycle 1	p	1	2													
			a															
		Cycle 2	p															
			a															
		Cycle 3	p															
			a															
	Level 3	Cycle 1	p	1	3													
			a		1	2												
		Cycle 2	p															
			a															
		Cycle 3	p															
			a															
	Level 4	Cycle 1	p		3	1												
			a	1	6	2												
		Cycle 2	p					1										
a								2										
Cycle 3		p																
		a																
Level 5	Cycle 1	p	3	1														
		a																
	Cycle 2	p					4	4		2								
		a					4	6										
	Cycle 3	p									2							
		a										1						
Level 6	Cycle 1	p																
		a																
	Cycle 2	p						2										
		a							2									
	Cycle 3	p									2							
		a									1	4	1					
Level 7	Cycle 1	p																
		a																
	Cycle 2	p																
		a																
	Cycle 3	p										1	7	2				
		a											1	3				
Level 8	Cycle 1	p																
		a																
	Cycle 2	p																
		a																
	Cycle 3	p														1		
		a														1		

In Cycle Two:

- of the nine students who demonstrated partial Level 3 understanding of *technological modelling*, these students demonstrated achievement in *brief development* that ranged from partial achievement at Level 4 to achievement of all indicators at Level 5, with the majority (88.9%) of these students demonstrating Level 5 achievement
- of the twelve students who demonstrated an understanding of all indicators at Level 3 for *technological modelling*, these students demonstrated achievement in *brief development* that ranged from partial achievement at Level 5 to demonstrating partial Level 6 achievement, with 83.3% of these students demonstrating Level 5 achievement
- of the four students who demonstrated partial Level 4 understanding of *technological modelling*, two students (50%) demonstrated achievement in *brief development* in all indicators at Level 4 and two students (50%) achievement of all indicators at Level 6
- the two students who demonstrated an understanding of all indicators at Level 4 for *technological modelling* demonstrated partial achievement at Level 5 in *brief development*.

In Cycle Three:

- of the five students who demonstrated partial Level 5 understanding of *technological modelling*, these students demonstrated achievement in *brief development* that ranged from partial achievement at Level 5 to achievement of all indicators at Level 6, with the majority of these students (60.0%) demonstrating Level 5 achievement
- of the six students who demonstrated an understanding of all indicators at Level 5 for *technological modelling*, these students demonstrated achievement in *brief development* that ranged from achievement of all indicators at Level 5 to demonstrating partial Level 7 achievement, with the majority of these students (66.7%) demonstrating Level 6 achievement

- of the nine students who demonstrated partial Level 6 understanding of *technological modelling*, these students demonstrated achievement in *brief development* that ranged from achievement of all indicators at Level 6 to all indicators at Level 7, with the majority of these students (77.8%) demonstrating Level 7 achievement
- of the five students who demonstrated an understanding of all indicators at Level 6 for *technological modelling*, these students demonstrated achievement in *brief development* that ranged from partial achievement at Level 7 to achievement of all indicators at Level 7, with the majority of these students (60.0%) demonstrating Level 7 achievement
- of the two students who demonstrated partial Level 7 understanding of *technological modelling*, one student (50%) demonstrated achievement in *brief development* at partial Level 8 and one student (50%) all indicators at Level 8.

The Cycle Two findings suggest that there may be a relationship between an increase in understanding of *technological modelling* and student's ability to demonstrate achievement in *brief development*. That is, when student curriculum level understandings of *technological modelling* increase their curriculum level achievement for *brief development* also increases. This emergent theme, identified in Cycle Two findings, between student understandings of *technological modelling* and their achievement in *brief development* was confirmed by the Cycle Three findings.

The findings for Cycle One, Two and Three, from combined student participant understanding of *technological modelling*, and their achievement in *planning for practice*, are presented in Table 26.

Table 26: Cycle One, Two and Three: student understandings of technological modelling and their achievement in undertaking planning for practice

		n =27		Technological Modelling																
				Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Planning for Practice	Pre-level 1	Cycle 1																		
		Cycle 2																		
		Cycle 3																		
	Level 1	Cycle 1	P		2															
			a		7		3													
		Cycle 2	P																	
			a																	
		Cycle 3	P																	
			a																	
	Level 2	Cycle 1	P	2	3		1													
			a		3		1													
		Cycle 2	P																	
			a																	
		Cycle 3	P																	
			a																	
	Level 3	Cycle 1	P		1															
			a	4																
		Cycle 2	P																	
			a																	
		Cycle 3	P																	
			a																	
	Level 4	Cycle 1	P																	
			a																	
		Cycle 2	P						4	2										
a								5	7	2	1									
Cycle 3		P										2								
		a											1							
Level 5	Cycle 1	P																		
		a																		
	Cycle 2	P							1											
		a							2											
	Cycle 3	P										2	5	5	3					
		a										1		1	1					
Level 6	Cycle 1	P																		
		a																		
	Cycle 2	P								2	1									
		a																		
	Cycle 3	P											3							
		a												1	2					
Level 7	Cycle 1	P																		
		a																		
	Cycle 2	P																		
		a																		
	Cycle 3	P																		
		a																		
Level 8	Cycle 1	P																		
		a																		
	Cycle 2	P																		
		a																		
	Cycle 3	P																		
		a																		

In Cycle Two:

- of the nine students who demonstrated partial Level 3 understanding of *technological modelling*, these students demonstrated achievement in *planning for practice* that ranged from partial achievement at Level 4 (44.4%) to demonstrating achievement of all indicators at Level 4 (55.6%)
- of the twelve students who demonstrated an understanding of all indicators at Level 3 for *technological modelling*, these students demonstrated achievement in *planning for practice* that ranged from partial achievement at Level 4 to demonstrating partial Level 5 achievement, with the majority (75.0%) demonstrating Level 4 achievement
- of the four students who demonstrated partial Level 4 understandings of *technological modelling*, two of these students (50%) demonstrated in *planning for practice* achievement of all indicators at Level 4 and two students (50%) demonstrated achievement at partial Level 6
- of the two students who demonstrated all indicators at Level 4 understanding of *technological modelling*, one student (50%) demonstrated achievement of all indicators in *planning for practice* at Level 4 and one student (50%) demonstrated partial Level 6 achievement.

In Cycle Three:

- of the five students who demonstrated partial Level 5 understanding of *technological modelling*, these students demonstrated achievement in *planning for practice* that ranged from partial achievement at Level 4 to achievement of all indicators at Level 5, with the majority of these students (60.0%) demonstrating Level 5 achievement
- of the six students who demonstrated an understanding of all indicators at Level 5 for *technological modelling*, these students demonstrated achievement in *planning for practice* that ranged from of all indicators at Level 4 (16.7%) to demonstrating partial Level 5 achievement (83.3%)
- of the nine students who demonstrated partial Level 6 understanding of *technological modelling*, these students demonstrated achievement in *planning for practice* that ranged from partial achievement at Level 5 to

demonstrating all indicators at Level 6, with the majority of these students (55.5%) demonstrating Level 5 achievement

- of the five students who demonstrated an understanding of all indicators at Level 6 for *technological modelling*, these students demonstrated achievement in *planning for practice* that ranged from partial achievement at Level 5 to achievement of all indicators at Level 6, with the majority (80.0%) demonstrating Level 5 achievement
- the two students who demonstrated partial Level 7 understanding of *technological modelling*, both demonstrated in *planning for practice* achievement of all indicators at Level 6.

In Cycle Two students who demonstrated the highest curriculum level understandings of the concepts underpinning *technological modelling* demonstrated the highest curriculum level achievements in *planning for practice*. This is in contrast to the Cycle One findings, where students who demonstrated the highest practices associated with *planning for practice* displayed the lowest understandings of concepts underpinning *technological modelling*. This reversal of the Cycle One emergent theme in Cycle Two followed explicit teaching about concepts underpinning *technological modelling*.

In Cycle Three, again following explicit teaching focused on developing student understandings of concepts underpinning *technological modelling*, those students who displayed the highest achievements in *planning for practice* demonstrated the higher understandings of concepts underpinning *technological modelling*. This finding substantiates that which emerged in Cycle Two. This suggests therefore that there is a correlation between increases in understanding of *technological modelling* and higher achievement in *planning for practice*. The findings from Cycles Two and Three therefore overturn the initial findings from Cycle One. The reversal of the finding in Cycles One, to that identified in Cycles Two and Three suggests that when students receive focused teaching in *technological modelling* it impacts on their being able to demonstrate achievement in this component of Technological Practice.



The findings for Cycle One, Two and Three, from the combined student participant understandings of *technological modelling*, and their achievement in *outcome development and evaluation* are presented in Table 27.

Table 27: Cycle One, Two and Three: student understandings of technological modelling and their achievement in outcome development and evaluation

		<i>n</i> =27	Technological Modelling																
			Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a
Outcome Development and Evaluation	Pre-level 1	Cycle 1																	
		Cycle 2																	
		Cycle 3																	
	Level 1	Cycle 1	P		1														
			a		2														
		Cycle 2	P																
			a																
		Cycle 3	P																
			a																
	Level 2	Cycle 1	P	1	7		2												
			a	1	3		1												
		Cycle 2	P																
			a																
		Cycle 3	P																
			a																
	Level 3	Cycle 1	P	4	3		1												
			a																
		Cycle 2	P																
			a																
		Cycle 3	P																
			a																
	Level 4	Cycle 1	P																
			a				1												
		Cycle 2	P							1									
			a						2										
Cycle 3		P																	
		a																	
Level 5	Cycle 1	P																	
		a																	
	Cycle 2	P						4	7	2									
		a						2											
	Cycle 3	P																	
		a										3							

Chapter 5  
Research Findings: Cycle Two and Three

n =27 cont.			Technological Modelling – cont.															
			Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p
Level 6	Cycle 1	P																
		a																
	Cycle 2	P					1	1		1								
		a						3	2	1								
	Cycle 3	P									2	1						
		a										5	5					
Level 7	Cycle 1	P																
		a																
	Cycle 2	P																
		a																
	Cycle 3	P											4	4				
		a												1	1			
Level 8	Cycle 1	P																
		a																
	Cycle 2	P																
		a																
	Cycle 3	P													1			
		a																

In Cycle Two:

- of the nine students who demonstrated partial Level 3 understanding of *technological modelling*, these students demonstrated achievement in *outcome development and evaluation* that ranged from achievement of all indicators at Level 4 to partial achievement at Level 6, with the majority of these students (66.7%) demonstrating Level 5 achievement
- of the twelve students who demonstrated an understanding of all indicators at Level 3 for *technological modelling*, these students demonstrated achievement in *outcome development and evaluation* that ranged from partial achievement at Level 4 to demonstrating all indicators at Level 6, with the majority of these students (58.3%) demonstrating Level 5 achievement
- of the four students who demonstrated partial Level 4 understandings of *technological modelling*, two of these students (50.0%) demonstrated in *outcome development and evaluation* achievement at partial Level 5 and two students (50.0%) demonstrated achievement of all indicators at Level 6
- of the two students who demonstrated all indicators at Level 4 understanding of *technological modelling*, one student (50.0%) in *outcome*

*development and evaluation* demonstrated partial achievement at Level 6 and one student (50.0%) all indicators at Level 6.

In Cycle Three:

- of the five students who demonstrated partial Level 5 understanding of *technological modelling*, these students demonstrated achievement in *outcome development and evaluation* that ranged from partial achievement at Level 5 to partial Level 6 achievement, with the majority of these students (60.0%) demonstrating partial achievement at Level 5
- of the six students who demonstrated an understanding of all indicators at Level 5 for *technological modelling*, these students demonstrated achievement in *outcome development and evaluation* that ranged from partial achievement at Level 6 (16.7%) to demonstrating achievement of all indicators at Level 6 (83.3%)
- of the nine students who demonstrated partial Level 6 understanding of *technological modelling*, these students demonstrated achievement in *outcome development and evaluation* that ranged from achievement of all indicators at Level 6 to demonstrating partial Level 7, with the majority (55.5%) demonstrating Level 6 achievement
- of the five students who demonstrated an understanding of all indicators at Level 6 for *technological modelling*, these students demonstrated achievement in *outcome development and evaluation* that ranged from partial achievement at Level 7 (80%) to achievement of all indicators at Level 7 (20%)
- of the two students who demonstrated partial Level 7 understanding of *technological modelling*, one student (50.0%) demonstrated in *outcome development and evaluation* achievement of all indicators at Level 7 and one student (50.0%) partial achievement at Level 8.

The Cycle Two and Three data show that as students increase their conceptual understandings of *technological modelling* their achievement in *outcome development and evaluation* also increases. This finding disrupts the emergent theme identified in Cycle One, that is, there is no identifiable relationship between

student conceptual understandings of *technological modelling* and their achievement in *outcome development and evaluation*.

The relationship between student participant understandings of *technological modelling* and their *reasoning and decision making* is presented in Section 5.2.10.

### 5.2.10 Relationship between student understanding of technological modelling, and decision making and reasoning

Student participant understanding of *technological modelling* and their *decision making and reasoning* for Cycles One, Two Three and is presented in Table 28.

Table 28: Cycle One, Two and Three: student understandings of technological modelling and their decision making and reasoning

n =27			Technological Modelling																		
			Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a		
Reasoning	Practical Reasoning	Cycle 1	NE	2	7		2														
			s	4	9		3														
			r																		
		Cycle 2	NE						1												
			s					9	8	3	1										
			r						3	1	1										
		Cycle 3	NE																		
			s									5	6	2	4	1					
			r										7	1	1						
	Functional Reasoning	Cycle 1	NE	2	8																
			s	4	8		4														
			r				1														
		Cycle 2	NE						1												
			s					9	9	2	1										
			r						2	2	1										
		Cycle 3	NE																		
			s									5	4	4	2						
			r										2	5	3	2					
	No Evidence of Integrated Reasoning	Cycle 1	2	12		4															
		Cycle 2							3												
		Cycle 3									2										
	Outcome focused Integrated Reasoning	Cycle 1	4	4		1															
		Cycle 2						9	9	4	2										
		Cycle 3										3	6	6	4	1					
Practice focused Integrated Reasoning	Cycle 1																				
	Cycle 2																				
	Cycle 3											3	1	1							

$n = 27$			Technological Modelling - cont.																	
			Pre 1	1p	1a	2p	2a	3p	3a	4p	4a	5p	5a	6p	6a	7p	7a	8p	8a	
Decision making	Completed Outcome	Cycle 1	3	12		3														
		Cycle 2						1	3											
		Cycle 3										4								
	Best Outcome	Cycle 1	3	4		2														
		Cycle 2						8	9	4	2									
		Cycle 3										1	6	6	5	1				
	Best Technological Practice	Cycle 1																		
		Cycle 2																		
		Cycle 3											3			1				

In Cycle Two:

- the nine students (33.3%) that demonstrated partial achievement at Level 3 for *technological modelling* presented evidence of *superficial practical* and *functional reasoning*, and *outcome focused integrated reasoning*. One of these students (11.1%) focused their decision making on developing a *completed outcome* and eight students (88.9%) on completing a *best outcome*
- of the twelve students (44.4%) that demonstrated achievement of all indicators at Level 3 for *technological modelling*, one student (8.3%) presented no evidence of *practical reasoning*, eight students (66.7%) evidence of *superficial practical reasoning* and three students (25.0%) *robust practical reasoning*. One of these students (8.3%) presented no evidence of *functional reasoning*, nine students (75.0%) evidence of *superficial functional reasoning* and two students (16.7%) *robust functional reasoning*. Three students (25.0%) presented no evidence of *integrated reasoning* and nine students (75.0%) evidence of *outcome focused integrated reasoning*. Of the twelve students who demonstrated achievement of all indicators at Level 3, three students (25.0%) focused

their decision making on a *completed outcome* and nine students (75.0%) on completing a *best outcome*

- of the four students (14.8%) that demonstrated partial achievement at Level 4 for *technological modelling*, three students (75.0%) presented evidence of *superficial practical reasoning* and one student (25.0%) *robust practical reasoning*. Two of these students (50.0%) presented evidence of *superficial functional reasoning* and two students (50.0%) *robust functional reasoning*. All four students presented evidence of *outcome focused integrated reasoning* and focused their decision making on completing a *best outcome*
- of the two students (7.4%) that demonstrated achievement of all indicators at Level 4 for *technological modelling*, one student (50.0%) presented evidence of *superficial practical reasoning* and one student (50.0%) *robust practical reasoning*. One of these students (50.0%) presented evidence of *superficial functional reasoning* and one student (50.0%) *robust functional reasoning*. Both students presented evidence of *outcome focused integrated reasoning* and focused their decision making on completing a *best outcome*.

In Cycle Three:

- the five students (18.5%) that demonstrated partial achievement at Level 5 for *technological modelling* presented evidence of *superficial practical* and *functional reasoning*. Two of these students (40.0%) presented no evidence of *integrated reasoning* and three students (60.0%) *outcome focused integrated reasoning*. Four of these students (80.0%) focused their decision making on developing a *completed outcome* and one student (20.0%) focused on completing a *best outcome*
- the six students (22.2%) that demonstrated achievement of all indicators at Level 5 for *technological modelling* presented evidence of *superficial practical reasoning*. Four of these students (66.7%) presented evidence of *superficial functional reasoning* and two students (33.3%) presented evidence of *robust functional reasoning*. All six students (100.0%) presented evidence of *outcome focused integrated reasoning* and focused their decision making on completing a *best outcome*

- of the nine students (33.3%) that demonstrated partial achievement at Level 6 for *technological modelling*, two student (22.2%) presented evidence of *superficial practical reasoning* and seven students (77.8%) *robust practical reasoning*. Four of these students (44.4%) presented evidence of *superficial functional reasoning* and five students (55.6%) *robust functional reasoning*. Six students (66.7%) presented evidence of *outcome focused integrated reasoning* and three students (33.3%) evidence of *practice focused integrated reasoning*. Of the nine students who demonstrated partial achievement at Level 6, six students (66.7%) focused on completing a *best outcome* and three students (33.3%) placed an emphasis on completing *best technological practice*
- of the five students (18.5%) that demonstrated achievement of all indicators at Level 6 for *technological modelling*, four students (80.0%) presented evidence of *superficial practical reasoning* and one student (20.0%) *robust practical reasoning*. Two students (40.0 %) presented evidence of *superficial functional reasoning* and three students (60.0%) *robust functional reasoning*. Four students (80.0%) presented evidence of *outcome focused integrated reasoning* and one student (20.0%) *practice focused integrated reasoning*. All five students focused their decision making on completing a *best outcome*
- of the two students (7.4%) that demonstrated partial achievement at Level 7 for *technological modelling*, one student (50.0%) presented evidence of *superficial practical reasoning* and one student (50.0%) *robust practical reasoning*. Both students presented evidence of *robust functional reasoning*, one student (50.0%) presented evidence of *outcome focused integrated reasoning* and one student (50.0%) evidence of *practice focused integrated reasoning*. One student (50.0%) focused their decision making on completing a *best outcome* and one student (50.0%) on completing *best technological practice*.

Comparing Cycle Two data against Cycle One suggests that when student understandings of *technological modelling* increase:

- they are more likely to undertake *practical reasoning* - students demonstrating no evidence of *practical reasoning* reducing from eleven students (40.7%) in Cycle One to one student (3.7%) in Cycle Two. Students undertaking *superficial practical reasoning* increasing from sixteen students (59.3%) in Cycle One to twenty-one students (77.8%) in Cycle Two with a further five students (18.5%) presenting evidence of undertaking robust *practical reasoning*
- they are more likely to undertake *functional reasoning* - students demonstrating no evidence of *functional reasoning* reducing from ten students (37.0%) in Cycle One to one student (3.7%) in Cycle Two. Students undertaking *superficial functional reasoning* increasing from sixteen students (59.3%) in Cycle One to twenty-one students (77.8%) in Cycle Two, and *robust functional reasoning* from one student (3.7%) in Cycle One to five students (18.5%) in Cycle Two
- they are more likely to undertake *integrated reasoning* - students demonstrating no evidence of *integrated reasoning* reducing from eighteen students (66.7%) in Cycle One to four students (11.1%) in Cycle Two and *outcome focused reasoning* increasing from nine students (33.3%) in Cycle One to twenty-four students (88.9%) in Cycle Two
- their decision making moves from developing a *completed outcome* to a *best outcome* - *completed outcome* reducing from eighteen students (66.7%) in Cycle One to four students (14.8%) in Cycle Two; and *best outcome* increasing from nine students (33.3%) in Cycle One to twenty-three students (85.2%) in Cycle Two.

When these emerging themes from the Cycle One and Two findings are compared with Cycle Three findings, again it is seen that when student understandings of *technological modelling* increase:

- they are more likely to increase from undertaking *superficial practical reasoning* to *robust practical reasoning* - students demonstrating *no* evidence of *practical reasoning* or *superficial practical reasoning* reducing



from twenty-two students (81.5%) in Cycle Two to eighteen students (66.7%) demonstrating *superficial practical reasoning* in Cycle Three, and *robust practical reasoning* increasing from five students (18.5%) in Cycle Two to nine students (33.3%) in Cycle Three

- they are more likely to increase from undertaking *superficial functional reasoning* to *robust functional reasoning* - students demonstrating *no evidence of functional reasoning* or *superficial functional reasoning* reducing from twenty-two students (81.5%) in Cycle Two to fifteen students (55.6%) demonstrating *superficial practical reasoning* in Cycle Three, and *robust practical reasoning* increasing from five students (18.5%) in Cycle Two to twelve students (44.4%) in Cycle Three.

Between Cycles Two and Three although students increased their understandings of *technological modelling*:

- there is no identifiable relationship between this increase and them progressing from *outcome focused integrated reasoning* to undertaking *practice focused integrated reasoning*. Rather, any progression appeared to be aligned to the nature of the *practical* and *functional reasoning* they undertook, rather than being directly related to their understandings of concepts underpinning *technological modelling*. As seen in the Cycle Three data, when students demonstrated *practice focused integrated reasoning* their *practical* and *functional reasoning* was observed to be robust in nature, while students who demonstrated *outcome focused integrated reasoning* undertook superficial *practical* and/or *functional reasoning*
- this did not result in a movement from students developing a *best outcome* to a *best technological outcome*. Rather progression in *integrated reasoning* appears to depend on both the nature of the *practical* and *functional reasoning* students undertake, as well as the curriculum level understanding of concepts underpinning *technological modelling* they possess. As seen in the Cycle Three data, when student decision making was focused on *best technological practice* they demonstrated Level 6 or above understandings of concepts underpinning *technological modelling* and their *practical* and *functional reasoning* was observed to be *robust* in nature.

## 5.3 Summary of Findings

This chapter presented findings from data gathered in Cycles Two and Three. These findings contribute to answering the research sub questions:

3. What impact did interventions in Cycles Two and Three have on student achievement in *technological modelling*, *brief development*, *planning for practice*, and *outcome development and evaluation*?
4. What impact did interventions in Cycles Two and Three have on student reasoning and decision making when undertaking technological practice?
5. What is the relationship between student achievement in *technological modelling*, and their achievement in *brief development*, *planning for practice*, and *outcome development and evaluation*?
6. What is the relationship between student achievement in *technological modelling*, and their reasoning and decision making when undertaking technological practice?

Answers to each sub question are presented in the following Sections.

### 5.3.1 Cycle Two and Three: what impact did interventions have on student achievement in technological modelling, brief development, planning for practice, and outcome development and evaluation?

Student curriculum level understandings of concepts underpinning *technological modelling* and achievement for *brief development*, *planning for practice*, and *outcome development and evaluation* increased, following interventions specifically focused on enhancing student understandings of concepts underpinning *technological modelling*, between the Cycle One and Cycle Two data, and again between the Cycle Two and Cycle Three data.

In Cycle One, students demonstrated curriculum level understanding of concepts underpinning *technological modelling* that ranged from no evidence of understanding, to partial Level 2 understandings, with the majority of students (81.5%) presenting Level 1 understandings. In Cycle Three, understandings increased to demonstrating a range from partial Level 5, to partial Level 7

understandings, with the majority of students (51.9%) demonstrating Level 6 understandings at the end of Cycle Three. While students demonstrated a large shift in curriculum level understandings from those identified in Cycle One to those at the end of Cycle Three, they were still however, below the expected Year Level curriculum understandings.

In Cycle One, student curriculum level achievement in *brief development* ranged from demonstrating partial Level 2 to partial Level 5 achievement, with the highest percentage of students (48.2%) demonstrating Level 4 achievement. At the end of Cycle Three, following interventions in Cycles Two and Three, student achievement increased ranging from demonstrating partial Level 5 to partial Level 8, with the highest percentage of students (48.2%) demonstrating Level 7 achievement.

In Cycle One, student level achievement in *planning for practice* ranged from partial Level 1 to demonstrating achievement of all indicators at Level 3, with the highest percentage of students (44.4%) demonstrating Level 1 achievement. At the end of Cycle Three, following interventions in Cycles Two and Three, student achievement increased, ranging from demonstrating partial Level 4 to achievement of all indicators at Level 6, with the majority of students (66.7%) demonstrating achievement at Level 5.

In Cycle One, student curriculum level achievement in *outcome development and evaluation* ranged from demonstrating partial Level 1 to achievement of all indicators at Level 4, with the majority of students (55.6%) demonstrating achievement at Level 2. At the end of Cycle Three, following interventions in Cycles Two and Three, student achievement increased ranging from demonstrating partial Level 5, to partial achievement at Level 8, with the highest percentage of students (48.2%) demonstrating Level 6 achievement.

### 5.3.2 Cycle Two and Three: what impact did interventions have on student reasoning and decision making when undertaking technological practice?

Following intervention, focused on enhancing student understandings of concepts underpinning *technological modelling*, between Cycle One and Cycle Two data, and again between Cycle Two and Cycle Three, evidence of student decision making when undertaking technological practice was analysed against the reasoning and decision making category labels identified from the research literature (see Chapter 3: Section 3.3.7).

In Cycle Two, following intervention, student *practical reasoning* shifted from 40.7% of students demonstrating no evidence and 59.3% *superficial practical reasoning* in Cycle One to 3.7% of students presenting no evidence of *practical reasoning*, 77.8% *superficial practical reasoning* and 15.5% *robust practical reasoning*. At the end of Cycle Three, this shift was furthered with all students either demonstrating *superficial* or *robust practical reasoning*. The number of students demonstrating *superficial practical reasoning* reduced to 66.7% and those demonstrating *robust practical reasoning* increased to 33.3%.

Student shifts in *functional reasoning* changed from 37.7% demonstrating no evidence, 59.3% *superficial functional reasoning*, and one student (3.7%) demonstrating *robust functional reasoning* in Cycle One to one student (3.7%) demonstrating no evidence of *functional reasoning*, 77.8% demonstrating *superficial* and 15.5% of students *robust functional reasoning* in Cycle Two. In Cycle Three, this shift was furthered with the number of students demonstrating *superficial functional reasoning* reducing to 55.6% and those demonstrating *robust functional reasoning* increasing to 44.4% of students.

Student *integrated reasoning* shifted from 66.7% of students demonstrating no evidence *integrated reasoning* and 33.3% demonstrating *outcome focused integrated reasoning* in Cycles One, to 11.1% of students demonstrating no evidence of *integrated reasoning* and 88.9% demonstrating *outcome focused integrated reasoning* in Cycle Two. In Cycle Three, the number of students demonstrating no evidence of *outcome focused integrated reasoning* further reduced and the number of students demonstrating *practice focused integrated*

*reasoning* increased to 18.5% of students. Although students were seen to demonstrate increased *practice focused integrated reasoning* between Cycles One, Two and Three, this increase appears to be more aligned to the nature of the *practical* and *functional reasoning* they undertook, rather than being directly related to their increasing understandings of concepts underpinning *technological modelling*.

Student decision making shifted from 66.7% of students focusing on a *completed outcome* and 33.3% of students on *best outcome* in Cycle One, to 14.8% of students focusing on a *completed outcome* and 85.2% focusing on developing a *best outcome* in Cycle Two. In Cycle Three the number of students focused on developing a *completed outcome* remained at 14.8% and the number of students focused on realising a *best outcome* reduced to 70.4%. Students who focused on *best technological practice* increased to 14.8% of students.

Those students who continued to focus their decision making in Cycle Three on a *completed outcome* did so by informed choice. Their decision making therefore bore no relationship to their conceptual understanding of *technological modelling*. Had these students been removed from the student cohort<sup>48</sup>, due to their choice to simply make products, the shifts in student decision making described above would have further increased to all students (100%) demonstrating *best outcome* focused decision making in Cycle Two; and 82.6% focused on realising a *best outcome* and 17.4% focused on *best technological practice* in Cycle Three.

### **5.3.3 What is the relationship between student achievement in technological modelling, and their achievement in brief development, planning for practice, and outcome development and evaluation?**

Findings from Cycle Two and Three demonstrated that:

- when student understandings of *technological modelling* increase, they demonstrate increased curriculum level achievement in the components: *brief development, planning for practice, and outcome development and evaluation*

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<sup>48</sup> Had these four students had been removed the cohort size would equal 23 students (n=23)

- students who showed the highest curriculum level understanding of *technological modelling* (partial Level 7 understanding) demonstrated the highest curriculum level achievement in the components: *brief development*, *planning for practice*, and *outcome development and evaluation*
- students who demonstrated the lowest curriculum level understanding of *technological modelling* (partial Level 5 understanding) demonstrated the lowest curriculum level achievement in the components: *brief development*, *planning for practice*, and *outcome development and evaluation*
- following interventions focused on enhancing student understandings of concepts underpinning *technological modelling* the greatest shift in student curriculum level achievement between Cycles One and Three occurred in *outcome development and evaluation*, with the majority of students shifting from partial Level 2 achievement, to achieving all indicators at Level 6. The next greatest shift occurred in *planning for practice*, where the majority of students had demonstrated achievement of all indicators at Level 1 in Cycle One. This shifted to the majority demonstrating partial Level 5 achievement in Cycle Three. The least shift was in *brief development*, the majority of students between Cycles One and Three shifted from demonstrating achievement of all indicators at Level 4 to partial Level 7 achievement. It is acknowledged however that the highest student achievement in Cycle One was for *brief development* therefore the higher starting point is a likely explanation for the smaller shift.

#### **5.3.4 What is the relationship between student achievement in technological modelling, and their reasoning and decision making when undertaking technological practice?**

Findings from Cycle Two and Three demonstrated that there was:

- a relationship between student understandings of concepts underpinning *technological modelling* and their employing robust practical and/or functional reasoning when undertaking technological practice. Students who demonstrated Level 6 or above understandings in *technological modelling* were more likely to employ robust practical and/or functional reasoning when developing technological outcomes. Students who presented Level 5 or below

understandings of *technological modelling* most often demonstrated *superficial practical* and/or *functional reasoning* following intervention.

- an interdependent relationship between the types of *reasoning* (practical, functional and/or integrated), and the nature of the *reasoning* students employed when undertaking technological practice and their understandings of concepts underpinning *technological modelling*.

Students progression from undertaking *outcome focused integrated reasoning* to *practice focused integrated reasoning* was identified as being dependent on the nature of the *practical* and *functional reasoning* (*superficial* or *robust*) they undertook. That is, students who undertook robust *practical* and *functional reasoning*, typically displayed *practice focused integrated reasoning* - these students typically demonstrated Level 6 or above understandings in *technological modelling*.

Students who undertook *outcome focused integrated reasoning* typically displayed *superficial practical* and/or *functional reasoning*, and *outcome focused integrated reasoning* - these students usually also demonstrated Level 5 or below understandings in *technological modelling*.

- an interdependent relationship between the nature of student *decision making* (focused on a *completed outcome*, *best outcome* or *best technological practice*), the type and nature of their *reasoning* when undertaking technological practice, and their understandings of concepts underpinning *technological modelling*.

Students who focused their decision making on *best technological practice* were identified to also undertake *robust practical* and *functional reasoning*, and *practice focused integrated reasoning*. These students held Level 6 or above understandings of concepts underpinning *technological modelling*.

Students who focused their decision making on a *best outcome* however typically displayed *superficial practical* and/or *functional reasoning*, and *outcome focused integrated reasoning* – they held Level 5 or below understandings in *technological modelling*.



Students, who focused their decision making on a *completed outcome*, following intervention focused on enhancing their understandings of concepts underpinning *technological modelling*, did so for other reasons. Their conceptual understanding was not used to inform their technological practice - see Section 5.2.2 for an explanation.

The research findings above demonstrate a positive connection between student achievement of concepts underpinning *technological modelling*, the reasoning and decision making they employed when undertaking technological practice, and their curriculum level achievement in the components of Technological Practice. That is, when student understanding of *technological modelling* was increased, through explicit teaching focused on developing their knowledge of concepts underpinning *technological modelling*, the nature of their reasoning and focus of their decision making was enhanced. Similarly, their achievements in *brief development*, *planning for practice*, and *outcome development and evaluation* also increased when teachers intervened to enhance their understanding of *technological modelling*, and then encouraged students to use this understanding-in-technological practice.

In Chapter Six, the findings from this research are discussed further in relation to the literature presented in Chapter Two and the research question:

What is the relationship between student conceptual understanding of technological modelling, their achievement in the components of Technological Practice, and their reasoning and decision making when undertaking technological practice?



# CHAPTER SIX

## DISCUSSION AND IMPLICATIONS

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### 6.1 Overview of the Chapter

This chapter summarises and discusses the research, and addresses its overall aim; that of identifying the relationship between student conceptual understanding of *technological modelling*, their achievement in the components of Technological Practice, and their reasoning and decision making when undertaking technological practice.

The chapter begins with a brief review of the reason for undertaking this study, and why student reasoning and decision making when undertaking technological practice was a focus. A discussion on the usefulness of the category labels (see Chapter 3, Section 3.3.7) that were used to evaluate student reasoning and decision making within technological practice, and their contribution to the literature on technology education then follows. The findings from the research questions presented in Chapter One are discussed along with their contribution to supporting improved student learning in technology education. Implications of the research findings on the design of classroom based technology programmes that focus on students justifying technological outcomes as ‘fit for purpose’ are also considered. This chapter concludes with a discussion on the impact that the research findings may have on future initiatives focused on enhancing the delivery of technology education inside New Zealand classrooms, making suggestions for future research, before acknowledging the limitations of the research and presenting conclusions.

## 6.2 Contribution to Research Literature

The overall aim of technology, as defined in the *NZC* (Ministry of Education, 2007), is for students to develop a technological literacy which is ‘broad, deep and critical’ in nature (Compton, 2007; Compton & France, 2007a). A person who possesses such a literacy is identified as going beyond simply being able to undertake technological practice with a strong sociological focus (Barnett, 1995; Pacey, 1983; MacKenzie & Wajcman, 1985; McGinn, 1990). They can also contribute to the determination of their future technological society as informed citizens (Compton & Harwood, 2008; Dakers, 2006; Keirl, 2006). To support students to develop a technological literacy that is ‘deep, broad and critical’ in nature, the *LAS* for technology in the *NZC* (Ministry of Education, 2007) defined three strands: Technological Practice, Technological Knowledge and Nature of Technology with eight associated strand components. It is believed that these curriculum strands together support students to develop a sound philosophical insight about technology, alongside robust understandings about technological knowledge and an ability to undertake technological practice to develop outcomes that they can justify as ‘fit for purpose’ in their broadest sense (Compton, 2007; Compton & France, 2007b).

While the belief expressed above is well founded on national and international literature in technology education (For discussion on this see: Compton, 2009; Compton & France, 2007a; Compton & France, 2007b), no research has been conducted to date in New Zealand classrooms to explore the relationship between individual curriculum strand components, and whether combinations of these strands lead to students being better prepared to develop technological outcomes that are ‘fit for purpose’ in their broadest sense (Compton, 2007; Compton & France, 2007b). Similarly, no research has been undertaken to determine if, when student understanding/competencies are enhanced in an individual curriculum component, it also increases their understanding/competencies in another. This research study therefore selected one Technological Knowledge component, *technological modelling*, and set out to explore if, when students are supported to improve their conceptual understanding of *technological modelling*, this led to them improving their achievement in the three components of Technological

Practice: *brief development, planning for practice and outcome development and evaluation*. The research also, as described in Chapter One, looked at students' decision making when undertaking technological practice, and explored if improved student conceptual understanding of *technological modelling* led to them developing technological outcomes that they could justify as 'fit for purpose'. The requirement for students to develop a conceptual understanding about how reasoning and decision making contributes to the development of technological outcomes, and the role reasoning plays in managing risk, is identified in the Technological Knowledge component, *technological modelling* (Ministry of Education, 2007). How such conceptual understandings translate into students being able to justify the nature of their intended outcomes (conceptual designs) and realised technological outcomes (products or systems) as 'fit for purpose' is, however, under researched. This lack of research is reflected in the NZQA external moderation and examination reports (New Zealand Qualifications Authority, 2004, 2005; 2006; 2007; 2008), where it was identified as an area of weakness, student's lack of justifiable arguments as to why their developed outcomes are 'fit for purpose'.

The Indicators of Progression for *technological modelling* (Compton & Compton, 2010b) and Technological Practice (Compton & Harwood, 2010b) were used to determine the level of student attainment against the Level 1-8 curriculum achievement objectives. To enable student decision making to be determined, category labels for the 'nature of student reasoning' and 'nature of the practice sought' were determined from the literature. This literature included understandings on decision making (Bohanec, 2009; Broome, 2001; Carruthers, 2003; Chakrabarti & Bligh, 2001; Far & Elamy, 2005; Hardy-Vallée, 2007; Klein, 2008; Milkman, Chugh & Bazerman, 2008) and reasoning (Bratman, 1991; Hitchcock, 2002; Pollock, 1998; Railton, 1999; Streumer, 2007), and their relationship to technology and technology education (Compton & France, 2006b; Fisher, 2008; Ullman, 1992). These determined category labels enabled links between student reasoning and their decision making, when selecting alternatives, to be explored. They also supported understandings to be evolved of how student reasoning and decision making influenced what they did next when undertaking technological practice.

### 6.2.1 Reasoning and decision making category labels

Categorising coded data into the essence of ‘language based’ or ‘visual’ data (Saldana, 2009) that share common characteristics, allows researchers to evolve thematic understandings and explain abstract constructs (Richards & Morse, 2007). The category labels evolved from the literature on reasoning (Bratman, 1991; Hitchcock, 2002; Pollock, 1998; Railton, 1999; Streumer, 2007) and from an analysis of student data to identify common characteristics of the ‘nature of student reasoning’ included:

- practical reasoning
- functional reasoning
- integrated reasoning

Integrated reasoning was used to categorise students who applied both practical and functional reasoning when undertaking technological practice. It became apparent when analysing student data that while students were often seen to apply both practical and functional reasoning when undertaking technological practice to inform decision making, for some students their reasoning focused solely on ensuring that their developing outcomes were socially acceptable and technically feasible. Other students in the research, however, applied both forms of reasoning to determine and justify not only the social acceptance and technical feasibility of their developing outcomes, but also the social acceptance and technical feasibility of the technological practice they undertook when developing these outcomes. To distinguish these identified differences, the ‘integrated reasoning’ category label was therefore split into two separate categories: *outcome focused integrated reasoning* and *practice focused integrated reasoning*.

Data analysis also identified that there were differences in how students used practical and/or functional reasoning within their technological practice. Some students employed practical and/or functional reasoning in their technological practice but then did not use this as a ‘driver’ for future decision making while others consistently applied practical and/or functional reasoning to determine their future decision making. The former students were therefore classified as presenting *superficial* evidence while the latter *robust*. This distinction, within the category labels for practical and functional reasoning, allowed students’ demonstrated use of

practical and/or functional reasoning to be distinguished using these two sub-categories.

The category labels determined from the literature on decision making (Bohanec, 2009; Broome, 2001; Carruthers, 2003; Chakrabarti & Bligh, 2001; Far & Elamy, 2005; Hardy-Vallée, 2007; Klein, 2008; Milkman, Chugh & Bazerman, 2008), technology education (Compton & France, 2006b; Fisher, 2008; Ullman, 1992) and from an analysis of student data, to identify common characteristics of the ‘nature of the practice’, included:

- completed outcome
- best outcome
- best technological practice.

These category labels were selected to capture the differences seen in the data between those students whose decision making in practice focused solely on completing a functioning technological outcome; those whose decision making focused on developing a 'fit for purpose' technological outcome; and those whose decision making ensured that both the technological practice undertaken and the developed technological outcome were the ‘best’ available. These latter students were identified as developing technological outcomes that were ‘fit for purpose’ in their broadest sense (Compton, 2007; Compton & France, 2007b).

Using the category labels for ‘nature of student reasoning’ and ‘nature of the practice’ to analyse student data, revealed that there were strong links between students use of practical and functional reasoning and how they integrated these when undertaking technological practice. That is, students who undertook *robust practical* and *functional reasoning* also tended to integrate these to justify the social acceptance and technical feasibility of the practice they undertook when developing technological outcomes, as well as the outcomes themselves. These students were categorised for ‘nature of the practice’ under the *practice focused integrated reasoning* label. Students however who demonstrated *robust practical reasoning* but *superficial functional reasoning*, or vice versa, were more likely to integrate both reasoning types only with a focus on ensuring that the technological outcomes they developed were socially acceptable and technically feasible. As such these

students were categorised for ‘nature of the practice’ as demonstrating *outcome focused integrated reasoning*.

When using these category labels to interrogate the data, a strong relationship was found to exist between the ‘nature of reasoning’ students employ and the ‘nature of the practice’ they undertake. Students categorised as employing *practice focused integrated reasoning* were identified as more likely to focus their decision making on undertaking *best technological practice*. These students were seen to develop technological outcomes that were ‘fit for purpose’ in their broadest sense (Compton, 2007; Compton & France, 2007b). Students who employed *outcome focused integrated reasoning*, however, undertook practice which focused their decision making on developing a *best technological outcome*. While these students were focused on realising an outcome that was socially acceptable and technically feasible, they gave little consideration to the nature of the technological practice they undertook to create it, and if this practice was a ‘best’ fit - fit for purpose.

Repeated use of the category labels for the ‘nature of reasoning’ students employ and the ‘nature of the practice’ across the three research cycles allowed *content* and *convergent validity* of the labels to be verified (Davidson and Tolich, 1999). That is the category labels, when repeatedly used on data within and across the three research cycles, allowed data to be coded in a consistent way and allowed multiple data, including student portfolio and interview evidence, to be coded against the category labels.

The reasoning and decision making category labels together with the levelled Indicators of Progression, in *technological modelling*, and *brief development, planning for practice* and *outcome development and evaluation* (Compton & Compton, 2010b; Compton & Harwood 2010b), therefore enabled the research question established in Chapter One to be answered.

### **6.3 Relationship between student conceptual understanding of technological modelling, their achievement in the components of Technological Practice, and their reasoning and decision making when undertaking technological practice**

The research findings demonstrated a positive connection between student achievement of concepts underpinning *technological modelling* and their curriculum level achievement in the components *brief development, planning for practice, and outcome development and evaluation*. That is, when student understanding of *technological modelling* was increased, through explicit teaching focused on developing their knowledge of concepts underpinning *technological modelling*, and they were encouraged by the teacher to apply this understanding-in-technological practice, their achievement in *brief development, planning for practice, and outcome development and evaluation* also increased.

Those students who displayed the lowest curriculum level understandings of concepts underpinning *technological modelling* also demonstrated the lowest achievement in the components *brief development, planning for practice, and outcome development and evaluation*. By comparison, those who demonstrated the highest conceptual understanding of *technological modelling* also displayed the highest curriculum level achievements in the components of Technological Practice.

The research also showed that the majority of students, following teacher interventions that increased their curriculum level understandings of concepts underpinning *technological modelling*, changed the focus of their decision making. This change shifted from a focus on developing a *completed outcome*, to decision making focused on a *best outcome*. Some students, following an increase in their curriculum level understandings of concepts underpinning *technological modelling*, focused their decision making on undertaking *best technological practice*. Through personal choice, and by negotiation with the teacher, some students chose to continue to focus their decision making on developing a *completed outcome*, despite demonstrating increased understandings of concepts underpinning *technological modelling*. In this instance, these students were not motivated to



design and develop outcomes through undertaking technological practice, but rather held a predisposition to simply ‘making’ products. The focus of their decision making therefore was transfixed on developing *completed outcomes* irrespective of their theoretical understandings of *technological modelling*.

The research demonstrated that students who hold high curriculum level understandings of *technological modelling* (Level 6 or above) are more likely to employ *robust practical* and/or *functional reasoning* when developing technological outcomes. Such students can discuss how practical and functional reasoning “work together to enhance decision making during technological modelling”, and discuss “how evidence and reasoning is used during functional modelling to identify risk and make informed and justifiable design decisions” (Compton, 2010a, p.93). These students’ hold understandings that equip them to justify outcomes developed through undertaking technological practice as ‘fit for purpose in their broadest sense’ (Compton, 2007; Compton & France, 2007b).

In contrast to the above, the research also demonstrated that students who held low curriculum level understandings (below Level 5) of *technological modelling* were most likely to employ *superficial practical* and/or *functional reasoning* when undertaking technological practice. According to Compton (2010a) students who possess Level 5 understandings of *technological modelling* can “identify examples of functional and practical reasoning within decision making” and “explain how evidence gained from functional modelling was used to justify design decisions” (p.92). While this research supports Compton’s (2010a) claim, it also identified that students with Level 5 understandings lack awareness of how practical and functional reasoning work together to enhance decision making, to support informed and justifiable design decisions. Students with low curriculum level understandings (below Level 5) of *technological modelling* do not therefore possess the understandings necessary to support them to justify the outcomes they develop when undertaking technological practice as ‘fit for purpose in their broadest sense’ (Compton & France, 2007b; Compton, 2007).

This research identified that there is an interdependent relationship between the focus of student *decision making* (*completed outcome*, *best outcome* or *best technological practice*), the *types of reasoning* (*practical*, *functional* and/or



*integrated*) they employed when undertaking technological practice and their understandings of concepts underpinning *technological modelling*. Students who focused their decision making on *best technological practice* were identified to also undertake *robust practical* and *functional reasoning*, and *practice focused integrated reasoning*. These students held curriculum Level 6 or above understandings of concepts underpinning *technological modelling*. Students who, however, focused their decision making on a *best technological outcome*, typically displayed *superficial practical* and/or *functional reasoning*, and *outcome focused integrated reasoning*, and held curriculum Level 5 or below understandings in *technological modelling*.

Identifying the existence of a positive connection between student achievement in *technological modelling* and achievement in the components of Technological Practice adds support to Compton and France (2007a) claim, that when students embed conceptual understanding from the generic Technological Knowledge strand (and philosophical ideas from the Nature of Technology strand) within technological practice, it leads to more informed practice. This finding also supports Rowell's (2004) contention that when students' conceptual understandings are enhanced and they are supported to take these concepts into their technological practice, it equips them to be able to develop increased understandings of *knowledge in technological practice* (Rowell, 2004). Rowell (2004) describes *knowledge in technological practice* as the knowledge that helps to define a problem, determine the physical and functional features required in a 'fit for purpose' outcome, and the actions and their sequence required when developing such an outcome. This knowledge is foundational to the components of Technological Practice, underpinning students developing technological outcomes to address a need or opportunity (Compton & Harwood, 2005) that they can justify as 'fit for purpose in their broadest sense' (Compton, 2007; Compton & France, 2007b).

The recognition of a relationship existing between student achievement in developing understandings of concepts underpinning *technological modelling* and their being able to demonstrate increasingly sophisticated technological practice, also affirms Compton and France's (2006b) belief that students who understand

concepts underpinning *technological modelling* are better able to defend the outcomes they produce, and justify them as ‘fit for purpose’. As demonstrated by this research, supporting students to develop higher curriculum level understandings of concepts underpinning *technological modelling* and encouraging them to draw on these when undertaking technological practice, leads to them demonstrating achievement against the Technological Practice components at increased curriculum levels. This increase in achievement equipped them to justify the technological outcomes they developed as ‘fit for purpose in their broadest sense’ (Compton, 2007; Compton and France, 2007b).

The research also demonstrated, for technological outcomes to be determined as ‘fit for purpose in their broadest sense’, student decision making throughout their technological practice needs to focus on *best technological practice*. That is, their decision making deliberates upon the nature of the technological practice being undertaken and the selected alternative (design ideas) in order to determine that the ‘best’ available is selected. Decision making of this nature, focused on *best technological practice*, is therefore not only informed by reasoning focused on determining the physical description of a technological outcome and its technical feasibility (*functional reasoning*), it is also informed by social-technical considerations that underpin its development, and later implementation into its intended environment (*practical reasoning*) (Compton, 2007; Compton & France, 2006a; Fisher, 2008; Ullman, 1992).

### **6.3 Implications of the research findings on the design of classroom technology curriculum**

Teacher use of structured teaching activities within and across technology units, as described in Chapter 5, Section 5.2.1, focused on developing student understandings of concepts underpinning *technological modelling*. This was identified to increase students’ achievement in the components of Technological Practice. When teachers later supported students to incorporate such understandings into their own technological practice, when engaged in ‘real design activity’ to resolve authentic socio-technical problems (Rowell, 2004; Vincenti, 1984), students were shown to use their learnt understandings to inform their reasoning

and decision making. The concepts they had learnt therefore did not solely reside as an ‘in the head experience’ (Lave, 1988) but rather were drawn on to inform their undertaking of technological practice. The success of the teaching strategies used in this research to enhance student concepts of *technological modelling* were therefore not only evidenced in shifts in student understandings of concepts underpinning this curriculum component, but also in the type and nature of the reasoning they brought to their decision making, and the focus of their decision making when undertaking technological practice.

Using structured activity based teaching within technology course designs, focused on enhancing student understandings of concepts underpinning *technological modelling*, was also seen to improve student achievement of, and decision making within the components of Technological Practice. A number of the structured activities used by the research teachers, required students to critique the technological practices of technologists to identify their use of technological modelling-in-practice and the conceptual understandings technologists employed to do this – see Chapter 5, Section 5.2.1. This pedagogical approach to teaching technology is in keeping with the aim of technology in the NZC (Ministry of Education, 2007). That is, students are able to “develop a broad technological literacy” (p.32), so that they are not only able to create technological outcomes through undertaking technological practice, and demonstrate an understanding of Technological Knowledge and the Nature of Technology from within the boundaries of their current location (Compton & Harwood, 2003). They are also able to extend beyond this boundary to critique and undertake comparative analysis of past and current technologies, and the practices that developed them (Compton & France, 2006). The positive connection shown by the research, between using structured activity based teaching to increase student understandings of concepts underpinning *technological modelling*, and increased student achievement in the components of Technological Practice, suggests that there is merit in teachers employing similar activities as a pedagogical strategy to develop their own students understanding of the concepts underpinning *technological modelling*.

Using emancipatory Action Research design for this study enabled the use of findings to both monitor student achievement and identify opportunities to enhance next learning within and across the research cycles. This use of findings highlighted to, and validated for research teachers, the importance of undertaking ongoing formative assessment. While not an intended outcome of this research, modelling by the researcher of Lewin's 'Scheme of Action' (as cited in Cardino, 2003) where ongoing planning, acting, observing and reflecting were used to determine and support 'next' learning for students, led to research teachers adopting similar pedagogical approaches in their own teaching. Underpinning this pedagogy was ongoing judicious teacher (and researcher) questioning of students about 'why' they were doing the things they were doing (Thompson, 1990) and questioning 'what' they were attempting to achieve when undertaking technological practice. Making observation judgments about the technological practice students were undertaking and the resulting outcomes of this practice, was also an important pedagogical strategy adopted by the teachers and researcher. Such teacher critical reflection, supported by an 'outside' researcher working alongside teachers in their classroom, ensured that a focus remained on improving student understandings and practice (Elliot, 1991; Poskitt, 1994) by applying systematic actions to bring about change (Berg, 2004; Cardno, 2003; Cohen, Manion & Morrison, 2002). An advantage of such an approach was that it allowed the researcher and teachers to observe both "cause and effect" (Cohen, Manion & Morrison, 2002, p.181) of the activities used to enhance student concepts of *technological modelling* and so determine if further activities to raise student conceptual understandings were required.

The application of the action research design (Elliot, 1981; Poskitt, 1994) to identify student learning and determine and implement next steps, also highlighted to research teachers, the importance of providing 'space' in classroom programmes to allow time to revisit student conceptual understandings when a need to do so was identified. Providing this time allowed new activities to be introduced focused on enhancing student understandings and/or to address identified student misconceptions. It meant that opportunity existed to bring about a change, within and across teaching units, in student understandings through building on those which had previously been identified (Berg, 2004; Cardno, 2003; Cohen, Manion & Morrison, 2002).

The category labels for the ‘nature of (student) reasoning’ and the ‘nature of the (students) practice’, identified by this research, present themselves as a useful tool for determining the types of reasoning students are employing and the focus of their decision making when undertaking technological practice. If these labels are used as a formative assessment tool by teachers, to focus interventions with students, they present an opportunity for teachers to identify and address barriers to students developing technological outcomes that they can justify as ‘fit for purpose’. Similarly, as a summative assessment tool, the category labels offer support for teachers to plan ‘next’ or ‘subsequent’ student learning experiences, which include: addressing identified student misconceptions; enhancing how students apply practical and functional reasoning; and focusing their decision making when undertaking technological practice.

Use of the category labels as a teaching tool, also supports teachers to interact with their students within units to enhance their ability to justify, when addressing a need or opportunity, their technological practice and its outcomes for social acceptance and technical feasibility. As such, the tool enables teachers to focus teaching so that students develop the understandings and disposition, that allow them to develop and justify technological outcomes that are ‘fit for purpose’ in their broadest sense (Compton & France, 2007b; Compton, 2007), thus supporting students development of a technological literacy that is ‘broad, deep and critical’ in nature (Compton & France, 2007a; Compton, 2007).

## 6.4 Suggestions for Future Research

The research demonstrated that student achievement of, and decision making within, the components of Technological Practice can be enhanced when student understandings of concepts underpinning *technology modelling* are enhanced through explicit teaching. As such, this research study showed that relationships exists between student understandings of *technological modelling*, their demonstrating achievement against the curriculum level Indicators of Progression for the components of Technological Practice (Compton & Harwood, 2010b), and their reasoning and decision making when engaged in technological practice.

It was outside the framework of this research to explore if similar shifts in students achievement in the components of Technological Practice occur when their understandings in the components in the Nature of Technology strand (*characteristics of technology, characteristics of technological outcomes*) and the other Technological Knowledge components (*technological products and technological systems*) are enhanced. Nor did this research set out to explore if student decision making when undertaking technological practice, was enhanced by placing an explicit teaching focus on these other components in the Nature of Technology strand and the other Technological Knowledge components.

The findings of this research study provide insight into how enhancing student understandings of concepts that underpin *technological modelling*, through explicit teaching activities, can increase student curriculum level achievement in, and decision making within, the components of Technological Practice. Whether or not placing a teaching focus on increasing student understandings in the other components from the Technological Knowledge and Nature of Technology strands of technology in the NZC (Ministry of Education, 2007), will have the same outcomes for students is yet to be determined. A focus for future research that may provide further insight into how to enhance student learning in technology, therefore, may include identifying whether:

- increasing student understandings of concepts underpinning *technological systems* and/or *technological products* impacts on their decision making within technological practice, and achievement in the components of Technological Practice
- increasing students understandings in the component *characteristics of technology* and/or *characteristics of technological outcomes* impacts on student decision making within technological practice
- a relationship exists between student achievement in the components of Technological Practice and their understandings of concept in the Technological Knowledge component(s) - *technological systems* and *technological products*
- a relationship exists, and if so the nature of this relationship, between student understanding of concepts underpinning the Technological Knowledge

components and their understandings in the component *characteristics of technology* and/or *characteristics of technological outcomes*.

### ***Limitation of research***

Whilst the Cycle One (baseline) sample size of student research participants was 50 students, by Cycle Three, the second intervention, this number had reduced to 27 students (n=27). This reduction in research participant numbers was due to students either leaving school at the end of their Year 12 schooling year, or deciding not to continue studying technology in Year 13. As a result of this reduction in student research participant numbers, only 27 complete data sets that included baseline data (Cycle One), first intervention (Cycle Two) and second intervention (Cycle Three) were available for interrogation.

Despite the sample size of student research participants being small (n=27), following this number of students over two years provided opportunity for the researcher to obtain an in-depth and wide breadth of data from the students. To counter the small sample size, and the variability in number of student research participants within schools (School B had thirteen student research participants while School C had five), few comparisons between individual school data were made. Rather, student participants were treated as a single cohort to allow findings to be extrapolated out of these data and themes identified.

The teaching strategies used by the research teachers to enhance student understandings of concepts underpinning *technological modelling*, through intervention, were very similar. These strategies included: the use of case study reports on technologists using technological modelling (functional models and/or prototypes) to inform the development of technological outcomes; and group and class discussion about differences between technological models and how such modelling supports technologists to justify their outcomes as ‘fit for purpose’ in their broadest sense (Compton & France, 2007b; Compton, 2007).

The four students in School C (14.8% of the research students) who opted in Year 13 (Cycle Three), in negotiation with their teacher, to focus their efforts on ‘making products’ rather than undertaking technological practice to ‘develop products’,



provided a disproportionate impact on the research findings. These students were the only students by Cycle Three who continued to focus their decision making on *completing an outcome* – all of the other research students by Cycle Three shifted their decision making to focus on either *best outcome* or *best technological practice*.

Given the small sample size and the similarities in teaching strategies used by the research teachers, this research acknowledges that the themes identified out of this research would have been more defensible and externally valid (Davidson and Tolich, 1999) had the research sample been greater; or compared against a group who were not involved in the interventions.

## 6.6 Conclusion

Notwithstanding the limitations of this research, evidence has been provided to conclude that as a result of explicit teaching activity, focused on enhancing student understandings of concepts underpinning *technological modelling*, students' curriculum level achievement in, and decision making within, the components of Technological Practice can be enhanced. This focus on explicit teaching to enhance student understandings of concepts underpinning *technological modelling* was shown to move students towards developing technological outcomes that they could justify as 'fit for purpose' in the broadest sense (Compton & France, 2007b; Compton, 2007), through applying *practice focused integrated reasoning* and focusing decision making on undertaking *best technological practice*.

Highlighted by the research was the importance of teachers creating space within technology programmes to redress student understandings of concepts underpinning *technological modelling* when they were found to be deficient or misconceived. The research demonstrated that when teachers interact with their students and make such formative assessment judgments about what they have learnt, student conceptual understandings can be enhanced through introducing further focused activity(ies).



This research offers both teachers and researchers a set of connected category labels, which maybe thought of as a conceptual tool, that can provide deep insight into the relationships that exist between the reasoning types student employ and their decision making when undertaking technological practice to address a need or opportunity. When used formatively, this tool supports teachers to categorise student behaviours (data) and focus teaching on enhancing student abilities to develop and justify technological outcomes that are fit for purpose' in their broadest sense (Compton & France, 2007b; Compton, 2007). As shown by the research, these outcomes are realised when student dispositions for decision making is focused on undertaking *best technological practice* and their decision making is informed by *practice focused integrated reasoning*.

I have confidence that if teachers adopt pedagogical practices as used within this research, and employ the category labels as a tool to identify the nature of student reasoning and the focus of their decision making when undertaking technological practice, students will improve their abilities in developing technological outcomes that they are able to justify as fit for purpose in their broadest sense (Compton & France, 2007b; Compton, 2007), thereby supporting them towards a technological literacy that is 'broad deep and critical' in nature (Compton, 2007; Compton & France, 2007a).

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# APPENDIX

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	<i>Page</i>
Appendix A Information Sheet for Research Participants	227
<i>Student Research Participants/Board of Trustees/Principal</i>	
Consent Form	
<i>Board of Trustees</i>	
<i>Student Research Participants</i>	
Appendix B Student Questionnaire	236
Appendix C Interview Questions	239
Appendix D Indicators of Progression for Technological Practice	241
Appendix E Indicators of Progression for Technological Modelling	251

## **APPENDIX A**

### **Information Sheet for Research Participants**

*Student Research Participants/Board of Trustees/Principal*

### **Consent Form**

*Board of Trustees*

*Student Research Participants*



**Massey University**  
COLLEGE OF EDUCATION  
Te Kupenga o Te Mātauranga

Centre for Educational Development  
Private Bag 11 222  
PALMERSTON NORTH  
New Zealand

Website:  
<http://ced.massey.ac.nz>

Phone: 06 350 9269  
Fax: 06 350 9288

<teacher name>

<school>

<address>

<date>

Dear <BOT/Principal>

Enclosed is an Information Sheet on a thesis research study called *Fitness for Purpose: Exploring the impact of technological modelling on student justifications*<sup>49</sup> that I am conducting to complete my PhD at Massey University. This research study is focused on identifying if students are better able to justify their technological outcomes to resolve an issue when their learning is supported by understandings developed through focused teaching on two components from the Nature of Technology and Technological Knowledge strands of technology in the New Zealand Curriculum (Ministry of Education, 2007) – *technological modelling*.

Also enclosed are two copies of a Consent Form. Can I please ask that you complete one of these forms and return it to me in the enclosed addressed envelope, to indicate your willingness to allow teachers and students from your school to participate in this research study.

If you have any questions, please do not hesitate to contact me at:

Ph: 06 354 1097  
Mobile 0274 303 324  
Email: c.d.harwood@mohsl.co.nz

or one of my supervisors

Dr Jenny Poskitt  
Work Phone: 06 350 9099  
Email: j.m.poskitt@massey.ac.nz

Dr Vicki Compton  
Work Phone: 04 802 4353  
Email: v.compton@ackland.ac.nz

Yours sincerely

Cliff Harwood

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<sup>49</sup> Note title of research changed to: *Enhancing Student Decision Making in Technological Practice*.

# Enhancing Decision Making: Exploring the impact of Technological Modelling within technological practice

## INFORMATION SHEET (Teacher Participants /BOT/Principal)

### Researcher Introduction

A research study to identify if students are better able to justify their technological outcomes to resolve an issue when their learning is supported by understandings developed through focused teaching on the curriculum component *Technological Modelling* is to be conducted by Cliff Harwood. This research called *Enhancing Decision Making: Exploring the impact of Technological Modelling within technological practice* is part of Cliff's study towards a Doctoral study at Massey University. Cliff's research is being supervised by Dr Jenny Poskitt, Massey University College of Education and Dr Vicki Compton, Research Director, UniServices Ltd, The University of Auckland.

Cliff is currently employed on contract by the Ministry of Education as the National Professional Development Manager for Technology Education. A key role for Cliff in this contract is to provide research informed professional development to pre-service lecturers and in-service advisers in technology education at the Colleges of Education.

*Technology in the New Zealand Curriculum* (Ministry of Education, 1995) is now in its twelfth year of being taught in New Zealand schools as a compulsory learning area under the New Zealand Curriculum Framework (Ministry of Education, 1993). The Ministry of Education under the recently released New Zealand Curriculum [NZC] (Ministry of Education, 2007) has redefined Technology by identifying key knowledge and practices which are essential for working across all technological fields of endeavour and included a focus on the philosophy of technology. This has resulted in technology in NZC (Ministry of Education, 2007) now being structured into three curriculum strands:

- Technological Practice
- Nature of Technology
- Technological Knowledge

Each of these strands has been divided into sub-strands called *components*. The components of the Technological Practice strand are: *brief development, planning for practice* and *outcome development and evaluation*. The Nature of Technology strand components are: *characteristics of technological outcomes* and *characteristics of technology* and the components of the Technological Knowledge strand are: *technological products, technological systems* and *technological modelling*.

Since 2004, students have been able to sit qualifications specifically written for technology, in the National Certificate of Educational Assessment (NCEA) at Levels 1, 2 and 3, and Scholarship. At Level 2 and 3 there are technology achievement standards that focus on assessing students' abilities to:

- develop and model a conceptual design of a technological outcome (Achievement standard AS2.1 and AS3.1)
- develop and implement a one-off solution in technology (Achievement standard AS2.2 and AS3.2).

Achievement standards AS2.1 and AS3.1 require students to justify that the conceptual designs they develop have the *potential* to resolve the identified issue. To support such justifications, students need to demonstrate the effective use of technological modelling techniques. When assessed against AS2.2 and AS3.2 students need to justify that the one-off solution they develop *resolves* the issue (i.e. that their developed one-off solution is 'fit for purpose'). To do this, students must provide evidence of their solution functioning

within the environment for which it was intended. Due to the introduction of the NZC (Ministry of Education, 2007) all technology achievement standards are to be reviewed and where necessary rewritten to ensure that they align with technology as defined by this curriculum. This review is to begin in 2008 with the intention that the standards will be first registered for use in 2010 when the NZC (Ministry of Education) is gazetted and made mandatory for all schools to deliver from years 1-10. The National Moderator Reports<sup>50</sup> over the last three years have highlighted, that as yet student evidence presented for assessment against achievements standards AS2.1, 2.2 3.1 and 3.2 lacks substantiated justifications of either the *potential* (AS2.1 and AS3.1) or actual *fit for purpose* (AS2.2 and AS3.2) of the solution to resolve the issue.

This research will seek to identify whether students are better able to justify their technological outcomes - either in terms of it *potential* (AS2.1 and 3.1) or actual *fit for purpose* (AS2.2 and AS3.2) to resolve an issue when their learning is supported by understandings developed through focused teaching on concepts underpinning *Technological Modelling*. It will also focus on identifying understanding these concepts provides students with sufficient conceptual understandings to support them to undertake technological practice when developing conceptual designs and/or one-off solutions that meet the requirements of the Level 2 and particularly, the Level 3 standards. The study will focus on senior secondary school students (years 12 -13).

An additional outcome from this research will be the opportunity to determine valid and reliable means for identifying student understandings of the concepts embedded in the *Technological Modelling* component. This information will be useful to the Ministry of Education as they undertake to redevelop the Levels 1, 2 and 3 Technology Achievement Standards and Scholarship Standard to ensure their alignment with the 2007 technology curriculum when it is implemented in 2010.

### **Participant Recruitment**

Teachers who are:

- currently providing opportunity for their students to develop technological outcomes through the undertaking of technological practice
- likely to teach students in years 12 and 13 in 2008 and 2009, and offer them opportunity for assessment against either AS 2.1, AS2.2, AS3.1 and/or AS3.2
- have demonstrated a past willingness to trial innovative strategies that motivate, challenge and support students to present evidence of learning that represents their 'best' efforts

will be invited to participate in this research study.

Up to ten students from these teachers year 12 and/or 13 classes will be invited to participate in this research study. The criteria used to select students who will be invited to participate in this are:

1. only those students who have studied technology at year 11 in 2007
2. ensuring that a range of student ability levels are represented in the overall cohort of student participants involved in the research
3. ensuring that an overall gender balance is attained across the total student participants involved in the research
4. that invited students are likely, if year 12 in 2008, to continue their studies in technology in 2009.

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<sup>50</sup> This is an annual report written by the NZQA National Moderator which reports on student achievement of the internally assessed achievement standards. This report identifies the strengths and weaknesses found in the student evidence which has been assessed and moderated against these standards as well as suggesting areas for teachers to focus on to better support their students to demonstrate the competencies required for award of achievement grads for these standards.

The researcher will work with the teacher participants to ensure that this research study does not interfere with student participants (or other students in the technology classes) overall learning in technology and in their other school subjects.

### **Project Procedures**

Permission to conduct the research study will be obtained from school management/Boards of Trustees, participant teachers and students prior to the study commencing.

The main method of collecting research data from student participants will be via observation of students undertaking technological practice, analysis of student evidence presented for assessment against achievement standards 2.1, 2.2, 3.1 and/or 3.2, and data collected from interacting with students as they undertake their technological practice.

Planned teaching lessons/programmes from the teacher participants that focus on teaching concepts underpinning *Technological Modelling* will be analysed alongside observation of the pedagogical practices they use with their technology classes. This will assist the researcher to identify how students are encouraged and supported to justify their technological outcomes - either in terms of its *potential* (AS2.1 and 3.1) or *actual fit for purpose* (AS2.2 and AS3.2) to resolve an issue when their learning is supported by understandings developed and the strategies used to enhance students understandings about *Technological Modelling*.

To ensure anonymity of research participants and their schools names, all data that associates participants with a particular school, and participant names will be removed from all research data. All individual participants' data will be aggregated and this will be used to support any reported research results, so that readers cannot identify individual participants.

### **Participant involvement**

Teacher participants will be asked to:

- provide the researcher access to their planned teaching lessons for technology (programme)
- allow the researcher to observe their technology lessons when students are developing technological outcomes and producing evidence for assessment against AS 2.1, 2.2, 3.1 and/or 3.2
- allow opportunity for the researcher to question student participants, if required, to clarify the technological practice they have undertaken.

Student participants will be asked to:

- provide the researcher access to examples of past technological practice they have undertaken to model a conceptual design and/or implement a one-off solution
- allow the researcher to observe and discuss with them the justifications they provide for why their technological outcome (a modelled conceptual design and/or an implemented one-off solution) is fit for purpose.

It is anticipated that the research study will require approximately two hours of each participants' time during the time that the research study will be conducted. A unique identifier (e.g. number and/or letter) will be placed on all participant research data so that the individual identity of participants and their school is kept anonymous.

Due to an *action research* methodology being adopted for this research study, opportunity exists for identified research findings/trends to be reported back to research participants during the undertaking of this study. Such reporting may assist teachers in

the way they present learning opportunities to their students concerning *Technological Modelling*. It may also assist students to improve the way they go about justifying their technological outcomes as being fit for purpose. In doing this, the reported research findings/trends, if acted upon, could strengthen the teaching and delivery of the technology programme for all students in the class, not just those who are participating in the research study. Research data will at no stage *during* the research study be reported back to the Ministry of Education or other potentially interested parties. Findings at the *conclusion* of this research study will however be offered to interested parties to allow them insight into its outcomes.

### **Participants' Rights**

Teacher and student participants are under no obligation to accept this invitation to participate in the research study. If you decide to participate, you have the right to:

- decline to answer any particular question asked by the researcher
- withdraw from the research study at any stage during the data collection stage of the research
- ask the researcher or his supervisors any questions about the research study at any time during participation
- provide information on the understanding that your name will not be used unless you give permission to the researcher
- be given access to a summary of the research study findings when it is concluded.

### **Project Contacts**

If you have any further questions concerning this research study please do not hesitate to contact either:

#### **The Researcher**

#### **Cliff Harwood**

Cell Phone: 0274 303 324  
Email: c.d.harwood@mohsl.co.nz

#### *or Cliff's supervisors*

#### **Dr Jenny Poskitt**

Work Phone: 06 350 9099  
Email: j.m.poskitt@massey.ac.nz

#### **Dr Vicki Compton**

Work Phone: 04 802 4353  
Email: v.compton@auckland.ac.nz

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### **Committee Approval Statement**

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*This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 08/01. If you have any concerns about the conduct of this research, please contact Dr Karl Pajo, Chair, Massey University Human Ethics Committee: Southern B, telephone 04 801 5799 x 6929, email humanethicssouthb@massey.ac.nz.*



# Fitness for Purpose: Exploring the impact of Technological Modelling on student justifications<sup>51</sup>

## BOT/PRINCIPAL PARTICIPANT CONSENT FORM

This consent form will be held for a period of five (5) years

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to students and teachers from <name of school> participating in this study under the conditions set out in the Information Sheet.

**Signature:**

**Date:**

.....

**Full Name (printed)**

**Designation**

.....

.....

---

<sup>51</sup> Note: title of research changed to: *Enhancing Student Decision Making in Technological Practice*.

# Fitness for Purpose: Exploring the impact of Technological Modelling on student justifications<sup>52</sup>

## STUDENT PARTICIPANT CONSENT FORM

This consent form will be held for a period of five (5) years

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

**Signature:**

**Date:**

**Full Name (printed)**

**School:**

<name of school>

---

<sup>52</sup> Note: title of research changed to: *Enhancing Student Decision Making in Technological Practice*.

## **APPENDIX B**

### Student Questionnaire

## STUDENT QUESTIONNAIRE

### Technological Modelling

1. What do you think the purpose is for undertaking technological modelling when developing a technological outcome?
  
2. What type(s) of technological modelling have you used in your current technology project?
  - a. *where did you use these different types of technological models within your technological practice*
  
3. Why did you use these different types of modelling during your technological practice (ie *what where you attempting to find out by using each of the different types of technological modelling*)?
  - a. *what specific evidence/information did each of the technological models you used provide you with?*
  
  - b. *what impact did this evidence have on your technological practice and/or the development of the technological outcome?*
  
4. Were there any findings, that you identified from technological modelling, that contradicted what you and/or your stakeholders believed to be true? (e.g. the best material to use in your technological outcome etc).
  - a. *if so, what where they and whose opinion/beliefs did they contradict (yours and/or your stakeholders)*

yes/no

*Cross out*

*b. how did you deal with findings that contradicted what you and/or your stakeholders believed to be true.*

5. How confident are you that the technological outcome you have developed (are developing) is (will be) fit for purpose (i.e. will/does it address the problem that you are attempting to/have resolved)?

*confident/not confident*

*Cross out*

*a. what evidence do you have to support this confidence*

*b. if you are not confident – at what point in your technological practice, did you become aware that your outcome was (or wasn't) the best solution.*

## **APPENDIX C**

### Interview Questions – SAMPLE

# INTERVIEW QUESTIONS – SAMPLE

## Interview Questions June 2009

1. What do you think the purpose is for undertaking technological modelling when developing a technological outcome?
2. What type(s) of technological modelling have you used in your current technology project?
  - a. *where did you use these different types of technological models within your technological practice*
3. Why did you use these different types of modelling?
  - a. *explain why you used different types of modelling during your technological practice*
    - i. *what where you attempting to find out by using each of the different types of technological modelling*
  - b. *what specific evidence/information did each of the technological models you used provide you with*
  - c. *what impact did this evidence have on your technological practice and/or the development of the technological outcome.*
4. Were there any findings, that you identified from technological modelling, that contradicted what you and/or your stakeholders believed to be true? (e.g. the best material to use in your technological outcome; the most important design features to include in your technological outcome etc. – prompt if needed)
  - a. *if so, what where they and whose opinion/beliefs did they contradict (yours and/or your stakeholders)*
  - b. *how did you deal with findings that contradicted what you and/or your stakeholders believed to be true.*
5. What are some of the ‘key’ design decisions you had to make when developing your technological outcome
  - a. *what supported you to make these decisions/ allowed you to justify these design decisions as being correct*
  - b. *why where these design decisions ‘key’*
6. How confident are you that the technological outcome you have developed (are developing) is (will be) fit for purpose (i.e. will/does it address the problem that you are attempting to/have resolved)?
  - a. *what evidence do you have to support this confidence*
  - b. *if you are not confident – at what point in your technological practice, did you become aware that your outcome was (or wasn't) the best solution.*



## APPENDIX D

### Indicators of Progression for Technological Practice

## TECHNOLOGY INDICATORS OF PROGRESSION

The Indicators of Progression provide support for teachers to interpret the Achievement Objectives (AOs) for each strand of the technology curriculum within *The New Zealand Curriculum* (NZC) (2007). There are three matrices, each focused on one of the three strands of the technology curriculum, describing the eight levels of the NZC. Each matrix:

- restates the Achievement Objectives for each level
- provides guidance to teachers on what they could do to support student learning at each level
- provides indicators of what students should know or be able to do at each level.

The *Teacher Guidance* highlights the importance of the teacher's role in supporting student learning. It also acknowledges how the nature of teaching needs to change to ensure students are able to take more responsibility for their learning as they progress from levels 1-8 of the NZC. This has been emphasised by using the following terms to denote this shift in responsibilities from teacher to student.

- **Provide** is used when the teacher takes full responsibility for introducing and explicitly teaching new knowledge/skill or practices.
- **Guide** is used when the teacher assumes students will have some level of understanding/competency to draw from but continues to take the majority of the responsibility for developing these understandings further.
- **Support** is used when the balance shifts towards the student taking more responsibility for their learning, drawing from their past learning to consolidate and extend their understandings. In this case the teacher plays a more supportive role through questioning and challenging students to support them in their learning.

The *Teacher Guidance* also uses the term **ensure** to denote when the teacher plays a monitoring role to check that conditions critical for learning are present. For example, in 'planning for practice' and 'outcome development and evaluation' the teacher must ensure an appropriate brief is available to guide student work.

The *Indicators* describe generic understandings and capabilities that students should be able demonstrate consistently if they are to be considered to have met the related achievement objective. The indicators for each level should be viewed 'collectively' as indicating the AO at that level. Partial and/or inconsistent student demonstration of the indicators shows that additional and/or further consolidation learning experiences need to be provided to the student. This will ensure that future learning provides the opportunities necessary for the student to demonstrate the achievement described by all of the indicators at that level. It is expected that teachers will contextualise the indicators by re-phrasing them into appropriate language for the unit being studied, and the students they are teaching. By doing this the indicators can be used as targeted learning goals and assessment tools inside the classroom to plan for, guide, and acknowledge student learning.

The *Teacher Guidance* and *Indicators* have been developed through classroom research and refined through subsequent trialling. They are provided to guide formative and summative assessment practices, planning decisions and the development of effective and efficient reporting mechanisms for multiple audiences, including the students, their caregivers, and future teachers both within and across schools.

All three matrices will be periodically reviewed as implementation of the three strands proceeds and further development work in technology is undertaken.



## COMPONENTS OF TECHNOLOGICAL PRACTICE: INDICATORS OF PROGRESSION LEVEL ONE

Teachers should establish if students hold any misconceptions or partial understandings that would inhibit students meeting the level one achievement objectives for the technological practice, and plan learning experiences to challenge and/or progress these as guided by the level one Indicators below.

Brief Development	Planning for Practice	Outcome Development & Evaluation
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Describe the outcome they are developing and identify the attributes it should have, taking account of the need or opportunity and the resources available.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Outline a general plan to support the development of an outcome, identifying appropriate steps and resources.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Investigate a context to communicate potential outcomes. Evaluate these against attributes; select and develop an outcome in keeping with the identified attributes.</p>
<p><b>TEACHER GUIDANCE</b> To support students to undertake brief development at level one teachers could:</p> <ul style="list-style-type: none"> <li>• provide the need or opportunity and develop the conceptual statement in negotiation with the students</li> <li>• provide a range of attributes for discussion</li> <li>• guide students to identify the attributes an appropriate outcome should have.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake planning for practice at level one teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief against which planning to develop an outcome can occur</li> <li>• provide students with a detailed plan of what they will be doing during their technological practice. This could be presented and explained as a design process the teacher has developed, with key stages that need to happen clearly identified within it</li> <li>• provide a range of appropriate resources for students to select those suitable for their use. Teachers should ensure all resources provided are appropriate for use and students should only be responsible for selecting particular materials components, and/or software from these resources.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake outcome development and evaluation at level one teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief with attributes against which a developed outcome can be evaluated</li> <li>• establish an environment that encourages and supports student innovation when generating design ideas</li> <li>• provide opportunities to develop drawing and modelling skills to communicate and explore design ideas. Emphasis should be on progressing 2D and 3D drawing skills and using manipulative media such as plasticine, wire, card etc</li> <li>• provide opportunities to develop skills required to produce their outcome.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• communicate the outcome to be produced</li> <li>• identify attributes for an outcome.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• identify what they will do next</li> <li>• identify the particular materials, components and/or software they might use.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• describe potential outcomes, through drawing, models and/or verbally.</li> <li>• identify potential outcomes that are in keeping with the <b>attributes</b>, and selects one to produce</li> <li>• produce an outcome in keeping with identified attributes.</li> </ul>

**COMPONENTS OF TECHNOLOGICAL PRACTICE: INDICATORS OF PROGRESSION****LEVEL TWO**

Teachers should establish if students have developed robust level one competencies and are ready to begin working towards level two achievement objectives for the technological practice components, and plan learning experiences to progress these as guided by the level two Indicators below.

<b>Brief Development</b>	<b>Planning for Practice</b>	<b>Outcome Development &amp; Evaluation</b>
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Explain the outcome they are developing and describe the attributes it should have, taking account of the need or opportunity and the resources available.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Develop a plan that identifies the key stages and the resources available.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Investigate a context to develop potential outcomes. Evaluate these against identified attributes; select and develop an outcome. Evaluate the outcome in terms of the need/opportunity.</p>
<p><b>TEACHER GUIDANCE</b> To support students to undertake brief development at level two teachers could:</p> <ul style="list-style-type: none"> <li>provide the need or opportunity and develop the conceptual statement in negotiation with the students</li> <li>guide students to discuss the implications of the need or opportunity and the conceptual statements and support them to establish a list of attributes an appropriate outcome could have</li> <li>provide students with an overview of the resources available and guide them to take this into account when identifying the attributes for the outcome</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake planning for practice at level two teachers could:</p> <ul style="list-style-type: none"> <li>ensure that there is a brief against which planning to develop an outcome can occur</li> <li>provide students with an overview of the stages they will be working through during their technological practice. This could be presented and explained as a design process the teacher has developed, and it could be used to support students to identify what the key stages are</li> <li>provide a range of appropriate resources and guide students to decide which particular materials components, and/or software will be required for each key stage Teachers should ensure all resources provided are appropriate for use.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake outcome development and evaluation at level two teachers could:</p> <ul style="list-style-type: none"> <li>ensure that there is a brief with attributes against which a developed outcome can be evaluated</li> <li>establish an environment that encourages and supports student innovation when generating design ideas</li> <li>provide opportunities to develop drawing and modelling skills to communicate and explore design ideas. Emphasis should be on progressing 2D and 3D drawing skills and using manipulative media such as plasticine, wire, card etc</li> <li>provide opportunities to develop skills required to produce their outcome</li> <li>guide students to evaluate their outcome against the brief.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>explain the outcome to be produced</li> <li>describe the attributes for an outcome that take account of the need or opportunity being addressed and the resources available.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>identify key stages required to produce an outcome</li> <li>identify the particular materials, components and/or software required for each key stage.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>describe potential outcomes, through drawing, models and/or verbally</li> <li>evaluate potential outcomes in terms of identified attributes to select the outcome to produce</li> <li>produce an outcome in keeping with the brief</li> <li>evaluate the final outcome in terms of how successfully it addresses the brief.</li> </ul>



## COMPONENTS OF TECHNOLOGICAL PRACTICE: INDICATORS OF PROGRESSION **LEVEL THREE**

Teachers should establish if students have developed robust level two competencies and are ready to begin working towards level three achievement objectives for the technological practice components, and plan learning experiences to progress these as guided by the level three Indicators below

Brief Development	Planning for Practice	Outcome Development & Evaluation
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Describe the nature of an intended outcome, explaining how it addresses the need or opportunity. Describe the key attributes that enable development and evaluation of an outcome.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Undertake planning to identify the key stages and resources required to develop an outcome. Revisit planning to include reviews of progress and identify implications for subsequent decision making.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Investigate a context to develop ideas for potential outcomes. Trial and evaluate these against key attributes to select and develop an outcome to address the need or opportunity. Evaluate this outcome against the key attributes and how it addresses the need or opportunity.</p>
<p><b>TEACHER GUIDANCE</b> To support students to undertake brief development at level three teachers could:</p> <ul style="list-style-type: none"> <li>• provide the need or opportunity and develop the conceptual statement in negotiation with the students</li> <li>• guide students to describe the physical and functional nature of an outcome (e.g. what it looks like and what it can do) taking into account the need or opportunity, conceptual statements and resources available</li> <li>• guide students to identify the key attributes an appropriate outcome should have. Key attributes reflect those that are deemed essential for the successful function of the outcome.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake planning for practice at level three teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief against which planning to develop an outcome can occur</li> <li>• provide students with an overview of what they will need to do during their technological practice and guide students to identify key stages and place these on a timeline of some sort</li> <li>• provide resources including a range of appropriate materials, components, software, hardware, equipment, and/ or tools for students to select from and guide students to select those that will be suitable for their outcome</li> <li>• guide students to reflect on progress to make informed decisions regarding next steps.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake outcome development and evaluation at level three teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief with attributes against which a developed outcome can be evaluated</li> <li>• establish an environment that encourages and supports student innovation when generating design ideas</li> <li>• provide opportunities to develop drawing and modelling skills to communicate and explore design ideas. Emphasis should be on progressing 2D and 3D drawing skills and using manipulative media such as plasticine, wire, card etc</li> <li>• provide opportunity to develop knowledge and skills related to the performance properties of the materials/components students could use</li> <li>• support students to evaluate their outcome against the brief.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• describe the physical and functional nature of the outcome they are going to produce and explain how the outcome will have the ability to address the need or opportunity</li> <li>• describe attributes for the outcome and identify those which are key for the development and evaluation of an outcome.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• identify key stages, and resources required, and record when each stage will need to be completed to make sure an outcome is completed</li> <li>• explain progress to date in terms of meeting key stages and use of resources, and discuss implications for what they need to do next.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• describe design ideas (either through drawing, models and/or verbally) for potential outcomes</li> <li>• evaluate design ideas in terms of key attributes to develop a conceptual design for the outcome</li> <li>• select materials/components, based on their performance properties, for use in the production of the outcome</li> <li>• produce an outcome that addresses the brief</li> <li>• evaluate the final outcome against the key attributes to determine how well it met the need or opportunity.</li> </ul>



## COMPONENTS OF TECHNOLOGICAL PRACTICE: INDICATORS OF PROGRESSION LEVEL FOUR

Teachers should establish if students have developed robust level three competencies and are ready to begin working towards level four achievement objectives for the technological practice components, and plan learning experiences to progress these as guided by the level four Indicators below.

Brief Development	Planning for Practice	Outcome Development & Evaluation
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Justify the nature of an intended outcome in relation to the need or opportunity. Describe the key attributes identified in stakeholder feedback, which will inform the development of an outcome and its evaluation.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Undertake planning that includes reviewing the effectiveness of past actions and resourcing, exploring implications for future actions and accessing of resources, and consideration of stakeholder feedback, to enable the development of an outcome.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Investigate a context to develop ideas for feasible outcomes. Undertake functional modelling that takes account of stakeholder feedback, in order to select and develop the outcome that best addresses the key attributes. Incorporating stakeholder feedback, evaluate the outcome's fitness for purpose in terms of how well it addresses the need or opportunity.</p>
<p><b>TEACHER GUIDANCE</b> To support students to undertake brief development at level four teachers could:</p> <ul style="list-style-type: none"> <li>• provide an appropriate context and issue that allows students to access resources (including key stakeholders)</li> <li>• guide students to identify a need or opportunity and develop a conceptual statement</li> <li>• support students to understand the physical and functional nature required of their outcome, and how the key attributes relate to this</li> <li>• guide students to consider the key stakeholders and the environment where the outcome will be located.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake planning for practice at level four teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief against which planning to develop an outcome can occur</li> <li>• provide resources including a range of appropriate stakeholders, materials, components, software, hardware, equipment, and/or tools for students to select from and support students to select those that will be suitable for their outcome</li> <li>• provide planning tools and support students to use these to record key stages and resources needed, including when they will need to access stakeholder feedback, and to (Please note; records only need to capture what students plan to do and what they need to do it to guide their practice and allow them to review this regularly)</li> <li>• support students to identify regular review points and to review their progress at these points</li> <li>• guide students to manage time and organise their selected resources .based on regular reviews of progress</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake outcome development and evaluation at level four teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief with attributes against which a developed outcome can be evaluated</li> <li>• establish an environment that encourages and supports student innovation when generating design ideas</li> <li>• provide opportunities to develop drawing and modelling skills to communicate and explore design ideas. Emphasis should be on progressing 2D and 3D drawing skills and increasing the range and complexity of functional modelling</li> <li>• provide a range of materials/components and support students to develop the necessary knowledge and skills to test and use them</li> <li>• guide students to evaluate outcomes in situ against key attributes.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• identify a need or opportunity from the given context and issue</li> <li>• establish a conceptual statement that communicates the nature of the outcome and why such an outcome should be developed</li> <li>• establish the key attributes for an outcome informed by stakeholder considerations</li> <li>• communicate key attributes that allow an outcome to be evaluated as fit for purpose.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• use planning tools to manage time, identify and record key stages, associated resources, and actions to be undertaken, with progress review points clearly indicated</li> <li>• review progress at set review points, and revise time management as appropriate to ensure completion of an outcome.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• describe design ideas (either through drawing, models and/or verbally) or potential outcomes</li> <li>• undertake functional modelling to develop design ideas into a conceptual design that addresses the key attributes</li> <li>• test the key performance properties of materials/ components to select those appropriate for use in the production of a feasible outcome</li> <li>• produce and trial a prototype of the outcome</li> <li>• evaluate the fitness for purpose of the final outcome against the key attributes.</li> </ul>



**COMPONENTS OF TECHNOLOGICAL PRACTICE: INDICATORS OF PROGRESSION****LEVEL FIVE**

Teachers should establish if students have developed robust level four competencies and are ready to begin working towards level five achievement objectives for the technological practice components, and plan learning experiences to these as guided by the level five indicators below.

<b>Brief Development</b>	<b>Planning for Practice</b>	<b>Outcome Development &amp; Evaluation</b>
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Justify the nature of an intended outcome in relation to the need or opportunity. Describe specifications that reflect key stakeholder feedback and that will inform the development of an outcome and its evaluation.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Analyse their own and others' planning practices to inform the selection and use of planning tools. Use these to support and justify planning decisions (including those relating to the management of resources) that will see the development of an outcome through to completion.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Analyse their own and others' outcomes to inform the development of ideas for feasible outcomes. Undertake ongoing functional modelling and evaluation that takes account of key stakeholder feedback and trialling in the physical and social environments. Use the information gained to select and develop the outcome that best addresses the specifications. Evaluate the final outcome's fitness for purpose against the brief.</p>
<p><b>TEACHER GUIDANCE</b> To support students to undertake brief development at level five teachers could:</p> <ul style="list-style-type: none"> <li>• provide an appropriate context and issue that allows students to access resources (including key stakeholders)</li> <li>• support students to identify a need or opportunity and develop a conceptual statement</li> <li>• support students understand the physical and functional nature required of their outcome</li> <li>• guide students to develop key attributes into specifications.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake planning for practice at level five teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief against which planning to develop an outcome can occur</li> <li>• provide a range of planning tools and support students to analyse these to inform selection of the tools they will use to manage and efficiently record their planning</li> <li>• support students to review and evaluate progress to inform their ongoing planning decisions</li> <li>• guide students to ensure appropriate resources are available (stakeholder/s, materials, components, software, equipment, tools and/or hardware) suitable for their outcome</li> <li>• support students to manage time and resources, including stakeholder interactions.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake outcome development and evaluation at level five teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief with clear specifications against which a developed outcome can be evaluated</li> <li>• establish an environment that supports student innovation and encourages analysis of existing outcomes</li> <li>• provide opportunities to develop drawing and modelling skills to communicate and explore design ideas. Emphasis should be on progressing 2D and 3D drawing skills and increasing the range and complexity of functional modelling</li> <li>• provide a range of materials/components and support students to develop the necessary knowledge and skills to evaluate and use them</li> <li>• guide students to evaluate outcomes in situ against brief specifications.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• identify a need or opportunity from the given context and issue</li> <li>• establish a conceptual statement that justifies the nature of the outcome and why such an outcome should be developed</li> <li>• establish the specifications for an outcome based on the nature of the outcome required to address the need or opportunity, and informed by key stakeholder considerations</li> <li>• communicate specifications that allow an outcome to be evaluated as fit for purpose.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• analyse own and others use of planning tools to inform the selection of tools best suited for their use to plan and monitor progress and record key decisions</li> <li>• use planning tools to identify and record key stages, and manage time and resources (including stakeholder interactions) to ensure completion of an outcome</li> <li>• use planning tools to record key planning decisions regarding the management of time, resources and stakeholder interactions.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• generate design ideas that are informed by research and analysis of existing outcomes</li> <li>• undertake functional modelling to develop design ideas into a conceptual design that addresses the specifications</li> <li>• evaluate suitability of materials/components, based on their performance properties, to select those appropriate for use in the production of a feasible outcome</li> <li>• produce and trial a prototype of the outcome</li> <li>• evaluate the fitness for purpose of the final outcome against the specifications.</li> </ul>



**COMPONENTS OF TECHNOLOGICAL PRACTICE: INDICATORS OF PROGRESSION****LEVEL SIX**

Teachers should establish if students have developed robust level five competencies and are ready to begin working towards level six achievement objectives for the technological practice components, and plan learning experiences to progress these as guided by the level six indicators below.

<b>Brief Development</b>	<b>Planning for Practice</b>	<b>Outcome Development &amp; Evaluation</b>
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Justify the nature of an intended outcome in relation to the need or opportunity and justify specifications in terms of key stakeholder feedback and wider community considerations.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Critically analyse their own and others' past and current planning practices in order to make informed selection and effective use of planning tools. Use these to support and justify ongoing planning that will see the development of an outcome through to completion.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Critically analyse their own and others' outcomes to inform the development of ideas for feasible outcomes. Undertake ongoing experimentation and functional modelling, taking account of stakeholder feedback and trialling in the physical and social environments. Use the information gained to select, justify, and develop a final outcome. Evaluate this outcome's fitness for purpose against the brief and justify the evaluation using feedback from stakeholders.</p>
<p><b>TEACHER GUIDANCE</b> To support students to undertake brief development at level six teachers could:</p> <ul style="list-style-type: none"> <li>• provide an appropriate context and issue that allows students to access resources (including key stakeholders) and guide them to take into account wider community considerations</li> <li>• support students to identify a need or opportunity relevant to the given issue and context</li> <li>• support students to understand the physical and functional nature required of their outcome</li> <li>• support students to develop specifications and justify them based on key and wider community stakeholder considerations.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake planning for practice at level six teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief against which planning to develop an outcome can occur</li> <li>• support students to critically analyse a range of planning tools that have been used in past practice</li> <li>• support students to select planning tools that will provide appropriate support for their practice and efficient recording of why key planning decisions were made</li> <li>• support students to ensure appropriate resources are available (stakeholder/s, materials, components, software, equipment, tools and/or hardware) suitable for their outcome</li> <li>• support students to use selected tools to manage resources to ensure completion of an outcome.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to undertake outcome development and evaluation at level six teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief with clear specifications against which a developed outcome can be evaluated</li> <li>• establish an environment that supports student innovation and encourages critical analysis of existing outcomes</li> <li>• support students to develop drawing and modelling skills to communicate and explore design ideas. Emphasis should be on progressing 2D and 3D drawing skills and increasing the range and complexity of functional modelling</li> <li>• support students to explore a range of materials/ components and to develop the necessary knowledge and skills to evaluate and use them</li> <li>• support students to undertake prototyping to evaluate the outcome's fitness for purpose and identify any further development requirements</li> <li>• support students to gain targeted stakeholder feedback.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• identify a need or opportunity from the given context and issue</li> <li>• establish a conceptual statement that justifies the nature of the outcome and why such an outcome should be developed</li> <li>• establish the specifications for an outcome as based on the nature of the outcome required to address the need or opportunity, consideration of the environment in which the outcome will be situated and resources available</li> <li>• communicate specifications that allow an outcome to be evaluated as fit for purpose.</li> <li>• justify the specifications in terms of key and wider community stakeholder considerations.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• critically analyse own and others use of planning tools to inform the selection of planning tools best suited for their use to plan and monitor progress and record reasons for planning decisions</li> <li>• use planning tools to establish and review key stages, identify and manage all resources, and to determine and guide actions to ensure completion of an outcome</li> <li>• use planning tools to record initial plans and ongoing revisions in ways which provide reasons for planning decisions made.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• generate design ideas that are informed by research and the critical analysis of existing outcomes</li> <li>• undertake functional modelling to refine design ideas and enhance their ability to address the specifications</li> <li>• evaluate design ideas in terms of their ability to support the development of a conceptual design for a feasible outcome</li> <li>• evaluate the conceptual design against the specifications to determine the proposed outcomes potential fitness for purpose</li> <li>• evaluate suitability of materials/components, based on their performance properties, to select those appropriate for use in the production of a feasible outcome</li> <li>• produce and trial a prototype of the outcome to evaluate its fitness for purpose and identify any changes that would enhance the outcome</li> <li>• use stakeholder feedback to support and justify key design decisions and evaluations of fitness for purpose.</li> </ul>

**Components of TECHNOLOGICAL PRACTICE: indicators of progression**

Vicki Compton and Cliff Harwood: Version 4: October 2010

For context and the latest version, see <http://technology.tki.org.nz/Curriculum-support/Indicators-of-Progression>



**COMPONENTS OF TECHNOLOGICAL PRACTICE: INDICATORS OF PROGRESSION****LEVEL SEVEN**

Teachers should establish if students have developed robust level six competencies and are ready to begin working towards level seven achievement objectives for the technological practice components, and plan learning experiences to progress these as guided by the level seven Indicators of Achievement below.

<b>Brief Development</b>	<b>Planning for Practice</b>	<b>Outcome Development &amp; Evaluation</b>
<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Justify the nature of an intended outcome in relation to the issue to be resolved and justify specifications in terms of key stakeholder feedback and wider community considerations.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Critically analyse their own and others' past and current planning and management practices in order to develop and employ project management practices that will ensure the effective development of an outcome to completion.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Critically analyse their own and others' outcomes and evaluative practices to inform the development of ideas for feasible outcomes. Undertake a critical evaluation that is informed by ongoing experimentation and functional modelling, stakeholder feedback, and trialling in the physical and social environments. Use the information gained to select, justify, and develop an outcome. Evaluate this outcome's fitness for purpose against the brief. Justify the evaluation using feedback from stakeholders and demonstrating a critical understanding of the issue.</p>
<p><b>TEACHER GUIDANCE</b></p> <p>To support students to undertake brief development at level seven teachers could:</p> <ul style="list-style-type: none"> <li>• provide a context that offers a range of issues for students to explore</li> <li>• guide students to select an authentic issue within the context. An authentic issue is one which is connected to the context, and allows students to develop a brief for a need or opportunity that can be managed within the boundaries of their available resources.</li> <li>• support students to identify a need or opportunity relevant to the issue</li> <li>• support students to understand the physical and functional nature required of their outcome</li> <li>• support students to justify the nature of their outcome in terms of the issue it is addressing</li> <li>• support students to develop specifications and provide justifications for them drawing from stakeholder feedback, and wider community considerations such as the resources available to develop the outcome, ongoing maintenance of the outcome once implemented, sustainability of resources used to develop the outcome and the outcome itself, disposal of the developed outcome when past its use by date.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to undertake planning for practice at level seven teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief against which planning to develop an outcome can occur</li> <li>• support students to critically analyse a range of planning tools and project management practices that have been used in past technological practice</li> <li>• support students to select and use planning tools to make effective planning decisions and establish and manage all resources (including time, money, stakeholder/s, materials, components, software, equipment, tools and/or hardware etc). Effective planning decisions enable the outcome produced to successfully meet the brief.</li> <li>• support students to select and use planning tools which will allow for the efficient recording of justifications for key planning decisions made.</li> <li>• support students to ensure appropriate resources are available (stakeholder/s, materials, components, software, equipment, tools and/or hardware) suitable for their outcome.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to undertake outcome development and evaluation at level seven teachers could:</p> <ul style="list-style-type: none"> <li>• ensure that there is a brief with clear specifications against which a developed outcome can be evaluated</li> <li>• establish an environment that supports student innovation and encourages critical analysis of existing outcomes</li> <li>• support students to critically analyse evaluative practices used within functional modelling</li> <li>• support students to develop drawing and modelling skills to communicate and explore design ideas. Emphasis should be on progressing 2D and 3D drawing skills and increasing the range and complexity of functional modelling</li> <li>• support students to explore a range of materials/ components, and to develop the necessary knowledge and skills to evaluate and make effective use of them</li> <li>• support students to undertake prototyping to gain evidence that enables clear judgments regarding the outcome's fitness for purpose and determine the need for any changes to enhance the outcome</li> <li>• support students to gain targeted stakeholder feedback and understand the implications of the physical and social environment in which the outcome is to be located.</li> </ul>
<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• explore the context to select an issue</li> <li>• identify a need or opportunity relevant to their selected issue</li> <li>• establish a conceptual statement that justifies the nature of the outcome and why such an outcome should be developed with reference to the issue it is addressing</li> <li>• establish the specifications for an outcome using stakeholder feedback, and based on the nature of the outcome required to address the need or opportunity, consideration of the environment in which the outcome will be situated, and resources available</li> <li>• communicate specifications that allow an outcome to be evaluated as fit for purpose</li> <li>• justify the specifications in terms of stakeholder feedback, and the nature of the outcome required to address the need or opportunity, consideration of the environment in which the outcome will be situated, and resources available.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• critically analyse existing planning tools and project management practices to inform the selection of planning tools appropriate for the technological practice to be undertaken, and for recording evidence to support any revisions to planning</li> <li>• use planning tools to set achievable goals, manage all resources, plan critical review points, and revise goal and resources as necessary to ensure the effective completion of an outcome</li> <li>• use planning tools to provide evidence for any revisions made at critical review points and justifies the appropriateness of planning tools used.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• generate design ideas that are informed by research and critical analysis of existing outcomes</li> <li>• develop design ideas for outcomes that are justified as feasible with evidence gained through functional modelling</li> <li>• critically analyse evaluative practices used when functional modelling to inform own functional modelling</li> <li>• undertake functional modelling to evaluate design ideas and develop and test a conceptual design to provide evidence of the proposed outcome's ability to be fit for purpose</li> <li>• evaluate suitability of materials/components, based on their performance properties, to select those appropriate for use in the production of a feasible outcome</li> <li>• undertake prototyping to gain specific evidence of an outcome's fitness for purpose and use this to justify any decisions to refine, modify and/or accept the outcome as final</li> <li>• use stakeholder feedback and an understanding of the physical and social requirements of where the outcome will be situated to support and justify key design decisions and evaluations of fitness for purpose.</li> </ul>

**Components of TECHNOLOGICAL PRACTICE: indicators of progression**

Vicki Compton and Cliff Harwood: Version 4: October 2010

For context and the latest version, see <http://technology.tki.org.nz/Curriculum-support/Indicators-of-Progression>



**COMPONENTS OF TECHNOLOGICAL PRACTICE: INDICATORS OF PROGRESSION****LEVEL EIGHT**

Teachers should establish if students have developed robust level seven competencies and are ready to begin working towards level eight achievement objectives for the technological practice components, and plan learning experiences to progress these as guided by the level eight Indicators below.

Brief Development	Planning for Practice	Outcome Development & Evaluation
<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Justify the nature of an intended outcome in relation to the context and the issue to be resolved. Justify specifications in terms of key stakeholder feedback and wider community considerations.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Critically analyse their own and others' past and current planning and management practices in order to develop and employ project management practices that will ensure the efficient development of an outcome to completion.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Critically analyse their own and others' outcomes and their determination of fitness for purpose in order to inform the development of ideas for feasible outcomes. Undertake a critical evaluation that is informed by ongoing experimentation and functional modelling, stakeholder feedback, trialling in the physical and social environments, and an understanding of the issue as it relates to the wider context. Use the information gained to select, justify, and develop an outcome. Evaluate this outcome's fitness for purpose against the brief. Justify the evaluation using feedback from stakeholders and demonstrating a critical understanding of the issue that takes account of all contextual dimensions.</p>
<p><b>TEACHER GUIDANCE</b></p> <p>To support students to undertake brief development at level eight teachers could:</p> <ul style="list-style-type: none"> <li>support students to identify a context that offers a range of issues for them to explore. Context refers to the wider social and physical environment in which technological development occurs. Contexts may include but are not limited to: storage, afterschool snacks, outdoor living, sustainable energy, sport, educational software, streetwear, portability, furniture.</li> <li>support students to identify considerations that will need to be taken into account when making judgments of fitness for purpose in its broadest sense. Fitness for purpose in its broadest sense refers to judgments of the fitness of the outcome itself as well as the practices used to develop the outcome. Such judgments may include but are not limited to considerations of the outcome's technical and social acceptability, sustainability of resources used, ethical nature of testing practices, cultural appropriateness of trialling procedures, determination of life cycle, maintenance, ultimate disposal, health and safety.</li> <li>support students to select an authentic issue within their selected context</li> <li>support students to identify a need or opportunity relevant to the issue and context</li> <li>support students to understand the physical and functional nature required of their outcome</li> <li>support students to justify the nature of their outcome in terms of the issue and context</li> <li>support students to develop and justify specifications that will allow the evaluation of the outcome and its development to be judged as fit for purpose in the broadest sense.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to undertake planning for practice at level eight teachers could:</p> <ul style="list-style-type: none"> <li>ensure that there is a brief against which planning to develop an outcome can occur</li> <li>support students to critically analyse a range of project management practices and explore how project scheduling is used to manage technological practice</li> <li>support students to establish and implement a coherent project schedule that allows for the coordination and management of the: regular review of goals, planning tools, all resources required (time, money, stakeholder/s, materials, components, software, equipment, tools and/or hardware etc) and review points</li> <li>support students to provide evidence of effective and efficient planning decisions. Effective and efficient planning decisions ensures that the use of resources is optimised during the development and production of an outcome produced to successfully meet the brief.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to undertake outcome development and evaluation at level eight teachers could:</p> <ul style="list-style-type: none"> <li>ensure that there is a brief with clear specifications against which a developed outcome can be evaluated</li> <li>establish an environment that supports student innovation and encourages critical analysis of existing outcomes and knowledge of material innovations</li> <li>support students to critically analyse the ways in which the fitness for purpose of existing outcomes have been determined, and how appropriate development practices were established</li> <li>support students to develop drawing and modelling skills to communicate and explore design ideas. Emphasis should be on progressing 2D and 3D drawing skills and increasing the range and complexity of functional modelling</li> <li>support students to explore a range of materials/components and to develop the necessary knowledge and skills to evaluate and make effective use of them.</li> <li>support students to establish which materials/components would be optimal for use when taking into account all contextual dimensions</li> <li>support students to undertake prototyping to gain evidence that enables clear judgments regarding the outcome's fitness for purpose and determine the need for any changes to enhance the outcome</li> <li>support students to gain targeted stakeholder feedback and understand the implications of the physical and social environment in which the outcome is to be located.</li> </ul>
<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>identify and evaluate a range of contexts to select an authentic issue</li> <li>explore context to identify considerations related to fitness for purpose in its broadest sense</li> <li>identify a need or opportunity relevant to their selected issue</li> <li>establish a conceptual statement that justifies the nature of the outcome and why such an outcome should be developed with reference to the issue being addressed and the wider context</li> <li>establish the specifications for an outcome and its development using stakeholder feedback and based on the nature of the outcome required to address the need or opportunity, consideration of the environment in which the outcome will be situated, and resources available</li> <li>communicate specifications that allow an outcome to be evaluated as fit for purpose in the broadest sense.</li> <li>justify the specifications as based on stakeholder feedback and the nature of the outcome required to address the need or opportunity, consideration of the environment in which the outcome will be situated, and resources available.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>establish a coherent project schedule suitable for the physical and social environment where the outcome is to be developed and implemented, informed by critical analysis of existing project management</li> <li>implement project schedule, undertaking reflection at critical review points to revise or confirm schedule to ensure the effective and efficient completion of an outcome</li> <li>manage the project to provide evidence of the coordination of goals, planning tools, resources and progress review points and justify planning decisions.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>generate design ideas that are informed by research and critical analysis of existing outcomes and knowledge of material innovations</li> <li>develop design ideas for feasible outcomes that are justified with evidence gained through functional modelling that serves to gather evidence from multiple stakeholders and test designs ideas from a range of perspectives</li> <li>undertake evaluation of design ideas informed by critical analysis of evaluative practices to support the development of a conceptual design for an outcome that optimises resources and takes into account maintenance and disposal implications</li> <li>undertake functional modelling of the conceptual design to provide evidence that the proposed outcome has the potential to be fit for purpose</li> <li>evaluate suitability of materials/components, based on their performance properties, to select those appropriate for use in the production of a feasible outcome that optimises resources and takes into account maintenance and disposal implications</li> <li>undertake prototyping to gain specific evidence of an outcome's fitness for purpose and use this to justify any decisions to refine, modify and/ or accept the outcome as final</li> <li>use stakeholder feedback and an understanding of the physical and social requirements of where the outcome will be situated to support and justify an evaluation of the outcome and development practices as fit for purpose.</li> </ul>

**Components of TECHNOLOGICAL PRACTICE: indicators of progression**

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## **APPENDIX E**

### Indicators of Progression for Technological Modelling



## TECHNOLOGY INDICATORS OF PROGRESSION

The Indicators of Progression provide support for teachers to interpret the Achievement Objectives (AOs) for each strand of the technology curriculum within *The New Zealand Curriculum* (NZC) (2007). There are three matrices, each focused on one of the three strands of the technology curriculum, describing the eight levels of the NZC. Each matrix:

- restates the Achievement Objectives for each level
- provides guidance to teachers on what they could do to support student learning at each level
- provides indicators of what students should know or be able to do at each level.

The *Teacher Guidance* highlights the importance of the teacher's role in supporting student learning. It also acknowledges how the nature of teaching needs to change to ensure students are able to take more responsibility for their learning as they progress from levels 1-8 of the NZC. This has been emphasised by using the following terms to denote this shift in responsibilities from teacher to student.

- **Provide** is used when the teacher takes full responsibility for introducing and explicitly teaching new knowledge/skill or practices.
- **Guide** is used when the teacher assumes students will have some level of understanding/competency to draw from but continues to take the majority of the responsibility for developing these understandings further.
- **Support** is used when the balance shifts towards the student taking more responsibility for their learning, drawing from their past learning to consolidate and extend their understandings. In this case the teacher plays a more supportive role through questioning and challenging students to support them in their learning.

The *Teacher Guidance* also uses the term **ensure** to denote when the teacher plays a monitoring role to check that conditions critical for learning are present. For example, in 'planning for practice' and 'outcome development and evaluation' the teacher must ensure an appropriate brief is available to guide student work.

The *Indicators* describe generic understandings and capabilities that students should be able demonstrate consistently if they are to be considered to have met the related achievement objective. The indicators for each level should be viewed 'collectively' as indicating the AO at that level. Partial and/or inconsistent student demonstration of the indicators shows that additional and/or further consolidation learning experiences need to be provided to the student. This will ensure that future learning provides the opportunities necessary for the student to demonstrate the achievement described by all of the indicators at that level. It is expected that teachers will contextualise the indicators by re-phrasing them into appropriate language for the unit being studied, and the students they are teaching. By doing this the indicators can be used as targeted learning goals and assessment tools inside the classroom to plan for, guide, and acknowledge student learning.

The *Teacher Guidance* and *Indicators* have been developed through classroom research and refined through subsequent trialling. They are provided to guide formative and summative assessment practices, planning decisions and the development of effective and efficient reporting mechanisms for multiple audiences, including the students, their caregivers, and future teachers both within and across schools.

All three matrices will be periodically reviewed as implementation of the three strands proceeds and further development work in technology is undertaken.



## COMPONENTS OF TECHNOLOGICAL KNOWLEDGE: INDICATORS OF PROGRESSION **LEVEL ONE**

Teachers should establish if students hold any misconceptions or partial understandings that would inhibit them meeting the level one achievement objectives for technological knowledge and plan learning experiences to challenge and/or progress these as guided by the level one Indicators below.

Technological Modelling	Technological Products	Technological Systems
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand that functional models are used to represent reality and test design concepts and that prototypes are used to test technological outcomes.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand that technological products are made from materials that have performance properties.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand that technological systems have inputs, controlled transformations, and outputs.</p>
<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological modelling at level 1, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with the opportunity to discuss why technological modelling is important to the development of technological outcomes and that it involves both functional modelling and prototyping.</li> <li>guide students to identify that functional models are representations of potential technological outcomes and that they exist in many forms (e.g. thinking, talking, drawing, physical mock-ups, computer aided simulations etc)</li> <li>provide students with the opportunity to discuss that design concepts includes design ideas for parts of an outcome, as well as the conceptual design for the outcome as a whole</li> <li>provide students with the opportunity to interact with a variety of functional models and guide them to identify that the purpose of functional modelling is to test design concepts to see if they are suitable for use in the development of an outcome</li> <li>guide students to identify that prototypes are the first versions of fully completed technological outcomes</li> <li>provide students with a range of prototyping examples and guide them to identify that the purpose of prototyping is to test the outcome.</li> <li>examples should include the modelling practices of technologists.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological products at level 1, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with a range of technological products and encourage them to explore these through such things as: using, 'playing', dismantling and rebuilding as appropriate</li> <li>guide students to identify the materials that the products explored are made from</li> <li>provide opportunity for students to discuss that performance properties of materials refer to such things as thermal and electrical conductivity, water resistance, texture, flexibility, colour etc.</li> <li>provide students with the opportunity to explore common materials and guide them to identify their performance properties</li> <li>provide students with a range of technological products to explore and guide them to identify ways in which materials have been manipulated to make the product. For example, in a wooden toy the wood has been shaped, sanded and painted; In a sandwich, the bread dough has been shaped, cooked and sliced; in a cushion the fabric has been cut and sewn together.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological systems at level 1, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with a range of technological systems and encourage them to explore these through such things as: using, 'playing', dismantling and rebuilding as appropriate</li> <li>guide students to identify the components and how they are connected in the systems explored</li> <li>guide students to identify the inputs and outputs of technological systems and provide opportunity for them to recognise that a controlled transformation has occurred.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>describe what a functional model is</li> <li>identify the purpose of functional modelling</li> <li>describe what a prototype is</li> <li>identify the purpose of prototyping.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>identify materials that technological products are made from</li> <li>identify performance properties of common materials</li> <li>identify how the materials have been manipulated to make the product.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>identify the components of a technological system and how they are connected</li> <li>identify the input/s and output/s of particular technological systems</li> <li>Identify that a system transforms an input to an output.</li> </ul>



## COMPONENTS OF TECHNOLOGICAL KNOWLEDGE: INDICATORS OF PROGRESSION LEVEL TWO

Teachers should establish if students have developed robust level one understandings and are ready to begin working towards level two achievement objectives for technological knowledge and plan learning experiences to progress these as guided by the level two Indicators below.

Technological Modelling	Technological Products	Technological Systems
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand that functional models are used to explore, test, and evaluate design concepts for potential outcomes and that prototyping is used to test a technological outcome for fitness of purpose.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand that there is a relationship between a material used and its performance properties in a technological product.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand that there are relationships between the inputs, controlled transformations, and outputs occurring within simple technological systems.</p>
<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological modelling at level 2, teachers could:</p> <ul style="list-style-type: none"> <li>• guide students to understand that design concepts refers to design ideas for parts of an outcome, as well as the conceptual design for the outcome as a whole</li> <li>• provide students with the opportunity to explore a variety of functional models and identify the specific design concept/s being tested</li> <li>• guide students to discuss the sorts of things that could be explored and tested using functional modelling</li> <li>• provide students with a range of prototyping examples and guide them to identify the specifications that were used to evaluate the prototype</li> <li>• provide students with the opportunity to discuss how specifications provide a way of measuring the fitness for purpose of the prototype</li> <li>• examples should include the modelling practices of technologists.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological products at level 2, teachers could:</p> <ul style="list-style-type: none"> <li>• guide students to understand that performance properties of materials refer to such things as thermal and electrical conductivity, water resistance, texture, flexibility, colour etc.</li> <li>• provide students with the opportunity to research and experiment with a range of materials and guide them to describe how their performance properties relates to how they could be useful. For example, a material that was water and UV resistant, durable, and easily cleaned could be useful for outdoor furnishings</li> <li>• provide students with the opportunity to research and experiment with a range of materials and guide them to describe how particular materials can be manipulated.</li> <li>• provide students with a variety of technological products to explore and encourage them to explore these through such things as: using, 'playing', dismantling and rebuilding as appropriate</li> <li>• guide student to describe the relationship between the materials selected and their performance properties. For example, a school lunch box is made of plastic because plastic can be molded into different shapes, and is hard, durable, lightweight and easily cleaned.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological systems at level 2, teachers could:</p> <ul style="list-style-type: none"> <li>• provide students with the opportunity to identify that simple technological systems are systems that have been designed to change inputs to outputs through a single transformation process</li> <li>• provide students with a range of simple technological systems and encourage them to explore these through such things as: using, 'playing', dismantling and rebuilding as appropriate</li> <li>• guide student to understand the role of each component and to identify the changes that are occurring in the transformation process</li> <li>• guide students to understand that sometimes transformation processes may be difficult to determine or understand and these can be represented as a 'black box'. That is, a black box is described as a way of depicting a part of a system where the inputs and outputs are known but the transformation process is not known.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• describe the sorts of things that functional modeling can be used for in technology</li> <li>• identify the design concept being tested in particular functional models</li> <li>• identify why prototyping is important in technology</li> <li>• identify the specifications used to evaluate particular prototypes.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• describe the performance properties of a range of materials and use these to suggest things the materials could be used for</li> <li>• describe feasible ways of manipulating a range of materials</li> <li>• suggest why the materials used in particular technological products were selected.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>• describe the change that has occurred to the input to produce the output in simple technological systems</li> <li>• identify the role each component has in allowing the inputs to be transformed into outputs within simple technological systems.</li> </ul>



**COMPONENTS OF TECHNOLOGICAL KNOWLEDGE: INDICATORS OF PROGRESSION****LEVEL THREE**

Teachers should establish if students have developed robust level two understandings and are ready to begin working towards level three achievement objectives for technological knowledge and plan learning experiences to progress these as guided by the level three Indicators below.

<b>Technological Modelling</b>	<b>Technological Products</b>	<b>Technological Systems</b>
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Understand that different forms of functional modelling are used to inform decision making in the development of technological possibilities and that prototypes can be used to evaluate the fitness of technological outcomes for further development.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Understand the relationship between the materials used and their performance properties in technological products.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will: Understand that technological systems are represented by symbolic language tools and understand the role played by the "black box" in technological systems.</p>
<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological modelling at level 3, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with the opportunity to explore different forms of functional modelling and guide students to gain insight into the different types of information that have been gathered</li> <li>provide students with the opportunity to discuss how functional modelling informs decision making and guide them to identify the benefits and limitations of functional modelling in examples provided</li> <li>provide students with the opportunity to understand that benefits include such things as reducing the risk of wasting time, money and materials and limitations arise due to the representational nature of modelling. That is, what is being tested is necessarily partial and therefore prototyping is required to fully test the outcome</li> <li>provide students with the opportunity to discuss that specifications include both acceptability and feasibility considerations related to the outcome's fitness for purpose</li> <li>provide students with the opportunity to explore a range of examples of prototyping and guide them to gain insight into how appropriate information can be gained to evaluate a technological outcome's fitness for purpose against the specifications</li> <li>provide students with the opportunity to discuss the role of functional modelling and prototyping to develop an understanding of the importance of both in technological development.</li> <li>examples should include the modelling practices of technologists and should provide students with the opportunity to explore both successful prototypes and those that did not meet specifications.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological products at level 3, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with the opportunity to discuss that performance properties of materials can be measured objectively and subjectively. Subjective measurement is reliant on people's perception (tasty, evokes a sense of natural beauty, warm and inviting etc) where as objective measurement is not (conductivity, UV resistance etc). The fitness for purpose of a product relies on the material providing appropriate performance properties to ensure the product is technically feasible and acceptable (safe, ethical, environmentally friendly, economically viable, etc -as appropriate to particular products)</li> <li>provide students with a variety of technological products to explore and guide them to identify the performance properties of all the materials used, and to explain if these could be measured objectively or subjectively</li> <li>provide students with a variety of technological products and guide them to explain how properties combine to make the product both technically feasible and socially acceptable.</li> </ul>	<p><b>TEACHER GUIDANCE</b> To support students to develop understanding of technological systems at level 3, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with the opportunity to investigate a range of technological systems and guide them to understand that technological systems do not require further human design decision making during the transformation process for the inputs to be transformed to outputs. That is, a technological system will produce particular outputs in an automated fashion once the inputs have initiated the transformation process</li> <li>guide students to understand that a 'black box' is a term used to describe a part of a system where the inputs and outputs are known but the transformation process is not known</li> <li>provide examples of technological systems that contain unknown transformation processes (black boxes) and guide them to understand the role these play in terms of the advantages and/or disadvantages for developers and users</li> <li>provide opportunity for students to discuss that the fitness for purpose of a technological system relies on the selection of components, and how they are connected to ensure the system is technically feasible and acceptable (safe, ethical, environmentally friendly, economically viable, etc -as appropriate to particular systems)</li> <li>provide students with examples of how technological systems can be represented and guide students to interpret the specialised language and symbol conventions used</li> <li>provide students with opportunity to use specialised language and symbol conventions to represent technological systems to others.</li> </ul>
<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>discuss examples to identify the different forms of functional models that were used to gather specific information about the suitability of design concepts</li> <li>identify the benefits and limitations of functional modelling undertaken in particular examples</li> <li>describe examples of particular prototypes that did not meet specifications.</li> <li>explain why functional modelling and prototyping are both needed to support decision making when developing an outcome.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>describe the properties of materials used in particular products that can be measured objectively</li> <li>describe the properties of materials used in particular products that can be measured subjectively</li> <li>describe how the properties combine to ensure the materials allow the product to be technically feasible and socially acceptable.</li> </ul>	<p><b>INDICATORS</b> Students can:</p> <ul style="list-style-type: none"> <li>describe what 'black box' refers to within a technological system and the role of particular black boxes within technological systems</li> <li>identify possible advantages and disadvantages of having black boxed transformations within particular technological systems</li> <li>describe how the components, and how they are connected, allow particular systems to be technical feasible and socially acceptable</li> <li>describe particular technological systems using specialised language and symbol conventions.</li> </ul>



## COMPONENTS OF TECHNOLOGICAL KNOWLEDGE: INDICATORS OF PROGRESSION

## LEVEL FOUR

Teachers should establish if students have developed robust level three understandings and are ready to begin working towards level four achievement objectives for technological knowledge and plan learning experiences to progress these as guided by the level four Indicators below.

Technological Modelling	Technological Products	Technological Systems
<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Understand how different forms of functional modelling are used to explore possibilities and to justify decision making and how prototyping can be used to justify refinement of technological outcomes.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Understand that materials can be formed, manipulated, and/or transformed to enhance the fitness for purpose of a technological product.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Understand how technological systems employ control to allow for the transformation of inputs to outputs.</p>
<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological modelling at level 4, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with the opportunity to explore how using different media influences the type of information that can be gathered</li> <li>provide students with the opportunity to discuss how different possibilities can be explored through functional modelling of design concepts and prototyping in order to make socially acceptable as well technically feasible decisions</li> <li>guide students to examine examples of functional modelling practices to identify how these were used to explore possibilities and gather different types of information to justify design decisions</li> <li>guide students to examine examples of prototyping and identify how information from these were used to justify the fitness for purpose of technological outcomes or to identify the need for further development</li> <li>examples should include the modelling practices of technologists and should include instances where refinements to the prototype were required to meet specifications.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological products at level 4, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with the opportunity to discuss what is meant by materials being formed, manipulated and transformed. Forming refers to bringing two or more materials together to formulate a new material resulting in a different overall composition and structure to that of the original materials. This results in different performance properties. For example: mixing flour, water and salt to make dough; mixing wood fibres, resin and wax to make MDF; glass fibre and a polymer resin combined to form fiberglass or fibre reinforced polymer (FRP). Manipulating materials refers to 'working' existing materials in ways that do not change their properties as their composition and structure is not altered. For example: cutting; molding; bending; jointing; gluing; painting. Transforming refers to changing the structure of an existing material to change some of its properties, but in terms of its composition, it remains the same material. For example: felting; beating an egg white; steaming timber to soften its fibres and allow it to be manipulated (bent)</li> <li>guide students to understand that for materials to be selected for use in a technological product, their performance properties must align with the desired specifications of the product.</li> <li>guide students to recognise that during development of a product, specifications are established that will require the manipulation, and in some cases, transformation and formation, of materials.</li> <li>provide students with a variety of technological products to explore and guide students to identify examples of when materials needed to be manipulated, transformed and/or formed to enable material linked specifications of the product to be met and contribute to the product's fitness for purpose.</li> <li>provide students with a scenario outlining technical and acceptability specifications for a product and support them to explore and research materials to determine what material would be suitable and how they could be manipulated and/or transformed to meet product specifications</li> <li>support students to communicate material related details effectively. Material related details include such things as what materials would be feasible and how they would need to be formulated, manipulated and/or transformed. Effective communication uses specialised language and symbols.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological systems at level 4, teachers could:</p> <ul style="list-style-type: none"> <li>provide students with the opportunity to investigate a range of technological systems and guide them to identify how transformation processes are controlled</li> <li>support students to understand that control mechanisms can function to enhance the fitness for purpose of technological systems by maximising the desired outputs and minimising the undesirable outputs</li> <li>provide students with a scenario outlining technical and acceptability specifications for a system and support them to explore and research components and connectivity factors to determine what components would be suitable and how they could be connected to meet system specifications</li> <li>support students to communicate system related details effectively. System related details include such things as what components would be feasible, layout requirements, and how they would need to be connected. Effective communication uses specialised language and symbols.</li> </ul>
<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>explain how functional modelling and prototyping allows for consideration of both what 'can' be done and what 'should' be done when making decisions</li> <li>discuss examples to illustrate how particular functional models were used to gather specific information about the suitability of design concepts</li> <li>identify information that has been gathered from functional models about the suitability of design concepts and describe how this information was used</li> <li>describe examples to illustrate how prototypes were tested to evaluate a technological outcome's fitness for purpose</li> <li>identify information that has been gathered from prototyping and describe how this information was used.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>describe examples to illustrate how the manipulation of materials contributed to a product's fitness for purpose</li> <li>describe examples to illustrate how the transformation of materials contributed to a product's fitness for purpose</li> <li>describe examples to illustrate how the formulation of new materials contributed to a product's fitness for purpose</li> <li>communicate, using specialised language and drawings, material related details that would allow others to create a product that meets both technical and acceptability specifications.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>explain how transformation processes within a system are controlled</li> <li>describe examples to illustrate how the fitness for purpose of technological systems can be enhanced by the use of control mechanisms</li> <li>communicate, using specialised language and drawings, system related details that would allow others to create a system that meets both technical and acceptability specifications.</li> </ul>



## COMPONENTS OF TECHNOLOGICAL KNOWLEDGE: INDICATORS OF PROGRESSION

## LEVEL FIVE

Teachers should establish if students have developed robust level four understandings and are ready to begin working towards level five achievement objectives for technological knowledge and plan learning experiences to progress these as guided by the level five Indicators below.

Technological Modelling	Technological Products	Technological Systems
<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will:</p> <p>Understand how evidence, reasoning, and decision making in functional modelling contribute to the development of design concepts and how prototyping can be used to justify ongoing refinement of technological outcomes.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will:</p> <p>Understand how materials are selected, based on desired performance criteria.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will:</p> <p>Understand the properties of subsystems within technological systems.</p>
<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological modelling at level 5, teachers could:</p> <ul style="list-style-type: none"> <li>provide opportunity for students to identify practical and functional reasoning underpinning technological modelling. <i>Functional reasoning</i> provides a basis for exploring the technical feasibility of the design concept and the realised outcome. That is, 'how to make it happen' in the functional modelling phase, and the reasoning behind 'how it is happening' in prototyping. <i>Practical reasoning</i> provides a basis for exploring acceptability (including socio-cultural and environmental dimensions) surrounding the design concept and realised outcome. That is, the reasoning around decisions as to 'should it happen?' in functional modelling and 'should it be happening?' in prototyping.</li> <li>provide opportunity for students to explore how informed and justifiable design decision making relies on both functional and practical reasoning and draws from evidence provided from modelling</li> <li>guide students to analyse examples of functional modelling practices to explain how these were used to gain evidence to justify design decisions with regards to both technical feasibility and acceptability. Such justifications will rely on the synthesis of evidence gained from modelling that sought feedback from different stakeholders.</li> <li>guide students to analyse examples of prototyping to explain how results were used to justify an outcome as fit for purpose or requiring refinement.</li> <li>provide opportunity for students to understand that maintenance requirements can be identified through prototyping and guide them to identify that maintaining an outcome can involve controlling environmental influences and/or undertaking ongoing refinements of the technological outcome</li> <li>support students to gain insight from prototyping examples into how testing procedures can provide information regarding maintenance requirements of a technological outcome</li> <li>examples should include the modelling practices of technologists and should include instances where refinements to the prototype were required to meet specifications.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological products at level 5, teachers could:</p> <ul style="list-style-type: none"> <li>guide students to understand that the composition of materials determines what performance properties it exhibits. Composition relates to such things as the type and arrangement of particles that make up the material.</li> <li>support students to analyse examples of how materials have been selected to gain insight into how this selection relies on understanding the composition of the materials available and using this knowledge to help decide which materials in combination would provide the best 'fit' with the product specifications</li> <li>examples should include the material selection practices of technologists.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological systems at level 5, teachers could:</p> <ul style="list-style-type: none"> <li>guide students to understand that the properties of a subsystem relate to its transformation performance and its level of connective compatibility and that additional interface components may be required to ensure a subsystem can be effectively integrated into a system</li> <li>provide students with the opportunity to analyse a range of examples of complex technological systems that contain at least one subsystem. Complex technological systems are those designed to change inputs to outputs through more than one transformation process</li> <li>guide students to identify subsystems within technological systems and explain them in terms of their properties</li> <li>support students to use examples to gain insight into how the selection and interfacing of subsystems relies on understanding the transformation and connective properties of subsystems to ensure the best 'fit' with the required system specifications</li> <li>examples should include the subsystem selection and interfacing practices of technologists.</li> </ul>
<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>identify examples of functional and practical reasoning within design decision making</li> <li>explain how evidence gained from functional modelling was used to justify design decisions</li> <li>identify examples of functional and practical reasoning underpinning prototype evaluations and the establishment of maintenance requirements</li> <li>explain how evidence gained from prototyping was used to justify outcome evaluation as fit for purpose or in need of further development.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>discuss examples to illustrate how the composition of materials determines performance properties</li> <li>explain the link between specifications of a product and the selection of suitable materials for its construction</li> <li>discuss examples to illustrate how decisions about material selection take into account the composition of the material and the specifications of the product.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>identify subsystems within technological systems and explain their transformation and connective properties</li> <li>discuss how transformation and connection properties of subsystems impact on system layout and component selection</li> <li>discuss examples to illustrate how interfaces take into account the connective compatibility between subsystems and other system components.</li> </ul>



## COMPONENTS OF TECHNOLOGICAL KNOWLEDGE: INDICATORS OF PROGRESSION

## LEVEL SIX

Teachers should establish if students have developed robust level five understandings and are ready to begin working towards level six achievement objectives for technological knowledge and plan learning experiences to progress these as guided by the level six Indicators below.

Technological Modelling	Technological Products	Technological Systems
<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will:</p> <p>Understand the role and nature of evidence and reasoning when managing risk through technological modelling.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will:</p> <p>Understand how materials are formed, manipulated, and transformed in different ways, depending on their properties, and understand the role of material evaluation in determining suitability for use in product development.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will:</p> <p>Understand the implications of subsystems for the design, development, and maintenance of technological systems.</p>
<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological modelling at level 6, teachers could:</p> <ul style="list-style-type: none"> <li>• guide students to explain how practical and functional reasoning underpin technological modelling. <i>Functional reasoning</i> provides a basis for exploring the technical feasibility of the design concept and the realised outcome. That is, 'how to make it happen' in the functional modelling phase, and the reasoning behind 'how it is happening' in prototyping. <i>Practical reasoning</i> provides a basis for exploring acceptability (including socio-cultural and environmental dimensions) surrounding the design concept and realised outcome. That is, the reasoning around decisions as to 'should it happen?' in functional modelling and 'should it be happening?' in prototyping.</li> <li>• guide students to understand the concept of risk as it relates to reducing instances of malfunctioning of technological outcomes, and/or increasing levels of outcome robustness.</li> <li>• guide students to understand how technological modelling is used to manage risk through exploring and identifying possible risk factors associated with the development of a technological outcome</li> <li>• support students to analyse examples of technological modelling to understand how risk is explored and identified within particular technological developments.</li> <li>• examples should include the modelling practices of technologists and should include instances where modelling was undertaken to explore and identify risk.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological products at level 6, teachers could:</p> <ul style="list-style-type: none"> <li>• provide students with the opportunity to research and experiment with a range of materials to develop understandings of how the composition and structure of materials impacts on how they can be manipulated and/or transformed, or combined to formulate a new material.</li> <li>• guide students to understand that material evaluation enables decisions to be made about how a material would support, or not, the fitness for purpose of particular technological products, and decrease the probability of a product malfunction.</li> <li>• support students to analyse examples of how materials have been evaluated to determine their suitability for use in particular technological products</li> <li>• examples should include the material evaluation practices of technologists.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological systems at level 6, teachers could:</p> <ul style="list-style-type: none"> <li>• guide students to understand the role subsystems play in the design, development and maintenance of complex technological systems. Complex technological systems are those designed to change inputs to outputs through more than one transformation process.</li> <li>• support students to identify why subsystems may be 'black boxed' for development and/or maintenance purposes and guide them to understand how this can result in both advantages (reduced need to understand all aspects of the system, ability to replace faulty subsystem without disrupting the entire system) and disadvantages (trouble shooting can be difficult).</li> <li>• guide students to understand how control and feedback at a system level allow 'back up' or 'shutdown' subsystems to be employed to reduce malfunction and/or component damage</li> <li>• support students to analyse examples of how subsystems have been selected and used in particular complex technological systems.</li> <li>• support students to use examples to gain insight into how the use of subsystems can impact on system design, development and maintenance</li> <li>• examples should include system design, development and maintenance practices of technologists.</li> </ul>
<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• describe practical and functional reasoning and discuss how they work together to enhance decision making during technological modelling</li> <li>• explain the role of technological modelling in the exploration and identification of possible risk/s</li> <li>• discuss examples to illustrate how evidence and reasoning is used during functional modelling to identify risk and make informed and justifiable design decisions</li> <li>• discuss examples to illustrate how prototyping provides information to determine maintenance requirements to ensure minimal risk and optimal performance over time.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• explain how the composition and structure of different materials enables them to be manipulated in specific ways</li> <li>• explain how the composition and structure of materials determines the ways they can be transformed</li> <li>• explain how the composition and structure of materials impacts on how they can be combined to formulate a new material</li> <li>• describe the role of material evaluation in determining material suitability for use in a technological product</li> <li>• discuss examples to illustrate how material evaluation informed the selection of materials in particular product development.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• explain the variety of roles played by subsystems in complex technological systems</li> <li>• explain the implications of using subsystems during the design, development and maintenance of complex technological systems</li> <li>• describe examples to explain how control and feedback requirements impact on subsystem use.</li> <li>• discuss examples to illustrate the advantages and disadvantages of subsystems employed in particular technological systems.</li> </ul>



## COMPONENTS OF TECHNOLOGICAL KNOWLEDGE: INDICATORS OF PROGRESSION

## LEVEL SEVEN

Teachers should establish if students have developed robust level six understandings and are ready to begin working towards level seven achievement objectives for technological knowledge and plan learning experiences to progress these as guided by the level seven Indicators below.

Technological Modelling	Technological Products	Technological Systems
<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand how the "should" and "could" decisions in technological modelling rely on an understanding of how evidence can change in value across contexts and how different tools are used to ascertain and mitigate risk.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand the concepts and processes employed in materials evaluation and the implications of these for design, development, maintenance, and disposal of technological products.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b> Students will:</p> <p>Understand the concepts of redundancy and reliability and their implications for the design, development, and maintenance of technological systems.</p>
<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological modelling at level 7, teachers could:</p> <ul style="list-style-type: none"> <li>• support students to explore how context impacts on the perception of the validity of evidence presented. Therefore, shifting from one context to another can change the status of the evidence provided by technological modelling.</li> <li>• support students to explore how and why different people and communities accept different types of evidence as valid. That is, the status given to evidence is dependent on a range of factors including ethical views and the perceived authority of people involved in the presentation of the evidence</li> <li>• support students to understand how decisions underpinning technological modelling based on what should and could happen, rely on an understanding of how evidence gained may differ in value across contexts and/or communities</li> <li>• support students to understand how technological modelling is used to ascertain and mitigate risk. Ascertaining risk involves establishing the probability of identified risks. Mitigation involves taking steps to reduce the probability of the risk being realised and/or severity of the risk should it be realised</li> <li>• support students to analyse examples of technological modelling to understand how risk is ascertained and mitigated within particular technological developments</li> <li>• examples should include the modelling practices of technologists and should include instances where modelling was undertaken to mitigate risk.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological products at level 7, teachers could:</p> <ul style="list-style-type: none"> <li>• support students to understand that material evaluation enables decisions to be made about what material would be optimal to ensure the fitness for purpose of particular technological products</li> <li>• support students to explore a range of subjective and objective evaluative procedures used to identify the suitability of materials for different uses</li> <li>• support students to describe the underpinning concepts and processes related to subjective and objective evaluative procedures</li> <li>• support students to understand the selection of appropriate material evaluation procedures relies on understanding the composition and structure of materials, how their properties can be enhanced through manipulation or transformation, the performance criteria required by technological products and an understanding of the physical and social context within which the technological product will be situated</li> <li>• support students to identify and analyse examples of how materials have been evaluated to allow material selection decisions that maximize the potential fitness for purpose of particular technological products and to gain insight into how material evaluation procedures can be used to identify product maintenance and disposal implications and therefore inform design, development and post production care decisions</li> <li>• examples should include the material evaluation practices of technologists.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological systems at level 7, teachers could:</p> <ul style="list-style-type: none"> <li>• support students to understand the concepts of redundancy and reliability in relation to technological systems. <i>Redundancy</i> relates to the inclusion of more time, information and/or resources than would strictly be needed for the successful functioning of the technological system. <i>Reliability</i> relates to the probability that a system will perform a required function under stated conditions for a stated period of time</li> <li>• support students to identify and analyse a range of examples of technological systems to gain insight into how redundancy and reliability factors have impacted on system design, development and maintenance decisions</li> <li>• examples should include system design, development and maintenance practices of technologists.</li> </ul>
<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• discuss examples to illustrate why the status of evidence gained from technological modelling might change across contexts</li> <li>• explain why different people accept different types of evidence as valid and how this impacts on technological modelling</li> <li>• explain the role of technological modelling in ascertaining and mitigating risk</li> <li>• describe examples to illustrate the strengths and weaknesses of technological modelling for risk mitigation.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• discuss a range of subjective and objective evaluative procedures used to determine the suitability of materials and describe the underpinning concepts and processes involved in particular procedures</li> <li>• discuss examples of material evaluation procedures undertaken to support material selection decisions and justify the appropriateness of these procedures</li> <li>• discuss examples to explain how material evaluation impacted on design and development decisions</li> <li>• discuss examples to explain how material evaluation impacted on maintenance and disposal decisions.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• explain the concept of redundancy in relation to technological systems</li> <li>• discuss examples of particular technological systems to illustrate how factors related to redundancy impacted on system design, development, and/or maintenance decisions.</li> <li>• explain the concept of reliability in relation to technological systems</li> <li>• discuss examples of particular technological systems to illustrate how factors related to reliability impacted on system design, development, and/or maintenance decisions.</li> </ul>



## COMPONENTS OF TECHNOLOGICAL KNOWLEDGE: INDICATORS OF PROGRESSION

## LEVEL EIGHT

Teachers should establish if students have developed robust level seven understandings and are ready to begin working towards level eight achievement objectives for technological knowledge and plan learning experiences to progress these as guided by the level eight Indicators below.

Technological Modelling	Technological Products	Technological Systems
<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Understand the role of technological modelling as a key part of technological development, justifying its importance on moral, ethical, sustainable, cultural, political, economic, and historical grounds.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Understand the concepts and processes employed in materials development and evaluation and the implications of these for design, development, maintenance, and disposal of technological products.</p>	<p><b>ACHIEVEMENT OBJECTIVE</b></p> <p>Students will: Understand operational parameters and their role in the design, development, and maintenance of technological systems.</p>
<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological modelling at level 8, teachers could:</p> <ul style="list-style-type: none"> <li>• support students to develop a critical and informed understanding of why technological modelling is an important aspect for ensuring responsible and defensible decisions are made during the design, development and any subsequent manufacturing of technological outcomes.</li> <li>• support students to critically analyse examples of technological modelling practices that were undertaken to address a range of competing and contestable factors to gain insight into how these factors can be handled. These factors arise from such things as differing moral, ethical, cultural, and/or political views and the way in which people adhere to and understand issues such as sustainability, globalisation, democracy, global warming etc.</li> <li>• examples should include the modelling practices of technologists and should include instances where modelling was undertaken to deal with competing and contestable factors.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological products at level 8, teachers could:</p> <ul style="list-style-type: none"> <li>• support students to understand that material evaluation enables decisions to be made about what material would be optimal to ensure the fitness for purpose when taking into account both the technical feasibility and social acceptability of the product.</li> <li>• support students to critically analyse a range of subjective and objective evaluative procedures used to justify material suitability and to explain the underpinning concepts and processes involved in these procedures</li> <li>• support students to understand why the selection of appropriate material evaluation procedures relies on understanding the composition and structure of materials, how their properties can be enhanced through manipulation or transformation, the performance criteria required by technological products and an understanding of the physical and social context within which the technological product will be situated.</li> <li>• support students to understand that the development of new materials relies on understanding: existing materials including their advantages and limitations; new material composition and structure possibilities; formulation procedures; future requirements, needs and desires; and an awareness that new evaluative procedures may need to be developed to determine the suitability of new materials</li> <li>• support students to identify and analyse examples where new materials have been developed, including past and contemporary examples, to gain insight into how material formulation and subsequent evaluation procedures are used to address performance, maintenance and disposal implications and inform design and development decisions</li> <li>• examples should include material development (including formulation procedures) and evaluation practices of technologists.</li> </ul>	<p><b>TEACHER GUIDANCE</b></p> <p>To support students to develop understanding of technological systems at level 8, teachers could:</p> <ul style="list-style-type: none"> <li>• support students to understand what operational parameters are and the role they play in the design, development and maintenance of technological systems. <i>Operational parameters</i> refer to the boundaries and/or conditions within which the system has been designed to function and are influenced by a number of factors associated with the technical feasibility and social acceptability of the system.</li> <li>• support students to identify and differentiate highly complex systems. Highly complex systems include self-regulatory and intelligent systems. <i>Self regulatory</i> systems are those that have been designed to adjust the functioning of transformation processes in response to feedback from any part of the system to produce desirable and known outputs. <i>Intelligent systems</i> have been designed to adapt to environmental inputs in ways that change the nature of the system components and/or transformation processes in known and unknown ways to produce desirable but unspecified outputs.</li> <li>• support students to identify and analyse a range of technological systems including simple, complex and highly complex technological systems</li> <li>• support students to use examples to gain insight into underpinning operational parameters and how these have impacted on and been influenced by system design, development and maintenance decisions.</li> <li>• examples should include system design, development and maintenance practices of technologists.</li> </ul>
<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• explain the role of technological modelling in making informed, responsive and defensible design and development decisions</li> <li>• explain the role of technological modelling in making informed, responsive and defensible manufacturing decisions</li> <li>• discuss examples to illustrate a range of technological modelling practices that have been undertaken in situations with competing and contestable factors</li> <li>• critique examples of technological modelling practices in terms of how well they address underpinning factors.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• discuss examples of the formulation of new materials and explain the underpinning concepts and processes involved in their development</li> <li>• discuss examples of evaluation procedures undertaken to determine the suitability of new materials and explain the underpinning concepts and processes involved in particular evaluations</li> <li>• discuss examples of past material developments and explain how these impacted on product design, development, manufacturing, maintenance and disposal</li> <li>• discuss examples of contemporary material developments and suggest probable implications for future technological product design, development, manufacturing, maintenance and disposal.</li> </ul>	<p><b>INDICATORS</b></p> <p>Students can:</p> <ul style="list-style-type: none"> <li>• explain what operational parameters are in relation to technological systems</li> <li>• explain the operational parameters established for particular technological systems and explain the factors that influenced these</li> <li>• discuss examples of technological systems to illustrate how operational parameters impacted on system design, development and maintenance</li> <li>• discuss examples of simple, complex and highly complex technological systems to illustrate the demands that increasing complexity in system design requires in terms of establishing operational parameters.</li> </ul>